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A New Distributed Learning Automata Based Algorithm for Maximum Independent Set Problem

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***Abstract*—Maximum independent set problem is an NP-Hard one with the aim of finding the set of independent vertices with maximum possible cardinality in a graph. In this paper, we investigate a learning automaton based algorithm that finds a maximum independent set in the graph. Initially, a learning automaton is assigned to each vertex of graph. In order to find candidate independent set, a set of distributed learning automata collaborate with each other. The proposed algorithm based on learning automata is guided iteratively to the maximum independent set by updating the action probability vector. In order to study the performance of the proposed algorithm, we conducted some experiments. The reported numerical results confirm the superiority of our proposed algorithm in terms of cardinality of the obtained solution.**

Keywords*— *Maximum independent set; NP-Hard problems; Learning Automata; Distributed learning automata

I. INTRODUCTION

An independent set in an undirected graph G=(V,E) is a subset I⊆V, none of its members are adjacent. Due to variety of applications, finding Maximum Independent Set (MIS) attracted many researchers. The MIS is the independent set with largest possible cardinality. Some of its most important applications are including computer vision [1], scheduling [1], pattern recognition [2] and social network [3].

Many different methods have been proposed for MIS problem. Ramanujam and Sadayappan designed a neural network for MIS problem [4]. Also, Lamm et al [5] proposed an algorithm for finding near optimal independent set. Dahlum [6], in addition to providing a review on existing algorithms, outlined a local search based algorithm for MIS.

MIS is a NP-complete problem [7] with exponential time complexity. It's shown in [8] that even approximating the MIS with a constant factor is a NP-Hard problem. Since it is not possible to outline a deterministic algorithm for solving such a complicated problem, most scholars considered Meta-heuristic approaches. In [9] a simulated annealing algorithm is proposed for finding MIS and its efficiency is confirmed. A Typical direction in research for finding MIS is using Genetic Algorithm (GA) approach. For instance, a GA algorithm for MIS problem was outlined by Back and Khuri [10]. Another GA algorithm is presented in [11] where the applied knowledge based crossover mechanism leads to appropriate solution in comparison with the existing state-of-the-art algorithms. Moreover, a hybrid GA algorithm is suggested in [12] to improve the quality of the obtained solution by implying equal chance to all vertices for being a part of the solution. On the other hand, Leguizamon et al [13] proposed an Ant Colony Optimization (ACO) based algorithm for MIS problem with a performance comparable to several algorithms. In [14] another ACO algorithm is investigated for which the efficiency is established based on the cardinality of the obtained independent sets as reported in numerical results.

In this paper, we propose an algorithm based on distributed learning automata for finding MIS in a graph. Learning automata is an efficient tool for solving many complicated problems. More precisely, learning automata, according to its stochastic nature, is useful for solving any stochastic problem such as finding MIS. On the other hand, Distributed Learning Automata (DLA) determine implicitly, which edge to be sampled by evaluating the allocated reinforcement signal. This leads to prevent unnecessary sampling from the edges which probably are not included in the maximum independent set and thus reduces the overall sampling size.

In our DLA based proposed algorithm, we design a network of learning automata by assigning a learning automaton to each vertex. At each iteration, the learning automata randomly chooses one of its actions to form an independent set and the selected actions are classified through a proper benchmark. After a number of iterations, the learning automata tend to a common policy that determines the optimal solution meaning the maximum independent set. The simulation results show that our proposed algorithm outperforms the existing

algorithms in terms of the cardinality of the obtained maximum independent set.

The rest of the paper is organized as follows. In Section 2, we provide a brief review on learning automata and distributed learning automata. In Section 3, we present our DLA based proposed algorithm for finding MIS. The numerical results are reported in Section 4. Section 5 gives our concluding remarks.

II. LEARNING AUTOMATA

Learning automaton (LA) [12, 14] is a model for adaptive decision making in random environment and has a finite set of actions. The learning process of the learning automata consist of interactions with stochastic environment and action selection based on action probability vector in each iteration. The environment evaluates the response corresponding to the chosen actions by rewarding or penalizing the LA. The LA uses feedback of environment to select the next action. During this process, LA learns how to choose the feasible action from its action set. The interaction between learning automata and the random environment is shown in Figure 1.

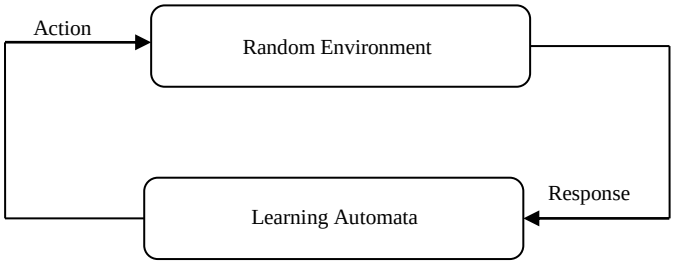


Figure 1. Learning Automata and random environment

Variable structure is represented by a Triple {β, α, T}, where β is the set of input, α is the set of actions and T is the learning algorithm. The learning algorithm is the recurrence relation to update the action probability vector. Let α_i be the action chosen at instance n as a sample realization from distribution P(n). The updated probability vector based on reinforcement signal β is described in (1) and (2). Learning automata updates its action probability vector based on

$$P_i(n+1) = P_i(n) + a(1 - P_i(n)) \qquad (1)$$
$$P_j(n+1) = (1-a)P_j(n) \qquad \forall\ j \neq i$$

for a desirable response and

$$P_i(n+1) = (1-b)P_i(n) \qquad (2)$$
$$P_j(n+1) = \frac{b}{r-1} + (1-b)P_j(n) \qquad \forall\ j \neq i$$

for an undesirable one, where P(n) is the action probability vector at time *n* and *r* is the number of actions that can be taken by the LA. In addition, *a* and *b* represent reward and penalty parameters and determine the amount of increase and decrease of action probability vector respectively.

If *a*=b the learning algorithm is called linear reward penalty (L_{RP}), if *b*<<*a* the given learning algorithm is called linear reward-ε penalty ($L_{R-\varepsilon P}$) and finally if b=0 it is called linear reward inaction (L_{RI}).

III. DISTRIBUTED LEARNING AUTOMATA

A network of learning automata which collectively cooperate to solve a specific problem called Distributed learning automata[15]. A DLA can be modeled by a directed graph. In a DLA, only one automaton is active at each time and the number of possible actions for active automata is equal to the number of automata connected to it. Figure 2 denotes a DLA network corresponding to a graph by allocating an automaton to each vertex [16].

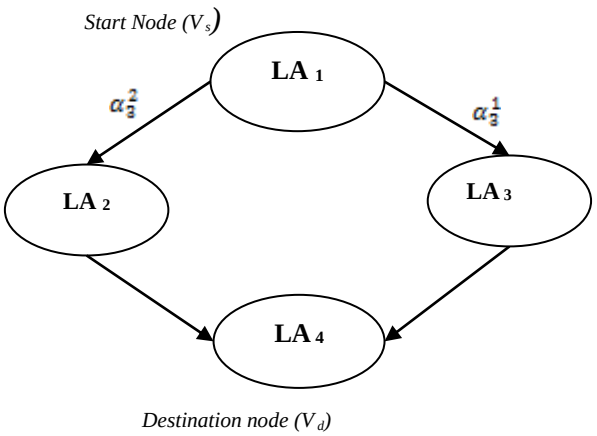


Fig 2. Distribute learning automata

IV. THE PROPOSED ALGORITHM

In this section, we describe a DLA based algorithm for finding MIS. Suppose the undirected graph *G=(V,E)* be the input of the algorithm with V and E being the set of vertices and edges respectively. The goal is to find the corresponding MIS.

In our proposed algorithm, a network of learning automata is designed to be isomorphic to the vertices of input network. The possible action set for each learning automata is equal to the set of connected vertices.

Let *IS(t)* be the candidate solution at iteration t. Initially, all learning automata are set to be inactive. Then, a random learning automaton is selected and activated. Letting LA_i be the selected learning automaton, it chooses one of the available actions, LA_j, based on the probability vector. Next, LA_i is deactivated and added to *IS(t)*. In addition, all its neighbors are moved to NV_i. Now, LA_j is activated and selects one of possible actions. The process of selecting a learning automaton, activating it and choosing one of its possible actions is terminated when no more learning automata can be activated. The cardinality of the obtained

independent set at iteration t is compared with the mean of *IS(t)* cardinalities' up to iteration t that might be written as

$$\Omega_t = \sum_{k=1}^{t} \left| IS(k) \right|, \quad (3)$$

in which $\left|IS(k)\right|$ is the cardinality of the computed independent set at iteration k. If the cardinality of *IS(t)* is greater, *IS(t)* must be rewarded and otherwise must be penalized by the algorithm. This process is continued until a maximum iteration number or a predefined threshold reaches. The algorithm converges to an *IS* having maximum cardinality with probability as close as possible to unity. The threshold here is defined as $P_{MIS}(t)$ being less than the predefined value P_t, where $P_{MIS}(t)$ is defined to be

$$P_{MIS}(t) = \prod_{v_i \in IS(t)} \max\left(P(v_i)\right). \quad (4)$$

The main steps of the proposed algorithm are gathered in Figure 3.

Note. In order to continuation of the proposed algorithm in special cases like reaching a vertex with degree one or two, we add a vertex which is connected to all vertices. When the algorithm is stopped in such a situation, the added vertex is selected and since it is connected to all vertices of the graph, it selects one of the vertices based on its probability vector and the algorithm is continued until one of the stopping conditions is satisfied.

Algorithm 1: Proposed algorithm for finding maximum independent set

Input: A graph $G=(V, E)$, Thresholds T, P
Output: maximum independent set MIS*
Assumptions
- Assign an automaton A_i to each vertex v_i and initial action set of each automaton is set equal;
- Insert a new vertex v_t to graph G and it to all other vertices and assign a pure chance learning automata to v_t;
- Let t is the iteration number of algorithm and initially set to 1;
- Let *IS(t)* be the candidate independent set at iteration *t*.
- Let NV_i be the neighboring vertex of v_i which belong to *IS(t)*;
- Let MIS* denotes the maximum independent set and initially empty;

Begin
Let Ω_t be the average cardinality of maximum independent set up to iteration t and initially set to zero;
Let $P_{MIS}(t)$ be the product of maximum probability of learning automata of the vertices connected to *IS(t)* at iteration *t*.
While (*t <T or* $P_{MIS}(t) < P_{MIS}(t)$**)**
- Select v_i randomly as starting vertex;
- *IS(t)* ← v_i ;
- Insert neighboring vertex into NV_i;
- Learning automata Ai is activated and choose an action according to its action probability;
- Disable all the action corresponding to the Learning automata connected to v_i;
- Let chosen action by learning automata A_i be the action corresponding v_j;

Repeat
- Disable all the action corresponding to the Learning automata connected to v_j;
- Learning automata A_j is activated and then selects an action according to it action probability vector;
- Let the action selected by A_j be vertex v_k;

Algorithm 1: Proposed algorithm for finding maximum independent set (Cont'd)

If ($v_k \neq v_t$) **then**
- IS(t) ← v_k ;
- Insert neighboring vertex into NV_k
- Learning automata A_k is activated and choose an action according to its action probability;

- v_j ← v_k;

Else
- v_j ←Learning automata v_t select an action randomly

End if
Until (A learning automata can be activated**)**
- Compute Dynamic threshold Ω_t using (3)

If (IS(t)>Ω_t)**then**
Reward chosen action by all activated automata
Else
Penalize chosen action by all activated automata
End if
- Compute $P_{MIS}(t)$ according to (4)
- $t \leftarrow t+1$;

End while
End Algorithm

Figure 3. The Pseudocode for our proposed algorithm

V. SIMULATION RESULT

In order to establish the performance of the proposed algorithm, we conducted experiments on well-known DIMACS datasets. We then compared the size of obtained MIS of our algorithm with two existing algorithms outlined by Andrade [17] and Grosso [18]. For proposed algorithm, all experiments have been implemented using L_{R-I} with learning rate 0.06. Table 1 shows the characteristics of data sets in terms of nodes, edges and maximum independent set size that used in experiments.

Table 1. DIMACS Network Graph.

Dataset	*Nodes*	*Edges*	*Max-MIS-Size*
Brock200_1	*200*	*14800*	*21*
Brock200_2	*200*	*9900*	*12*
Brock400_1	*400*	*59700*	*27*
Brock400_2	*400*	*59800*	*29*
MANN_a27	*378*	*70551*	*126*

We reported corresponding result in Fig 4, where *DLA-MIS*, *ILS* and *GLP* refer to our proposed algorithm, the presented algorithms in [17] and the algorithm introduced in [18] respectively. Based on demonstrated results, the proposed algorithm has proper performance in terms of finding maximum independent set.

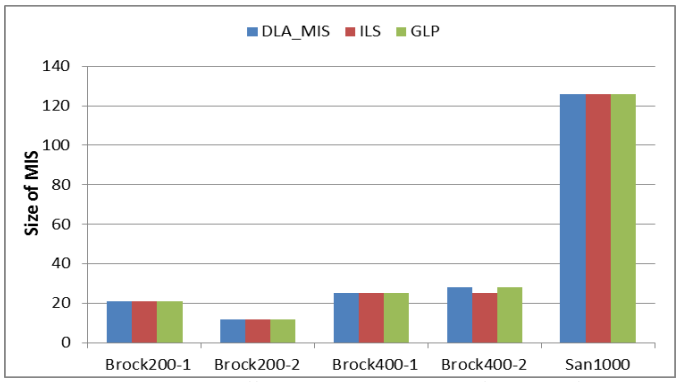
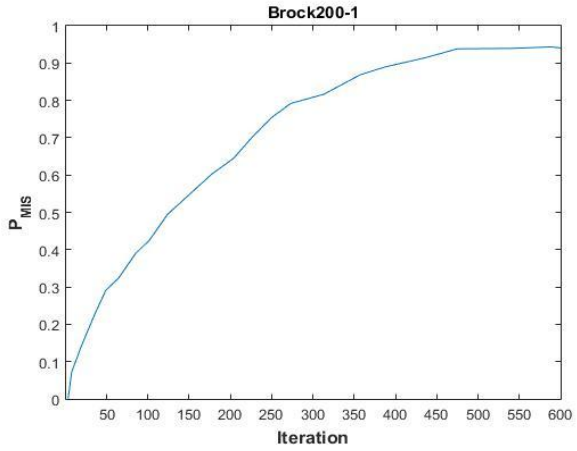
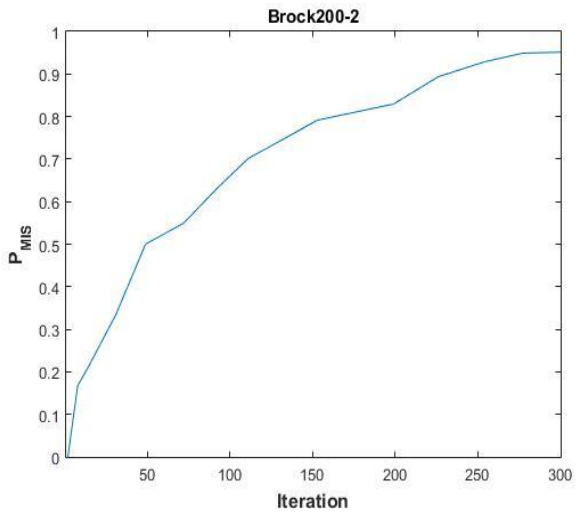


Fig 4. Obtained result by different algorithms in term of number of maximum independent set.

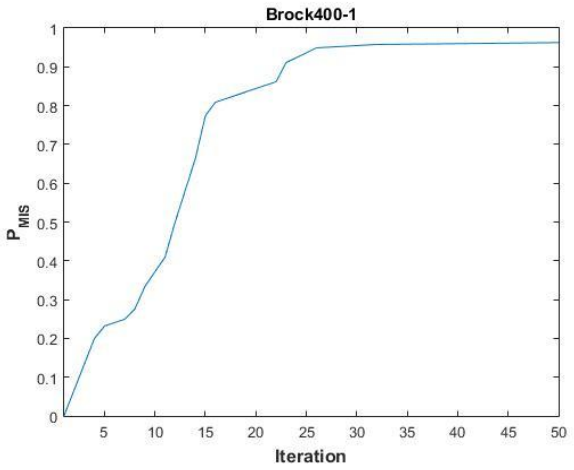
The convergence of the proposed algorithm based on P_{MIS} is demonstrated in Fig 5. In order to perform this experiment, we plot P_{MIS} versus iteration number.



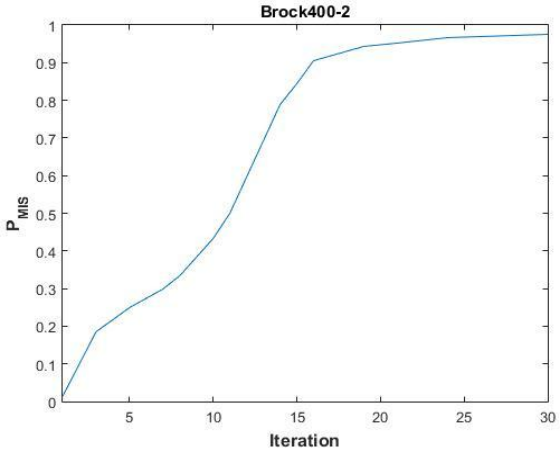
a) brock200-1



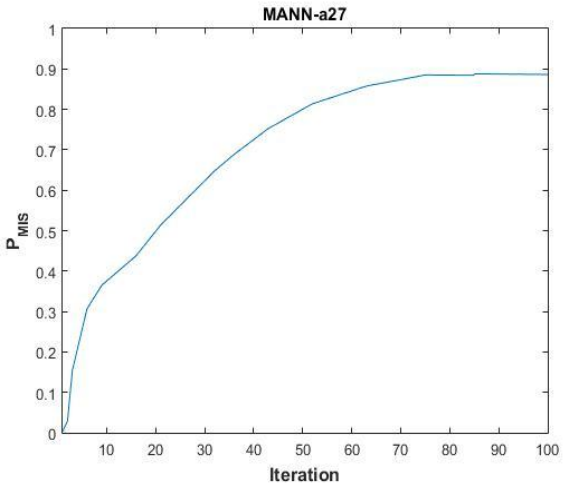
b) brock200-2



c) brock400-1



d) brock400-2



e) MANN_a27

Fig. 5. P_{MIS} of action probability vector of LAs that member of MIS.

Based on the obtained results in figure 5, the upward movement of the P_{MIS} in data sets indicates useful information on convergence and is close to the optimal value. We note that the proposed algorithm has proper convergence speed in experiments.

VI. CONCLUSION

In this paper, we presented a new distributed learning automata based algorithm in order to solve the maximum independent set problem. Computing the maximum independent set in a network is important in different areas such as pattern recognition and social network. Making use of learning automata in solving MIS problem is motivated by its stochastic nature and its ability for solving complicated problems. Moreover, DLA, being able to find a solution with lower sampling size, is a proper structure to outline a learning automaton based algorithm for MIS problem. Hence, in our proposed algorithm by activating or deactivating automata and performing a guided search, we find a path of learning automata corresponding to vertices included in MIS. According to the experiment results the proposed algorithm is compatible with existing methods.

VII. REFERENCES

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new approach to road detection in chalenging outdoor environment for autonomous vehicle

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***Abstract*-Road detection from a single image is a challenging problem. In this paper, a new color feature based on road detection method has been introduced. The proposed method utilized color features to learn and estimate the road straight part and provide vanishing points. In order to extract the road area, a combination of new learned color features and vanishing point algorithm have been used that can be released as the proposed method contribution. The experimental results show the efficiency of new method and Obtained results; Recall 92%, F-Measure 84% and accuracy 90% are compared with existing methods which show superiority of the proposed method.**

Keywords - Conversion of color space; learning; road detection; vanishing point

I. INTRODUCTION

Independent road area Detection according to a range of challenging environmental conditions such as the presence of light, sunny and obstacles ahead of the vehicle, is very difficult. The difference in road appearance depend on the condition of access during the day, type of road and light intensity. Many road detection algorithms appeared first time for autonomous vehicles. Road detection common approaches are used pixel-level features (color or texture) to describe the appearance of the road. The algorithms based on low level features while color and texture information is not reliable, reach their limits. Therefore, by using high-level features and then combining with low-level features can enhance strength and accuracy road area detection. By studying and reviews the different methods and algorithms presented in the past, in this paper we have provided an analysis of the previous and the current approaches and then the algorithm will be presented that uses visual and spatial of the images, so it can increase the accuracy of road area detection.

II. RELATED WORK

In general, the road images can be divided into two categories; structured(like a road in urban areas) and unstructured (like a road in the desert or rural area). (Fig. 1).In structured road, locating the road boundaries or signs are one of the most common methods that is used. color cue [1-3], Hough transform [4-5], steerable filters [6-7], Spline [8-9], etc. are used for borders or road signs. A limitation of these methods are that they are always working for structured roads that have significant marks or boundaries. Methods based upon segmenting the road using the color cue have also been proposed, but they do not work well for general road image, especially when the roads have little difference in colors between their surface and the environment.



Fig. 1. Examples of structured and unstructured roads

laser [10], radar [11] and the stereovision [12] have also been used for structured road detection. For unstructured roads or structured roads without remarkable boundaries and markings, Alon et. al.[13] have combined the Adaboost-based region segmentation and the boundary detection constrained by geometric projection to find the "drivable" road area. Stereo cameras [14] are also used to determine terrain traversability. When there is little difference in color between the road and off-road areas, it is hard to find strong intensity change to delimit them. The one characteristic that seems to define the road in such situations is "texture". The associated approaches [15-17] have attempted to define the forward "drivable" image region by utilizing the texture cue. They compute the texture orientation for each pixel, then seek the vanishing point of the road by a voting scheme, and finally localize the road boundary using the color cue. In order to segment the road area, a VP[1]-constrained group of dominant edges are frequently detected, and two most dominant edges are selected as the road borders[18]. Some of the methods presented in recent years despite using the specificity of vanishing point and the standard color space YCbCr, work only on the structured roads and in situations where lane marks ahead of the vehicle on the road with no lines will not work correctly. [20]. In the method presented by Johan Hu et. al. [21] vanishing point is calculated by using a probabilistic voting method, in which can have a good performance in the structured roads with clear lines. Chan Zhang et. al. [22] using a biological model to calculate the number of vanishing point and Accordingly, the movement multi-path detection is performed. The proposed method don't work correctly in low light conditions and shadows that lane borders is not clear.

[1] Vanishing Point

III. KONG ET. AL. METHOD[18] (LASV)

texture-based methods for VP detection are very effective for both structured and unstructured roads by utilizing the texture information from a single road image. All of these studies consist of three steps: i) calculate the texture orientations by applying a directional filter bank ii) determine the voters and VP candidates and iii) vote for obtaining the VP by a voting algorithm. One person who has used the algorithm appropriately is Kong et. al. [18] that using Gabor wavelet filters to calculate the dominant contextual orientations, then by using the voting algorithm has achieved vanishing point. Fig. 2 shows a block diagram of Kong method. Global hard voting method to detect the vanishing point was proposed, by Rasmussen [16-15]; in this approach , we find that Pixels that as vanishing points are at the top of image receive More votes than the pixels that are on the bottom of image, so this can cause sometimes to large estimation errors, especially when the true VP is in the lower part of the road image.

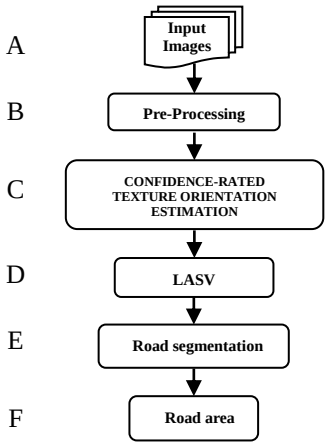


Fig. 2. Kong method Block diagram

In order to overcome the above problems, Kong et. al.[18] proposed an effective VP detection method, in which a "confidence level" function and a local adaptive soft voting (LASV) method were proposed. The confidence function is used to determine the voters by checking the reliability of the obtained texture orientations. Before applying the LASV method, a half-disk voting region is created for each VP candidate, and only voters within this half-disk vote for the VP candidate. The above mentioned LASV method for VP detection performs well in general road images. This method is more effective and faster than previous texture-based methods However, the computational cost of the LASV method is still high due to a large number of scanning pixel and also is effective on The processing speed.

IV. PROPOSED METHOD (CCSL)[2]

In this section of the paper, a new method is proposed for realizing detection with high accuracy, based on the road color features and estimating the main (straight) part of the road vanishing points. contributions presented in this paper are Respectively; extraction road area color features and combine them with the vanishing points algorithm. To extraction color features and the overall road texture; a new method is proposed based on color space conversion [19], with learning in new space by maximum color difference, between road and non-road areas. in the implementation of the main straight of road vanishing points algorithm, for more robust and increasing the accuracy of detection method, as well as calculating the texture orientations in each of the pixels, we are considered the confidence coefficient for each of the estimates. This mechanism vanishing points algorithm, seems has better performance, because by considering the confidence components, insignificant parts are removed. To segment the road area, a vanishing-point constrained group of dominant edges are detected based upon an orientation consistency ratio (OCR) feature, and two most dominant edges are selected as the road borders by combining color cue. This road detection method integrates texture orientation and color information of the road, and it handles well changes of illumination and applies to general road images. The definition of OCR is given in Fig. 3. In Fig. 3. l is a line consisting of a set of discrete oriented points/pixels (the Orientation of these points denoted by a black arrow in the figure). For each point P, if the angle between the point's orientation and the line's direction is smaller than a threshold, this point is viewed to be orientationally consistent with the line. OCR is defined as the ratio between the number of orientationally consistent points and the number of total points on the line.

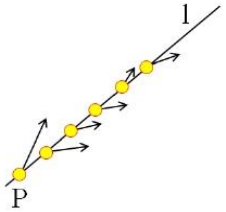


Fig. 3. An illustration of OCR calculation.

Notably, according to the our first contribution , the new color space in proposed method in addition to highlighting and extraction the relative road areas , is robust against light different conditions. In general the proposed method is as follows:

1. The input image and pre-processing
2. Color space conversion with learning
3. Extraction the vanishing point and dominant edges
4. Detection road area

In fact the proposed method, steps A and B as shown in Fig. 2 are processed and significant impact on the better results to estimate the vanishing point and detection road area. to create a new color space, in the first step, we formed two clusters road and Non-road, it is noteworthy that in road and non-road training samples collection, in the learning process for each of the clusters, try to be collected the largest range of samples in the following format sub-image 25 × 25 pixels from road and non-road image. The goal is the maximization of distance between the two clusters and assume that by converting both road and non-road clusters to new color space ,maximum distinction to be created between images, so the color space conversion are as follows:

$$[X_k]= [W_{ij}] \times [C_{RGB}] \quad k, i, j=1, 2, 3 \ (1)$$

In Equation (1) , matrix X is pixel in the new color space and 3×3 matrix W_{ij} is special weight in RGB color space

[2] Conversion of Color Space with Learning

conversion, to the new space and pixel matrix of training C_{RGB}; are road and non-road color input image. Now quadratic objective function $\Psi(W)$ as a function that explain distances every two clusters from each other, are defined as follows:

$$\Psi(W)=\sum_{i=1}^{N} d_i + \sum_{j=1}^{M} r_j - L \qquad (2)$$

in Equation (2), the Σ's are Total distances of road sample pixels (*d*) and non-road (*r*) of each cluster to cluster centers, and *L* is the distance between the centers of the two clusters that formed unknown variables have converted the same specific weight. The main objective of the proposed approach is minimization of this function. To solve and minimization of this equation, is used the Lagrange method and the values of the variables are calculated that are also special weight in the equation. In The Lagrange method by adding variable λ to the equation, a new equation for the minimization is defined that C(w) is compound equality and inequality constraints :

$$F(w,\lambda)=\Psi(w)+\lambda C(w) \qquad (3)$$

For minimization of the equation, need to be as follows:

$$\begin{cases} \dfrac{\partial F(w,\lambda)}{\partial w}=0 \\ \dfrac{\partial F(w,\lambda)}{\partial \lambda}=0 \end{cases} \qquad (4)$$

To solve the equation we must each of the variables independently bind up to converge equation and also, all weights must be limited into defined range as:

$$a \le w_{ij} \le b \qquad (5)$$

Due to the high volume of calculations to solve the Lagrange equation, the computer analysis is used with MATLAB software. Based on the foregoing, objective function is minimized and new color space conversion weights after normalization, are obtained as follows:

$$w_{ij}=\begin{bmatrix} 0.14 & -0.08 & 0.08139 \\ -1 & 0.7 & 0.7 \\ -0.81 & -0.91 & 0.361 \end{bmatrix} \qquad (6)$$

V. EXPERIMENTAL RESULTS

The proposed method is used datasets of road images set of Kong method (LASV) and were compared with them. These images was used in presented paper by Kong et. al.[18] detection public road from a road image in 2010. Estimating of vanishing point and extraction road area has been tested on about 1020 images of various images of road. These images coverage a wide range of different environmental conditions on the diversity in color, texture and light and tried to consider all challenging road conditions. The size of all images are normalized by 180×240 pixels. To assess the algorithm's performance vs. human perception of the vanishing point location, we request 3 persons to manually mark the vanishing point location after they are trained to know the vanishing point concept. A median filter is applied to these human recorded results and the average of the median filter results is regarded as the ground truth position. Finally, by using the proposed road detection algorithm, the detection results are determined and performance of the algorithm are compared with the final ground truth.

A. The effect of color space conversion in detection vanishing point and road area

As is clear from Fig. 4, right; highlighting color features during Color conversion cause to homogenize road areas texture orientations, so the precision of the location of vanishing point can be done better.

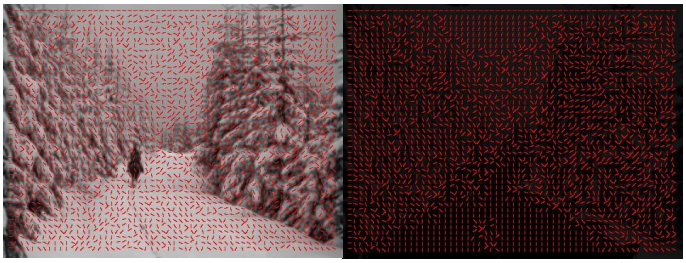


Fig. 4: images overlaid with texture orientations estimated using Gabor filters. Kong method (left), proposed method (right).

If the confidence components in proposed method by Kong, examine, we will see that in our proposed approach these components are far more precise. With respect to the confidence components , ultimately, the decision can be , unnecessarily worthless orientations is removed, so the performance of proposed approach and Kong method at this stage, act vary strongly each other .(Fig. 5.)

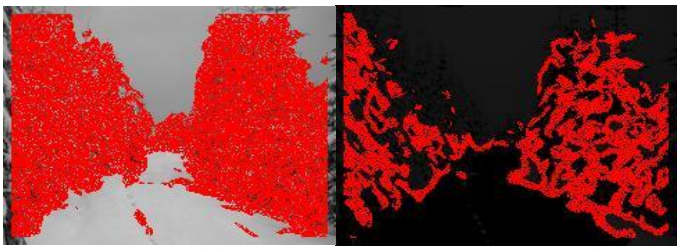


Fig. 5: Pixels with confidence level larger than 0.3. Kong method (left), proposed method (right).

Fig. 6 shows the results of the road detection in two images With respect to vanishing point detection and the dominant edge detection of the proposed methods and Kong method.

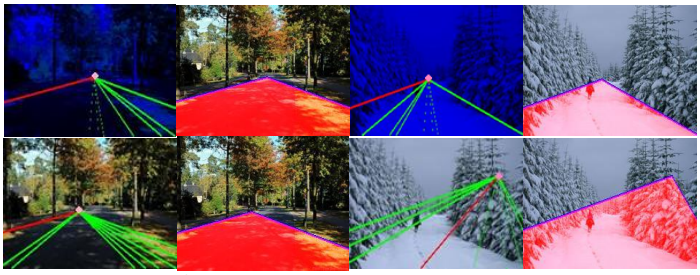


Fig. 6: Detection of vanishing point, dominant edges and road area. First row proposed method and second row Kong method.

The most important evaluation criteria are provided that they are Accuracy, Precision, Quality, Recall, F-measure and Error rate that their output values are numbers between 0 and 1. For example Precision and recall provide different insights in the performance of the method: low precision means that many background pixels are classified as road, whereas low recall indicates failure to detect the road surface. F-measure is the tradeoff using weighted harmonic mean between precision and recall. According to the Table 1 and calculation the evaluation criteria can be seen that the proposed method (CCSL) compared to the Kong method (LASV) has much better performance. the measures are represented in percentage. In our method the three criteria FPR, FNR and Error rate are closer to 0 so indicate that the detection error are less. The other criteria are much closer to 1 that indicate algorithm results are better.

Table. 1 : Comparing the average evaluation criteria for the two methods

Benchmark average	*Proposed method (%)*	*Kong method (%)*
Recall	92.11	88.36
Accuracy	90.48	88.48
Precision	79.34	79.30
F-Measure	83.69	80.76
Quality	73.93	70.42
TNR	89.37	88.77
Error rate	9.52	11.52
FPR	10.63	11.23
FNR	7.89	11.64

The ROC curve is expressed for comparing system performance; much of the area under the curve graph means better performance of method. By drawing ROC curve based on various tests on the images database, performance of algorithm represents the proposed method CCSL has better result than Kong method LASV. Chart 1 ROC curve shows result of two methods in diverse environmental on 65 samples images. As the chart shows more area under the curve of the proposed method is more than Kong method. This means that the proposed method is better. Charts 2 and 3 show Respectively Accuracy and Precision based on the Recall of the proposed method (CCSL) and Kong method (LASV). The charts show different values of Accuracy and Precision based on the Recall for 65 sample images. So if area under the curve is much greater than other one the performance of method is better. In the other words when quantity of recall is increased, quantities of accuracy and precision also are increased. So as you can see, the proposed method is more Accuracy compared to Kong method.

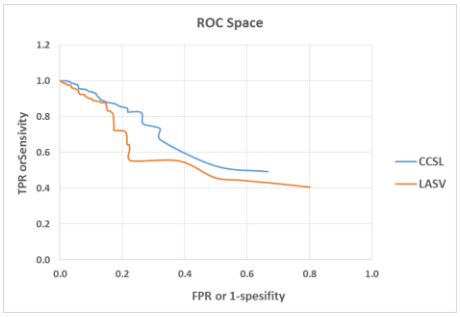


Chart. 1: Comparing proposed method (CCSL) and Kong method (LASV).

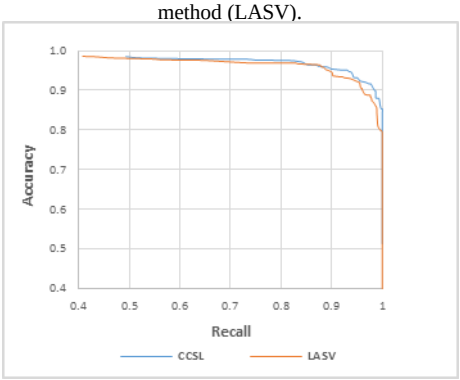


Chart. 2: Comparing proposed method (CCSL) and Kong method (LASV).Recall-Accuracy

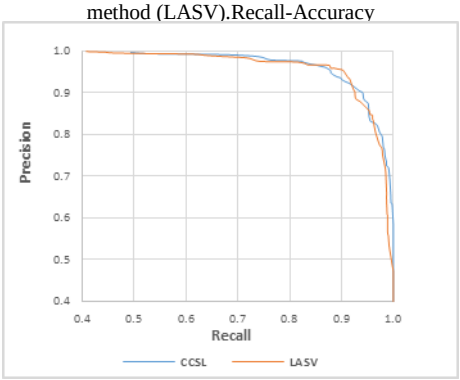


Chart. 3: Comparing proposed method (CCSL) and Kong method (LASV). Recall-Precision

VI. CONCLUSION

In this paper, the method was presented which detect road area in two phases; color feature extraction and vanishing point . Stated method, the color features of the road, highlighted by mapping color space and then in extraction phase of the vanishing point, helped to detect the boundaries of the road. for making mapping color space were used the Euclidean space features and pixel samples collected from road and non-road area images in learning phase. and based on the definition a new target function and optimization by the Lagrange tool, we solved it and found the most appropriate mapping. according to the results, It seems, by combining adaptive color features and vanishing points can be dependent on the conditions of input images, present better quality to detect road areas .

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Applications of Data Mining in Robotics

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***Abstract*— From a high-level viewpoint, robotics is all about data. In other words, each robot agent for performing its designated tasks should deal with data in some form- from collecting data from the environment to generating internal data. For this reason and due to broad range of possible applications, managing and dealing with such data is an important issue in the field. On the other side, data – in its different types- is known as an invaluable treasure of knowledge and insight within any information system. In this regard, extracting such hidden knowledge through data mining has been in the center of focus for more than two decades. In fact, data mining could be considered as a super-influential phenomenon on all scientific fields and robotics is not an exception. Over the recent years, many studies have been conducted on different aspects of leveraging data mining techniques in the robotic domain to improve performance of robots in various ways. However, despite the current disparate and unorganized studies in different directions, there are some potential areas that have not received enough attention. In this paper, we provide a high-level overview of the field and try to organize the current studies as a reference point and road map for future works. Moreover, challenges and future possible directions will be studied.**

***Keywords*— Robotics; Data Mining; Decision-making; Learning; Robot Control; Robot Soccer**

I. INTRODUCTION

Nowadays and after many years of research and development, robots are in use in a wide variety of applications ranging from medical [1, 2] to space exploration [3]. From a high-level technical perspective, most robotic operations and processes are dealing with data in some form. For this reason, managing and processing such kind of data could be very useful. In other words, alongside with developments in Artificial Intelligence (AI), kinematics and other related fields, gaining insight from robotics data could be considered as a means to improve processes and performance of robots. Of course, exploitation of data is not a new trend and leveraging data mining techniques [4] for extracting hidden knowledge from (large amount of) data has been in center of focus for more than two decades. Following this approach, over the recent years several studies have been conducted to benefit data mining techniques in different fields of robotics. However, majority of these studies performed in different directions and with different contributions. In this regard, despite the fertile body of the literature, lack of a study to organize the literature is an essential shortcoming. Therefore, in this paper we are aimed to perform an overview on different aspects of the topic by providing a current status report and discussing challenges and future possible directions. The authors believe this study may be regarded as a roadmap for both researchers and practitioners for their future studies and projects in the context of leveraging data mining for enhancing robotic-related applications. The rest of the paper is organized as follows: in section 2 relationships between robotics and data are explained. Section 3 is devoted to studying quality of different data sources in the context of robotics. Overviewing different applications of data mining for robotics is the subject of section 4 and in section 5 the focus is on possible directions and applications of data mining for Robot Soccer. Finally, major challenges and likely future directions are introduced in section 6.

II. ROBOTS AND DATA

Nowadays we are getting closer to what Sci-Fi industry told us about robots, their structure and applications. Despite early days of robotics, they are not only intended to perform repetitive and non-intelligent tasks. Thanks to many years of developments in hardware, kinematics, control, etc. as well as advancements in AI and related fields, we are witnessing impressive progress in the domain. In this regard, today's robotics provides humans with facilities and assistance in a broad range of application areas from surgery and medical

operations to exploration of outer space and inner sea [5]. Generally, robots may be studied from several perspectives. One high-level aspects of robotics is its relationship with data and based on that robotics is all about data. In other words, each robot agent for performing its designated tasks and operations should deal with data in some form. Specifically and according to their defined purposes, robots:

- Collect data from the environment
- Operate based on a set of data (and information)
- Generate some data

Based on this concept and regarding their relationship with data, robots could be classified in two major categories (Fig. 1):

1. Robots as data (information) collectors (gatherers)
2. Robots as information systems

In fact, robots that belong to the first class are a subset of second ones; however due to their specific applications it would be better to described in a separate group. Such robots actually do not do anything special with data and only supposed to be a means to collect (and probably transmit) desired data from the environment. Therefore, such agents may be as simple as a controllable device and in many cases there is no need to be intelligent or even autonomous. As some examples of this kind of robots, underwater robots [6], Unmanned Aerial Vehicles (UAVs) [7] and disaster information gatherer robots [8] could be mentioned. Robots of second kind may be considered as a type of complex information system that deals with different types of data and takes benefits of processing them to improve its performance in many aspects. This group contains a broad range of robotic agents including autonomous and intelligent ones and deal with large amount of data from various sources. Since the main objective of the paper is to study of data mining and its applications to robotics, in the rest of the paper we will focus on the second group of robots that are directly interact with data. Of course, forthcoming concepts and approaches may be applied to the first group.

III. Robotics Data Sources

Generally, robots – specifically intelligent and autonomous ones- work based on their cognition of the environment. Each robot through its sensor(s) collects some data from the environment in which it operates and after processing such data, it makes response (reacts) via its actuator(s). From a high-level perspective, this process may be described as follows: to response to the situation and react accordingly, robots are making decisions based on their acquired knowledge. However, there are essential differences on details of this process regarding the context, types of robots and their sensors and application areas. Therefore, since the input data to a given robot is considered as main source for feeding the decision making process, it emphasizes importance of data management in robotics. Also, data types, formats and sources vary from case to case and all robots (that are aimed to do different operations in different contexts) may not be fueled by identical data sources. All in all, the schematic architecture of different input data sources for robotic systems is illustrated in the Fig. 2. Each of the pointed data sources in the figure is described as follows.

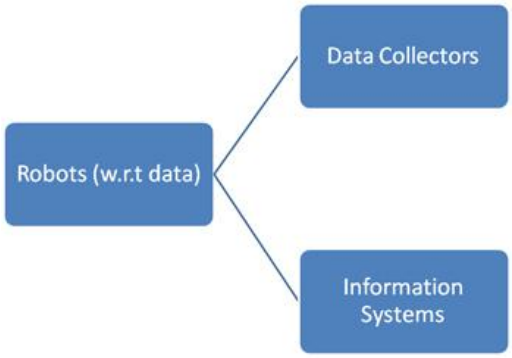


Figure 1. General classification of robots respecting their relationship with data

1. Sensor data are most common types of data that almost all robots are equipped with the facilities to take benefits of them. Any (intelligent) robotic agent need to collect such data from the environment to operate within. According to the robot's features and its intended applications, sensory data may be visual (e.g. in the context of robot soccer), sound, thermal, etc. Due to the nature of these data, they should be called raw, unprocessed or noisy data. From the management viewpoint, the major problem with sensor data is their volume that nowadays could be considered as a type of big data. Mining sensor data may be useful for a broad scope of applications as works reported in [9, 10].
2. On the opposite direction of sensory data as input to the system, actuator or output data are related to the quality of robot's reaction/response to the environment. Despite the nature of such data that is regarded as output; it could be leveraged as feedback data and provides the system with information about quality of the performed (re)actions.
3. Another class of input data to the robot that within the recent years gained more attention is non-sensory data. As some examples for such data which are originated beyond the sensors, following could be mentioned: communication data between robots (and humans), web and social media data, etc. Non-sensory data that may be or may not be about the environment; however these complementary data are useful since they expand domain knowledge of the robot and help them to have better understanding of the environment, events and interactions. As a previously futuristic and currently realized idea, following scenario can be mentioned: When an explorer robot faces an unidentified/unknown object in a room, it can search the web (connect to the data center) to find out what is it and how to deal with. The main challenges of leveraging such data are enabling

robots for acquiring them and providing facilities to make the data usable/interpretable by robots. As an

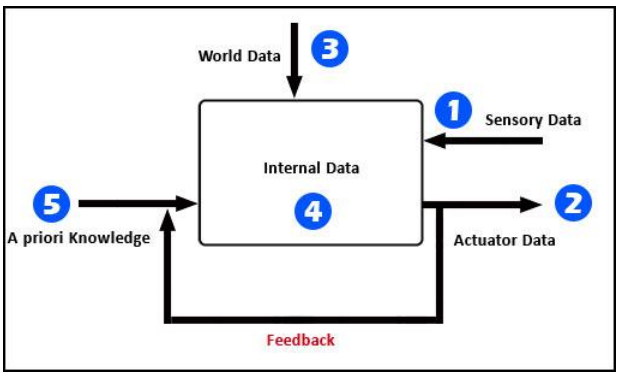


Figure 2. Schematic representation of Robotic data sources

example, social network mining is a fertile subject area that could be very useful specifically in the context of social robot and Human-Robot Interaction (HRI) [11].

4. Forth class points to the data that are produced within the system in the form of performance data, system log information, etc. These types of data are usually used for robot fault identification [12], maintenance, improvements and similar management processes.

5. Each one of the mentioned classes of data could be used as input to the system as a priori knowledge. Such (mostly processed) data which may be provided by analysts and/or expert systems are probably used as background knowledge to help the system deal with predicted situations. Moreover, those are potential candidate to be used as training data for robot learning and adaptation. Map of the incident area for rescue robot and opponent teams' strategy and formation for soccer robots are some example of such data.

Characteristics of the five mentioned groups of data are summarized in Table 1.

Table 1. Summary of characteristics of robotics data sources

	Source(s)	Benefits (of mining)	Challenges
Sensory data	Surrounding environment	Making robot aware of the environment	Real-time processing, High volume, Noisiness
Actuator data	Robot's decisions	Serving as feedback (of decisions)	Noisiness, Case-specificity
World data	Web, Social Media, External Networks, etc.	Expanding robot's view and context	Unstructured nature of data, Connectivity
Internal data	Performance and log data	Improving internal and system-related processes	Accurate and timely logging
A priori knowledge	Processed form of all other data	Providing robots with high-level information (insight)	Generating and processing, need to expert persons/systems

So far, the community has conducted many researches to leverage robotic related data by employing data mining techniques. Major works of this field will be introduced and categorized in the following section.

IV. Applications of Data Mining in Robotics

The most important promise of data mining is to discover hidden knowledge of data that is not achievable by classical analytical processes. In other words, data mining is in charge of transforming data into insight for making better decisions in general, and for being more intelligent and applicable in the context of robotics. (Fig. 3) Regarding robots' features, capabilities and their data sources that discussed in the previous section, data mining techniques may be applied for various application purposes. In this section to provide a broad view of the literature, the major works done in the domain will be bibliographically overviewed from an application-oriented perspective. In this regard, the fertile body of literature is categorized based on the main research directions.

A. Data Mining for Robot Control

Control in the realm of robotics is a generic concept that comprises a set of operations in different levels. Specifically, control system in a given robot may be regarded as the main computational unit which is in charge of performing complex real-time information processing tasks [13] to turn the input data/signal to operational decisions, including routing, localization, etc. In this regard, applying data mining techniques for control-related purposes can dramatically improve the performance of the robot in various aspects. Following this trend, authors in [14] to control a robotic arm and gripper have leveraged Support Vector Machine (SVM) for classification of electromyographic signals. Authors of [15] proposed a five-step self-organizing polynomial data mining algorithm to attitude control of planar space robots. In addition to the generally control-related mentioned studies, several more specific works have been done in the field as follows. To solve the problem of routing mobile robot within wireless sensor network (WSN), a clustering-based parallel genetic algorithm (CBPGA) solution has been presented in [16]. In this work, the problem is formulated as a Traveling Salesman Problem with Neighborhoods (TSPN). One of the important issues in multi-robot environment is to prevent robots from collision. This problem is the subject of work done in [17] in which authors tried to avoid collision in multi-robot systems by leveraging behavior mining. In this work, collected behavioral data from a simple 2D game in which human player prevents robots from collision will be mined. Then, the extracted patterns (behavioral model constructed from data) may be used to learn robots to deal with collision situations.

An autonomous robot should be able to construct a map of the (unknown) environment which it operates within to localize itself. To improve the process, several studies in the field devoted to utilizing data mining methods as follows: in

[18] to build accurate map for mobile robot, application of k-means clustering of laser ranger sensor data has been studied. As another work of such kind, to improve the performance of

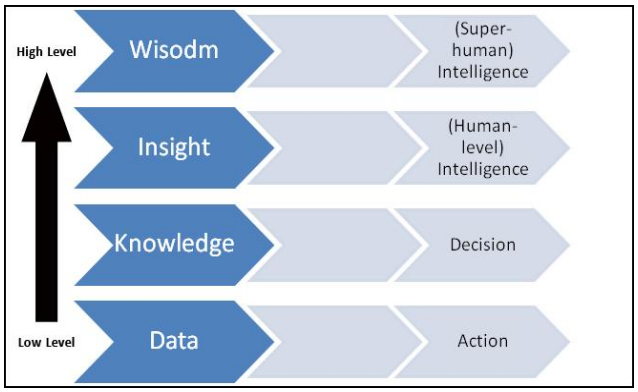


Figure 3. Different levels of knowledge and its implication on robots

robot localization and mapping within an unknown environment a method has been proposed [19]. This method tries to cluster the feature values obtained by visual attention during a pre-traveling stage for determining automatic landmarks. Problem of automatically generating topological maps from sensor-obtained data using spectral clustering and classification has been investigated in [20]. Authors of [21] leveraged self-organizing Kohonen neural network alongside with hyperellipsoid clustering in the context of mobile robot map building. [22] is another work in the field that attempted to create topological map using Isomap nonlinear dimension reduction and Bayesian clustering. In a most recent work in the field, two algorithms for generating 1) straight line map using clustering spatial domain and 2) robot mapping by using clustering in a Hough domain have been proposed in [23]. One of the most important advantages of this study is that the proposed algorithms could efficiently work in noisy environments.

B. Data Mining for Robot Vision

Almost all of the advanced robots, such as soccer player and rescue ones are equipped with some type of vision system. Such capabilities enable autonomous robots to be aware of their surrounding environments and make proper decisions based on the visual input. Since there are many vision-based applications for robots, mining such data including videos and images acquired by the agents could be very useful and applicable. In this regard, an image mining framework for robot vision based on concept lattice theory and cloud model theory has been proposed in [24]. Another similar work in this domain is performed in [25] in which a clustering algorithm for a real-time general-purpose vision system has been introduced. Also, in [26] issue of classification of Autonomous Underwater Vehicles (AUVs) imagery (of biological species and physical formations) is investigated. It could be said that efficiency of a vision system greatly depends on how effective object detection process will be. In order to enhance the process, data mining techniques come in handy as in the following studies: in [27] a data-grouping method based on K-means algorithm, inequality binary division method, and LBG algorithm has been proposed. The main contribution of this study is to provide an object detection method for mobile robot which is used for localization and map building. The authors claimed that applying the proposed data mining algorithm resulted in organizing the path planning more correctly and finding optimized path easily. Authors in [28] presented an unsupervised scene parsing algorithm to improve its own performance during operation time. To achieve such functionality (namely, continuous updating) they combined an online clustering algorithm with an undirected graphical model that grows continually over time. A place recognition algorithm by using spectral clustering that is mainly used for robot mapping is introduced in [29]. To solve the problem of estimation of the pose of known objects in unknown scenes, [30] introduces a solution in the form of a pose clustering method. As a novel and interesting idea, authors of [31] presented a solution for 3D object classification for mobile robots by leveraging web data. In fact, the main prominence of this study is obtaining web data – in addition to contextual and sensor data- to build more rigorous knowledge base for the robot. Another related field in this context is vision-based terrain identification that is beyond the scope of this paper. However, research activities performed in [32]: clustering sensor data, [33]: performing data mining during rover and [34]: clustering vibration signal may be mentioned as some examples of leveraging data mining techniques for terrain identification.

C. Data Mining for Robot Learning

A key feature of autonomous, decision-maker robots is their ability to learn new skills (from other robots or humans), achieve new capabilities and adapt to an unknown environment. In this regard, over the years a great body of research devoted to developing algorithms and methods for robot learning. Following the trend of using data mining in robotics, there are several works around the topic of robot learning. As one of the early works in the field, Malone et al. [35] demonstrated use of a hybrid neural data mining technique to classify robot actions for imitation learning. In another study, authors in [36] proposed an adaptive semi-supervised learning method for object detection in a given environment with little user interaction. The core concept of this work is leveraging unsupervised learning prior to employing a semi-supervised classification. The underlying idea of work done in [37] is robot learning based on observing the environment and specifically k-medoid clustering of real time obtained sensor data. Learning by trial and error or Reinforcement Learning (RL) that aims to prepare the robot with capabilities of reacting to situations it is not familiar with is a popular topic in the context of robot learning. As an example of intersection of data mining and RL research, authors of [38] tried to improve learning process by employing data mining techniques. In another study of such kind, in [39], due to pattern discovery ability of data mining, a clustering algorithm is leveraged for automatic discovering of useful temporal abstraction in RL.

D. Data Mining for Robot Behavior

Based on the application and context, robots interact with others in the environment. In a multi-robot context, "others" refers to robotic agents and in the case of social robots, "others" implies humans. To study the behaviors of robots, several researches have been conducted with respect to applications of data mining. One important direction in this field is using data mining to improve robots' behavior. Following this approach, in [40] authors take benefits of the web (through web mining) and specifically social media in which users participate as a knowledge source alongside with contextual information to discover users' needs. Another study of this kind that takes benefit of web mining to acquire common-sense object locality knowledge is presented in [41]. The idea of learning through mining temporal patterns of robots' behavior is investigated in [42]. The main goal of this study is to improve the agent's behavior through learning and based on experienced patterns. [43- 45] are other research activities in which robot's behavior has been analyzed by using data mining techniques.

V. Data Mining for Robot Soccer

Since the early days of robotics, one of its most interesting and popular domains is robot soccer. Probably the most important reason for focusing on this domain is its specific features and requirements that made it a fertile platform for further developments in the context of AI, multi agent systems and so on. Moreover, the RoboCup 2050 vision – to beat winner of the most recent FIFA World Cup by a team of fully autonomous humanoid robot agents [46]- is considered as a strong motivation for researchers in the field. For this reason, in addition to the applications mentioned in the previous sections, Robot Soccer domain can be investigated from some different aspects. From a data-centric viewpoint, there are two major classes of data in a given Robot Soccer match: 1) data related to the team and 2) data related to the opponent (team). Such data include records about function, position and performance of each agent in particular and teams (as multi agent systems) in general, in the form of log files. (Fig.4)

In this regard, over the years, researchers tried to leverage data mining to take benefits of such data for, e.g. prediction of opponent actions [47] and behaviors [48] and team strategy [49, 50].

Moreover, and as some concrete recommendations for future studies in the field, following could be mentioned:

- Improving teams' performance by discovering (Spatio-temporal) patterns about receiving and scoring goals
- Analyzing rate and frequency of failure by soccer agents with respect to the elapsed time in the match and its effects on the result
- Analyzing successful strategies of winner teams for efficient decision making

To be more specific, details of applications of data mining process in a given robot soccer scenario may be explained as follows:

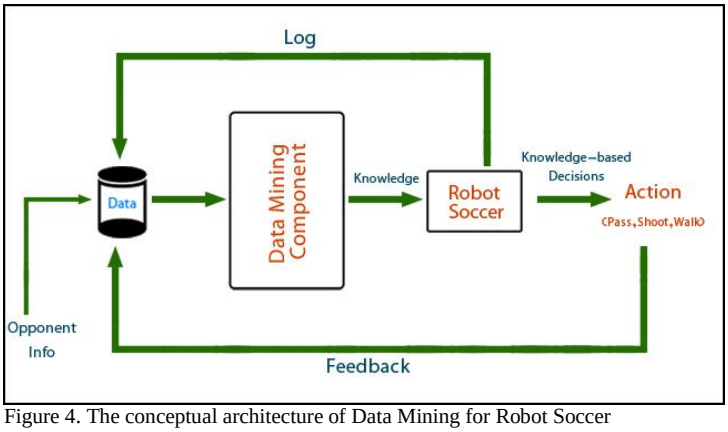


Figure 4. The conceptual architecture of Data Mining for Robot Soccer

Before the Game: analyzing the opponent's strategy to train the team based on the extracted patterns.

Within the Game: 1) online mining of the opponent's patterns to achieve adaptivity in strategy as well as tactics. 2) mining the team's status for matching with predefined plans.

After the Game: 1) analyzing team's performance in general and agents in particular to evaluate the success rate. 2) leveraging information (events, interactions, etc.) recorded in the form of log by process mining to study the system efficiency, fault detection and diagnosis, etc. The results obtained in the phase will be used to feed the first phase (before the game) analytical process.

It could simply be said that by taking advantages of data mining for, e.g., robot soccer, the classical operational sequence of ***Agent$_i$ (action, target)*** will be changed (improved) to ***Agent$_i$ (action, target, knowledge)***.

VI. Challenges and Future Directions

Since different types of robots introduce their own specific requirements and implications, it would be hardly possible to discuss all the challenges. However, in this section some of the major challenges in the realm of data mining will be discussed.

- **Noisy Data:** The very first issue that comes in mind when dealing with mining robotic data is noisy sensor data. For the mining process to be efficient enough, input data – specifically sensor data- should be clean and noise-free. In this regard, there is need to a preprocessing phase to be in charge of removing noise from sensory input.
- **Data Acquisition:** As mentioned earlier, there are several data sources for a given robot. However, despite the sensory data that robots intrinsically equipped with facilities to acquire them; new data types, namely web data that are originally unstructured (or semi-structured), should be handled in such a way to be usable by the agents.

- **Large amount of Data:** Handling the sensory data that in some cases could be regarded as big-scale data is an important issues to be considered. Moreover, facilities and methods for managing and mining of data stream in real time should be developed.
- **Computational Issues:** To be able to perform in-robot data mining, computational and power resources of robots should be enhanced. Multi-robot based solutions may be considered as silver bullets for dealing with computational-related challenges.

Owing to progressive advancements in the related scientific fields, some of the likely future directions for improving the quality of data mining in the context of robotics may be thought as follows:

- Taking advantages of opportunities that Internet of Things (IoT) introduces, such as acquiring data from multiple sensors and devices as well as using their computational resources and capabilities can be an ongoing direction. Further development of robotics network to share knowledge and resources is also an effective solution.
- To enrich robots knowledge base for better decision-making, judgment and dealing with unknown environments and objects, leveraging computational knowledge engines is recommended.
- Since social robots (with various applications ranging from nursing to education) are nowadays prevalent, using social media as an invaluable repository for training robots may not be overlooked. Furthermore, social media analysis and mining could be handy in this way.

VI. CONCLUSION

In this paper we have studied the intersection of data mining and robotics as two important and game-changer fields of technology. From a high-level point of view, robotics is all about data and possibly large amount of it. On the other side, when it comes to taking benefits of data, the silver bullet is data mining. Following this idea, over the years many works performed on different aspects of the topic to leverage data mining for robotics applications, e.g. routing, mapping, learning, etc. Despite the current literature on utilizing data mining techniques in the realm of robotics, there are many opportunities that left behind or researchers did not pay proportionate attention to that. In other words, it could be said that concept of applying data mining in the context of robotics is still in its infancy and there is a long unpaved road ahead. Notwithstanding, in this paper we have tried to present a general overview to provide a reference point of major works done in the field. Moreover, the paper may be regarded as a roadmap for future studies in the field.

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Learning Decision Making for Soccer Robots: A Crowdsourcing-based Approach

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***Abstract*— From the early days of Soccer Robotics, they were not supposed to be only another funny game and entertaining hobby. They were shaped around a specific idea in the mind, to beat FIFA World Cup champions by 2050. In this regard and based on the prospective roadmap, soccer robot field has become a fertile testbed for developing Artificial Intelligence (AI) and machine learning algorithms and methods as well as mechanical equipments design. Despite the advancements achieved over the years, it seems there is a long way ahead to meet the determined goal, at least from the "soft" perspectives, including decision making, action selection, etc. In other words, lack of human-level intelligence to provide robots with capabilities to compete with human counterparts is a great drawback. To cope with such issues, a working solution may be to train soccer agents by humans. Following this idea, in this paper a conceptual view of a novel crowdsourcing-based framework for soccer robots to learn (human-like) decision making is proposed. Also, different aspects of the system are studied. It is believed that such an approach can greatly improve soccer robots' ability to make proper and effective decisions – and subsequently selecting best actions- in different situations. Moreover, it could be regarded as a first step towards equipping soccer agents with necessary human-level requirements for the ultimate goal.**

Keywords— Soccer Robots; High-level Control; Decision Making; Learning; Crowdsourcing

I. INTRODUCTION

The story was started in 1997 by proposing RoboCup competition with a visionary idea in the mind:

"By the mid-21st century, a team of fully autonomous humanoid robot soccer players shall win a soccer game, complying with the official rules of FIFA, against the winner of the most recent World Cup" [1].

After that, soccer robotics has become a popular and fertile research field for a broad range of scientific topics from AI and machine learning to mechanical engineering. Over the years the community has achieved many advancements in different directions, including robot localization [2, 3], vision [3, 4], cooperation ability [5, 6] and so on. However, there is a long unpaved way ahead to reach the prospective roadmap. Clearly, to be able to compete with human footballers in a standard match, soccer agents – in addition to mechanical and motor related issues or *the hard aspect*- need to be equipped with some essential soft capabilities including thinking, learning, decision making, action selection, etc. In other words, soccer robots –at least- should be as intelligent as their human counterparts to be ready to kick off a standard and fair match. For this reason, more efforts are needed to improve quality of soccer robots abilities, specifically their decision making. In fact, in addition to the benefits of such improvements for soccer robotics, it could be regarded as a practical, major step towards preparing soccerbots for the dreamt match. In this regard, leveraging humans' abilities to train soccer agents in the form of crowdsourcing may be considered as an effective and working approach.

Based on this idea, soccer robots could be trained to make the best decisions according to decision making ability of human beings in similar situations. This process could be considered as indirect training of robots. In this paper, the conceptual architecture of *CrowLDeM*, a **Crow**dsourcing-based framework for **L**earning **De**cision **M**aking to train soccer robots by human-level intelligence is proposed. Moreover, different aspects of the proposed system, including a pre-experiment evaluation of the underlying concept, will be explained. The rest of the paper is organized as follows: In section 2, position of decision making in the field of soccer

robots is studied. Applications of crowdsourcing for robotics and a concise review of the literature are presented in section 3. Architecture and nuts and bolts of *CrowLDeM* will be described in section 4.

II. Decision Making for Soccer Robots

One of the essential building blocks of robot autonomy is its quality of decision making. Such a feature provides robots with capability of making the best and most appropriate response to the environment and its different situations. For this reason, better decisions will be resulted in selecting better action(s) and consequently better outcomes. Generally, decision making as one of the control processes of a robotic system is in charge of determining next operation(s) based on the input data to the system, findings from the environment and analyzing the situation (Fig. 1).

In the context of soccer robotics, the environment is one of the most dynamic and challenging ones among other robotic fields. This is because there are several case-specific requirements that may be not presented in other related domains such as need to collaboration with other robotic teammates, following the strategy, facing with different conditions, making team-level and player-level decisions, etc. The decisions made in soccer robots are usually among a limited set including passing, shooting, moving with the ball and other standard soccer-related actions and based on the team strategy and tactics. Over the years, researchers have tried to improve this ability in the field by proposing different methods and techniques, as works done in [7- 10]. However, we, as humans, are witnessing that quality of robots' decisions are far from which that one can expect from an amateur footballer.

In fact, current status of soccer robots' decision-making ability not only is not sufficient for a real world match, but affects quality of robot-robot matches. Nonetheless, this is not a context-specific drawback for soccer agents and robotics, in general, suffers from lack of adequate intelligence to do human-like actions. According to the combined results of surveys of top scientists and researchers in artificial intelligence, they believe that human-level machine intelligence may be attained by 2022 with only 10 percent of probability. While such an achievement is predicted to be attained in 2040 and 2075 with 50 and 90 percents of probability, respectively [11]. For this reason, the silver bullet to make robots capable of performing more intelligent actions may be taking benefits of humans as trainers. Thanks to the concept of human intelligent task (HIT) [12], this is what in recent years is under study and investigation by researchers in the form of crowdsourcing based robot learning.

III. Crowdsourcing for Robotics

The idea of leveraging human's capabilities to solve different (computational) problems [13] is around for a decade. Such distributed problem-solving model was proposed in 2006 [14] and after that has been employed for a wide variety of applications in different domains ranging from computer science related problems [15, 16] to medical [17, 18] and even geography applications [19, 20].

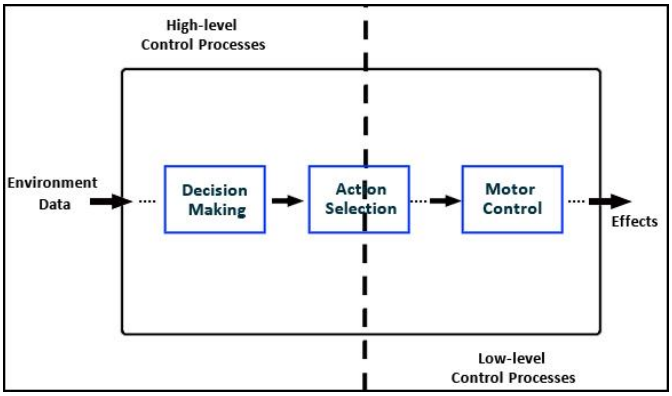


Figure 1. Position of decision making within a general robot control system

There are several benefits on taking advantages of humans' abilities to perform micro-tasks; though the major one is relying on converged opinions of all participants (or simply wisdom of crowds) on a specific solution that in most of cases may be considered as accurate. Further considerations of conducting a crowdsourcing project could be found in [21-23]. Due to its applicability, within the recent years several studies have been conducted on how crowdsourcing could help robotics.

A. Related Works

As a recent experience in taking benefits of using crowdsourcing for robotics, researchers at University of Washington have shown that it is a quick and effective way to teach a robot to complete tasks through crowdsourcing [24]. They used Amazon Mechanical Turk as crowdsourcing platform asking people to build similar models of a car, tree and others. Then the robot learnt to imitate the best model (based on some criteria) to construct the shape [24]. Some of the other notable works in this way are as follows: authors in [25] aimed to collecting a large dataset of images from real everyday living spaces and environments for robot modeling by crowdsourcing the process. In [26] a framework for robot supervision through Amazon Mechanical Turk has been proposed. Then, the users' provided semantic information about the world will be utilized by robots to improve their capabilities.

Idea of combining Reinforcement Learning (RL) and crowdsourcing to teach new skill to robots is presented in [27]. Also, issue of learning new actions [28] and path planning [29] for robots using crowdsourcing and based on the user feedbacks are studied recently. The aforementioned concise overview of the literature shows that crowdsourcing is a state-of-the-art and efficient direction towards robot learning. In this regard, this trend may be used for other robotic fields that have a strong need to perform human-like actions. Therefore, the idea of leveraging wisdom of crowds to train soccer robots will be introduced and described in the rest of the paper.

IV. CrowLDeM: Details and Architecture

The proposed framework for learning decision-making to train soccer robots by human-level intelligence, *CrowLDeM*, will be described in this section.

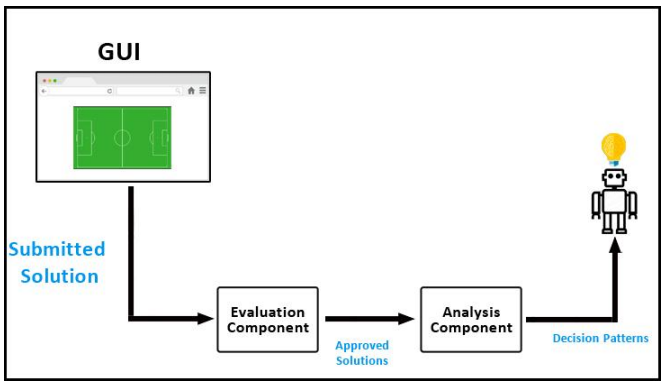


Figure 2. The conceptual architecture of *CrowLDeM*

As mentioned earlier, the underlying concept of *CrowLDeM* is to leverage human intelligence to train soccerbots for decision making in different situations. For any crowdsourced project to be successful, the most important factor is finding appropriate participants who have adequate knowledge of the field to provide working solutions/answers. For this reason, in some cases the ideal is to hire paid expert workers.

Of course, following this approach has its own problems like being costly and difficulties of finding skillful workers.

However, in the case of soccer robotics finding experts is far easier than other fields. This is because a large number of people around the world have some information about the game and in this regard they can provide (general) solutions. As some evidences, one billion fans worldwide watched [30] the final match of FIFA World Cup 2014 and about 500 million ones watches [31] El Clasico (FC Barcelona vs. Real Madrid) match twice per year. In addition to these mostly general potential participants, another remarkable group is the community of soccer game players that are highly skillful. Statistics says that 14.3 million copies of EA Sport FIFA 15 sold globally [32]. Hence, it seems that there is not any serious problem with finding potential workers for *CrowLDeM*. The conceptual architecture of the proposed framework is illustrated in Fig. 2. The workflow of the framework is as follows:

- A problem, P_i, (a scene of a soccer robot match) presented to participants
- Participants should provide a solution, S_i, (making decision on what the indicated agents should do) based on the presented problem
- The proposed solution will be presented to other participants for rating
- After *N* times rating, the solution will be evaluated
- If the solution passes the evaluation criteria, it will be analyzed
- The extracted patterns of the approved solution will be used to train soccer robots

The framework (illustrated in Fig. 2) is comprised of three main parts that each of which is explained in the following subsections.

A. User Interface

The front-end component of the framework is devoted to presenting the problems to users. The problem here refers to a snapshot of a particular scene of a (hypothetical/real) match. Based on the situation depicted in the image, users should decide the next operation of the ball-owner, including pass the ball (to whom), shooting to the target or moving with the ball (in which direction). Then, by submitting the solution it will be shown to other users to rate (judge) it. The scenes – including positions of soccer agents within the playground- may be captured or reconstructed from real soccer robot matches or randomly generated ones. Moreover, users could generate their own problems (design a playground) and put them in the queue to be solved by others. To be judged as accurate, each problem will be shown to a predetermined number (*N*) of users. (Fig. 3)

B. Evaluation

The second component of the framework is in charge of evaluating submitted solutions. After a solution being rated *N* times, it will be considered for evaluation. This process consists of three subprocesses.

In the first step, obtained scores of the solution will be computed (1).

$$SolScore\ (S_i) = \frac{|\sum_{i=0}^{n} Score_i|}{N} \quad (1)$$

Second function determines the frequency of submitting similar solutions for the same problem (2).

$$SolFreq\ (S_i, P_i) = \frac{|\sum_{i=0}^{n} freq\ (S_i, P_i)|}{N} \quad (2)$$

Finally, the last function checks the efficiency of the submitted solution against a predefined threshold. A give solution passes this check only if surpasses the threshold (3).

$$SolEff\ (S_i) = \{1\ if\ eff(S_i) \geq \theta_{th},\ 0\ otherwise\} \quad (3)$$

At last, sum of these three steps is considered as the result of evaluation process. Solutions with highest value will be passed to the next phase (4).

$$Eval(S_i) = SolScore\ (S_i) + SolFreq\ (S_i, P_i) + SolEff\ (S_i) \quad (4)$$

C. Analysis

In the final phase, the qualified solutions are analyzed and useful decision-making patterns will be extracted from them.



Figure3. Sample mockup of *CrowLDeM*

Such pattern will be categorized and employed to train soccer robots for dealing with similar situations. Moreover, decisions made by humans could be compared with robots decisions for same situations in real matches to find the intelligence gap between humans and robots. Also, applying data mining techniques on the decision patterns provide interesting and untouchable knowledge on how the process could be improved.

V. Pre-expriement User Study

As mentioned earlier, the proposed framework is still in the middle of implementation and has yet to be completed for the final evaluation. However, in order to be ensured of the accuracy of the underlying idea, a pre-experimental user study was conducted. The main goal of this experiment was to unveil the fact that human decision making ability surpasses robots one. Therefore, it supports the idea of leveraging humans' ability to train soccer agents.

In this experiment, six scenes (snapshots) of a 2D soccer simulation game (RoboCup 2013 final game between WrightEagle and HELIOS2013) in which the next decision of the ball owner agent resulted in failure (**failed decisions**) were captured.

Then, the participants asked to decide what they did (based on the standard soccer actions) if they were ball owner/could control the ball owner.

In fact, such an experiment can specify the difference between crowds and robots decisions as a benchmark for developing similar frameworks to *CrowLDeM*.

The appropriate participants - to be skilful enough- selected among those who watch, at least, one soccer match and spend, at least, one hour playing video soccer game per week.

The decisions made by 30 participants are summarized in Table 1 and Fig. 4.

Table 1. Summary of participants' decisions

	Scene 1	Scene 2	Scene 3	Scene 4	Scene 5	Scene 6
Human-specific decisions	19	25	27	29	29	4
Robot-like decisions	11	5	3	1	1	26

As predicted before and based on the researchers' estimation [11], the result of the experiment proved that there is a remarkable gap between human and robot intelligence and decision making abilities. However, there are several other variables that affect the decision making; this user study shows that in most cases human-made decisions are far different from robot ones.

In this regard, training soccer robots with humans' intelligence can be regarded as a great step towards making robots more intelligent and powerful.

VI. Conclusion and Future Works

The conceptual architecture of *CrowLDeM*, a crowdsourcing-based framework for learning decision making to train soccer robots by human-level intelligence is proposed. The major goal of this framework is to improve quality of soccer robots' decision making capabilities by leveraging human intelligence and problem-solving abilities. In addition to enhancing soccer agents' performance in soccer robotics competitions, it could be considered as a first step to preparing such robots with human-level reasoning and intelligence towards the horizon of 2050.

The work reported in this paper is the first step to train soccer robots for making more intelligent decisions. In this regard and for future works, following ideas are in the mind:

- Taking benefits of abilities (intelligence) of professional soccer players and coaches to train soccer robots
- Making the challenge interactive – rather than a snapshot- to acquire a sequence of decisions
- Creating a simple game to train soccer robots based on the humans' decisions and actions
- Conducting some experiments with real world data to evaluate and compare efficiency of *CrowLDeM* with traditional methods in soccer robot match

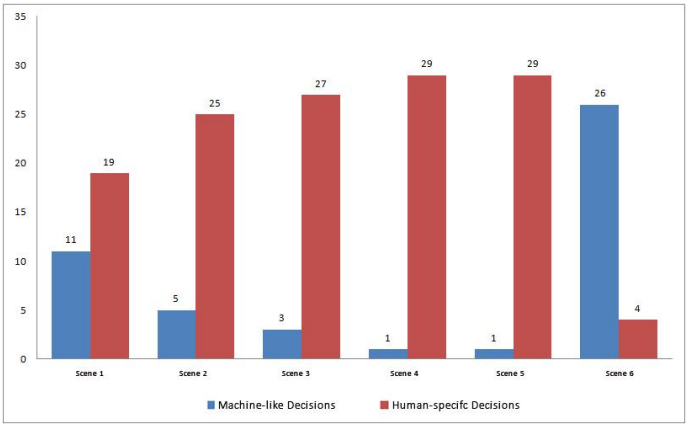


Figure 4. Summary of participants' decisions

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Detection of Both Positive and Negative Correlated Rows in Biclusters Using Squared Transposed Virtual Error

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***Abstract*— Biological Laboratories produce huge amounts of data every day. Biologists without proper processing tools and software are not able to analyze and discover hidden knowledge of these huge volumes of data. Biclustering technique is one of the bioinformatics approaches which is used to analysis obtained data from microarrays. Each microarray represents a data matrix of real numbers and biclustering algorithms are used to extract some sub-matrices including some specific patterns. HEvo-Bexpa is an evolutionary biclustering algorithm which can find biclusters including shift, scale and shift-scale patterns using Transposed Virtual Error (VET). VET is equal to zero for biclusters which containing positive correlated rows but it is not responsible for both positive and negative correlated rows at the same time. In this study, VET is extended to Squared Transposed Virtual Error (SVET). Obtained results demonstrate that it is possible to find rows with positive and negative scales using SVET.**

Keywords*— *biclustering; evolutionary algorithm; miroarray data analysis; squared transposed virtual error

I. INTRODUCTION

One of the main features of the biological labs is generating high volume of data, including microarray technique, which is a conventional technology in the field of biology. Microarrays represent an arrangement of biomarkers in the form of a data matrix. Because of the lack of experts and the considerable amount of data, analysis phase are usually done using bioinformatics methods. Many computational intelligence algorithms have been developed to work with matrices as input. Especially in the case of microarray data, Biclustering algorithms are used to extract biological components that may interest biologists. These algorithms take a matrix as input, and return some sub-matrices containing specified patterns as output. For the first time, biclustering algorithm was introduced by Hartigan[1]. He called the algorithm "direct clustering"; later on, same algorithms were known as biclustering which is called first time by Mirkin[2]. This method did not interest researchers for a long time, until Cheng and Church used it to analyze biological data obtained from microarrays for the first time. With widespread use of microarray technology, many biclustering algorithms were developed that focused on different search strategies and target patterns. Since biclustering algorithms are generally considered as NP-complete problems, it is common using evolutionary methods as the search procedures of the algorithms[3]–[7]. Also, selecting the appropriate metric to use in fitness functions play an important role in the success of evolutionary algorithms to find different patterns.

Transposed Virtual Error (VET) is one of the newest metrics raised in this domain[8]. The metric is able to predict shift, scale and shift-scale patterns, but it does not work to find scale and shift-scale biclusters which their rows are correlated negatively. In current study, we extend VET to Squared Transposed Virtual Error (SVET) for overcoming this problem. SVET is employed in a multi-objective fitness function of an evolutionary framework. We use an evolutionary biclustering algorithm which is called HEvo-Bexpa and we have proposed that in our previous study[9]. HEvo-Bexpa uses a combined evolutionary approach to escape from local optima. Search strategy of HEvo-Bexpa is a combination of Genetic Algorithm (GA)[10] and Asexual Reproduction Optimization (ARO)[11]. Also, because of SVET sensitivity to the initial population, we propose a two-level initialization procedure to achieve appropriate results with less initial population.

II. BICLUSTERING ALGORITHMS

In the case that M is an $n \times m$ matrix whose elements are real numbers and it is represented by two sets such as R and C for rows and columns respectively, a bicluster B is a sub-matrix of the given matrix consisting of rows $I = \{r_1, \dots, r_k\}$ and columns $J = \{c_1, \dots, c_l\}$ which is obtained by removing some rows and columns of M. An element b_{ij} stands for ith row and jth column of bicluster B.

In terms of computational intelligence, biclustering algorithms are composed of two main parts, a search mechanism and a metric for evaluating the patterns of obtained biclusters; but there are some studies about meaningfulness of algorithm's outputs with regard to biological perspective. Eren et al. have reviewed some common patterns which biclustering algorithms would find[12]. These patterns are listed in Table I.

TABLE I. PATTERNS OF BICLUSTERS

Patterns	Definition
Constant	Every element of sub-matrices are equal to mean of main matrix.
Constant upregulated	Every element of sub-matrices are equal to summation of mean of main matrix and a constant positive real number.
Shift-Scale	Each row of sub-matrices is added by a real number; afterward, it is multiplied by another real number without zero.
Shift	Each row of sub-matrices is added by a real number.
Scale	Each row of sub-matrices is multiplied by a real number without zero.
Plaid	Plaid biclusters are decomposable into a sum of multiple layers.

In this paper, the proposed algorithm has been evaluated under the mentioned patterns.

Each row of a bicluster (r_i) including one of the shift, scale and shift-scale patterns can be represented using the following relation:

$$r_i = \alpha_i \times \pi + \beta_i \quad (1)$$

Where α_i stands for scaling factor, β_i represents shifting factor and π is a base vector. In shift pattern, α_i and in scale pattern, β_i is equal to zero. If all scaling factors are positive or negative, the rows of the biclusters are correlated positively and if the scaling factors are both positive and negative at the same time, the biclusters indicate positive and negative correlation of rows, simultaneously[13].

III. METRICS

A type of various metrics has been applied in different biclustering algorithms. Some of them, especially the metrics that are used for detecting correlation scores, work based on pairwise of rows of biclusters; furthermore, there are some other types of metrics which are calculated for whole elements of a matrix to find some patterns in terms of minimization or maximization problems. Variance has been the first metric for evaluation biclusters which was employed by Hartigan in direct clustering algorithm[1]. Mean Squared Residue (MSR) has been introduced in CC algorithm[14]; afterwards, MSR has been modified by Mukhopadhyay et al.[15]. The new version of metric is called Scaling Mean Squared Residue (SMSR) which is used to detect scale pattern. Relevance Index (RI) is another measure which has been developed by Yip to find bicluster[16]. The metric is computed by summation of ratio of local variance to global variance for selected columns. Virtual Error (VE) which has been introduced by Pontes et al. is used to find one of the shift or scale pattern separately[17]. They have proved in their future researches that VE is equal to zero for shift and scale pattern in at the same time if input matrix is transposed. The new metric has been called Virtual Error Transposed (VET)[8]. The metrics are shown in the Table II.

TABLE II. SOME METRICS OF BICLUSTERING ALGORITHMS

Metric Name	Relation
Mean Squared Residue	$MSR(B) = \frac{1}{\lvert I\rvert \cdot \lvert J\rvert}\sum_{i=1}^{\lvert 1\rvert}\sum_{j=1}^{\lvert J\rvert}(b_{ij} - b_{iJ} - b_{1j} + b_{1J})^2$
Scaling Mean Squared Residue	$SMSR(B) = \frac{1}{\lvert I\rvert \cdot \lvert J\rvert}\sum_{i=1}^{i=\lvert 1\rvert}\sum_{j=1}^{j=\lvert J\rvert}\frac{(b_{iJ} \times b_{1j} - b_{ij} \times b_{1J})^2}{b_{iJ}^2 \times b_{1j}^2}$
Relevance index	$Q_i = \sum_{v_j \in V_i} R_{ij}$
Transposed Virtual Error	$VE^t(\mathcal{B}) = \frac{1}{\lvert I\rvert \cdot \lvert J\rvert}\sum_{i=1}^{\lvert I\rvert}\sum_{j=1}^{\lvert J\rvert}(\hat{b}_{ij} - \hat{\rho}_i)$

Where $R_{ij} = 1 - \frac{\sigma_{ij}^2}{\sigma_j^2}$ stands for Relevance Index of column$j$. Also in VET relation, the parameters are $\rho_i = \frac{1}{\lvert J\rvert}\sum_{j=1}^{\lvert J\rvert} b_{ij}$, $\hat{\rho}_i = \frac{\rho_i - \mu_\rho}{\sigma_\rho}$ and $\hat{b}_{ij} = \frac{b_{ij} - \mu_{c_j}}{\sigma_{c_j}}$.

The metrics can be considered as an objective function directly or used in a multi-objective function.

A. Virtual Error Transposed

The VET metric works based on the transposed input matrix. The output values of this metric can also be calculated for a non-transposed input matrix. The non-transposed metric that we use in HEvo-Bexpa is calculated as follows:

$$VE^t(\mathcal{B}) = \frac{1}{\lvert I\rvert \cdot \lvert J\rvert}\sum_{i=1}^{\lvert I\rvert}\sum_{j=1}^{\lvert J\rvert}\left|\hat{b}_{ij} - \hat{\rho}_j\right| \quad (2)$$

ρ_j is a virtual row:

$$\rho_j = \frac{1}{\lvert i\rvert}\sum_{i=1}^{\lvert I\rvert} b_{ij} \quad (3)$$

$\hat{\rho}_j$ stands for standardized virtual row:

$$\hat{\rho}_j = \frac{\rho_j - \mu_\rho}{\sigma_\rho} \quad (4)$$

$\hat{b}_{ij}$ is corresponding element (b_{ij}) of bicluster B in standardized virtual bicluster $\hat{B}$:

$$\hat{b}_{ij} = \frac{b_{ij} - \mu_{r_i}}{\sigma_{r_i}} \quad (5)$$

The value of VET is equal to zero for a scale or shift-scale bicluster if all of the scaling factors of its rows are greater than zero. Pontes et al. have used an assumption to prove equality of VET to zero for scale and shift-scale biclusters which is represented as $\sigma_{c_j} = \alpha_j \times \sigma_\pi$ for transposed input matrix. Because of being standard deviation, both σ_{c_j} and σ_π are positive; consequently, their assumption is false if the scaling factor is less than zero. Accordingly, only the biclusters containing positive correlated rows can be found using VET metric.

B. *Squared Transposed Virtual Error*

In the current study, for overcoming the inability of VET to find negative correlation, we extend VET to squared VET (SVET). The new metric is computable using the following formula:

$$SVE^t(\mathcal{B}) = \frac{1}{\sqrt{|I|\cdot|J|}} \sum_{i=1}^{|I|} \sum_{j=1}^{|J|} \left| \left(\hat{b}_{ij}\right)^2 - \left(\hat{\rho}_j\right)^2 \right| \quad (6)$$

Theorem: the value of SVET for a bicluster is equal to zero if the bicluster includes positive and negative correlated rows at the same time or separately.

Proof: Let B is a bicluster with shift-scale pattern so each row r_i can be represented by relation (1) where $\alpha_i \in \mathcal{R} - \{0\}$, the following formulas are established:

$$\mu_{r_i} = \alpha_i \times \mu_\pi + \beta_i \quad (7)$$

$$\mu_\rho = \mu_\pi \times \mu_\alpha + \mu_\beta \quad (8)$$

$${\sigma_{r_i}}^2 = {\alpha_i}^2 \times {\sigma_\pi}^2 \quad (9)$$

$${\sigma_\rho}^2 = {\mu_\alpha}^2 \times {\sigma_\pi}^2 \quad (10)$$

Every squared element of standardized bicluster is computable using the following relation:

$$\left(\hat{b}_{ij}\right)^2 = \frac{\left(b_{ij} - \mu_{r_i}\right)^2}{{\sigma_{r_i}}^2} = \frac{\left(\alpha_i \times \pi_j + \beta_i - (\alpha_i \times \mu_\pi + \beta_i)\right)^2}{{\alpha_i}^2 \times {\sigma_\pi}^2}$$

$$= \frac{\left(\alpha_i \times (\pi_j - \mu_\pi)\right)^2}{{\alpha_i}^2 \times {\sigma_\pi}^2} = \frac{(\pi_j - \mu_\pi)^2}{{\sigma_\pi}^2} \quad (11)$$

The following relation can be established to calculate the squared standardized elements of a virtual row:

$$\left(\hat{\rho}_j\right)^2 = \frac{\left(\rho_j - \mu_\rho\right)^2}{{\sigma_\rho}^2} = \frac{\left(\pi_i \times \mu_\alpha + \mu_\beta - \left(\mu_\pi \times \mu_\alpha + \mu_\beta\right)\right)^2}{{\mu_\alpha}^2 \times {\sigma_\pi}^2}$$

$$= \frac{\left(\mu_\alpha \times (\pi_j - \mu_\pi)\right)^2}{{\mu_\alpha}^2 \times {\sigma_\pi}^2} = \frac{(\pi_j - \mu_\pi)^2}{{\sigma_\pi}^2} \quad (12)$$

Since corresponding both element of the squared standardized bicluster $\left(\hat{b}_{ij}\right)^2$ and the squared standardized virtual row $\left(\hat{\rho}_j\right)^2$ are equivalent, the result for SVET is zero and the theorem is proved.

Trivially, the theorem is true for scale pattern, because scale pattern is equivalent to shift-scale pattern when shifting factor is equal to zero.

IV. Main Algorithm

The basic algorithm that is used to evaluate SVET, is named HEvo-Bexpa. The algorithm is proposed in our previous research[9].HEvo-Bexpa stands for Hybrid Evo-Bexpa and it is developed based on Evo-Bexpa algorithm which is proposed by Pontes et al[18]. Two major changes in HEvo-Bexpa, compared to the previous algorithm have happened. First, HEvo-Bexpa has hybridized two different evolutionary algorithms for global and local search phases. Second, the multi-objective function of Evo-Bexpa has been modified in HEvo-Bexpa to achieve better parameter settings and higher convergence speed.HEvo-Bexpa has been developed to work with VET metric, thus we modify the algorithm using a two-level initialization in order to find biclusters using SVET metric with less population size.

A. *HEvo-Bexpa*

HEvo-Bexpa has hybridized Genetic algorithm (GA) as main search procedure and an individual based evolutionary algorithm which is called Asexual Reproduction Optimization (ARO) as a local search phase. Second, the multi-objective function of Evo-Bexpa has been modified in HEvo-Bexpa to achieve better parameter settings and higher convergence speed. GA is one of the most famous meta-heuristic search procedures. ARO is another meta-heuristic algorithm which has recently been introduced. Both algorithms are nature-inspired and work based on reproduction of organisms, but they have one major difference: GA is a population-based search mechanism whereas ARO is an individual-based evolutionary algorithm. An individual in ARO algorithm is represented by a binary chromosome. In each iteration, a substring of the chromosome as a parent mutates while in binary representations it means a bit toggling process. The mutated chromosome represents a larva which is merged with the parent in next step; consequently, some toggled bits return to their original states. New chromosome is called bud. Since there are lack of resources, between parent and child only the best remains. Diagram of ARO search mechanism is shown in figure 1.

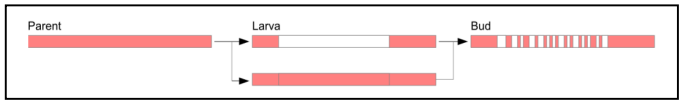


Fig. 1. Diagram of ARO search mechanism.

Maintaining diversity plays an important role to achieve an appropriate response, in the success of GA which requires proper control of selection pressure. Our experience showed that pre-convergence of population in Evo_Bexpa would be solved by increasing the initial population which it required to allocate more resources and more time was spent. ARO as a local search procedure prevents from premature convergence of the algorithm without the need to increase the number of population.

B. Multi-objective fitness function

We have proposed a modified version of the original fitness function of Evo-Bexpa which is resulted from summation of weighted relations:

$$Modofied_{\Phi(\mathcal{B})} = \frac{VE^t(\mathcal{B})}{VE^t(\mathcal{M})} + w_s \cdot Vol(\mathcal{B})$$

$$+w_{ov} \cdot Overlap(\mathcal{B}) + w_{var} \cdot \frac{1}{1 + GeneVar(\mathcal{B})}$$

$$+ w_{R_{to_C}} . \ R_to_C_Penalty(\mathcal{B}) \quad (13)$$

The Overlap function updates each element of a weight matrix (w) while the algorithm finds a corresponding element in a bicluster. All elements of the weight matrix are initially zero.

$$Overlap(\mathcal{B}) = \frac{\sum_{i\in I, j\in J} W(b_{ij})}{|I|\times|J|\times(index_of_current_bicluster-1)} \quad (14)$$

GeneVar function is used to ensure the variation in levels of gene expression for biological input datasets.

$$GeneVar(\mathcal{B}) = \frac{1}{|I|\cdot|J|}\sum_{i=1}^{|I|}\sum_{j=1}^{|J|}\left(b_{ij} - \mu_{g_i}\right)^2 \quad (15)$$

The modified Vol function is used to control the volume growth of biclusters:

$$Vol(\mathcal{B}) = \left(\frac{-\ln(|I|*|J|)}{\ln(|I|*|J|)+w_{gc}}\right) \quad (16)$$

We have proposed a penalty function to control biclusters balancing:

$$R_to_C_Penalty(\mathcal{B}) = \left(\frac{|J|}{|J|} - R_to_C\right)^2 \quad (17)$$

The favorable balance of number of rows to columns ratio (R_to_C) may be considered as implicit pre-knowledge; as a result, the use of this parameter leads to reduce the initial populations in modified multi-objective fitness function. In contrast number of seeds which is proposed by Pontes in the original algorithm which has been obtained by following relation, is much larger.

C. Two-Level Initialization

For determining number of 3*3 initialized population in Evo-Bexpa Pontes et al. have proposed following relation to calculate the probability of having at least one seed which is belonged to main bicluster[8] :

$$\frac{Favorable_seeds}{Total_seeds} = \frac{\binom{|I|}{3}\times\binom{|J|}{3}}{\binom{m}{3}\times\binom{n}{3}} \quad (18)$$

Duo to our modifications, HEvo-Bexpa could find biclusters using less population size based on VET metric. Since SVET is more sensitive than VET to the number of initial population, during first 200 iterations the algorithm is ran using VET metric and the best individuals are considered as the initial population for the algorithm based on SVET Metric. Pseudocode of the main algorithm using SVET metric is represented in table III.

TABLE III. PSEUDOCODE OF THE MAIN ALGORITHM

```
/* Main Algorithm*/
[ Found Biclusters ] = Main Algorithm(INPUT MATRIX, Biclusters
    Number, Iteration Number of ARO,Number of First Level Iterations)
Found Biclusters ← Empty List (Biclusters Number)
Weight Matrix ←Genrate Zero Matrix(Shape(Input Matrix))
For i in 1: Biclusters Number
Main Metric ← VET
 Counter = 0
 Stop Condition ← False
 WHILE ~(Stop Condition)
  Counter++
  IF (Counter == Number of First Level Iterations)
   Main Metric ← SVET
  EndIF
  All Chromosomes ← GA(All Chromosomes, Main Metric)
  FOR Chromosome in All Chromosomes
   Chromosome ←ARO (Chromosome, Iteration Number of ARO,
    Main Metric)
  EndFOR
  IF (Varianc(All Chromosomes) == 0) & (Main Metric == SVET)
   Stop Condition ← True
  EndIf
 EndWHILE
 Found Biclusters(i) =Best of (All Chromosomes)
EndFOR
Return(Found Biclusters)
```

V. EXPERIMENTAL RESULTS

There is a relation to compare the ability of biclustering algorithms which is proposed by Prelić et al. Let m_1 and m_2 are two sets of multiple biclusters. If both b_1 and b_2 are some biclusters, the following formula represents similarity score of m_1 and m_2:

$$S(m_1, m_2) = \frac{1}{|m_1|}\sum_{b_1\epsilon m_1} \max_{b_2\epsilon m_2} s(b_1, b_2) \quad (19)$$

The s can be consider as a similarity score for two bicluster. Eren et al. used Jaccard Index which can be computed as follows for b_1 and $b_2$biclusters:

$$jac(b_1, b_2) = \frac{|b_1\cap b_2|}{|b_1\cup b_2|} \quad (20)$$

Assuming that m_1 and m_2 are expected and found set of biclusters, respectivly. $S(m_1, m_2)$ represents the recovery ability of algorithms and $S(m_2, m_1)$ is used to calculate the relevance amount of found bicluster using algorithms. Eren et al. have developed a toolbox which is named BiBench to compare the ability of some different biclustering algorithms to find biclusters including mentioned patterns, besides extracting meaningful biclusters in the biological perspective. Eren et al. have developed a toolbox which is named BiBench to compare the ability of some different biclustering algorithms to find biclusters including mentioned patterns, besides extracting meaningful biclusters in the biological perspective.

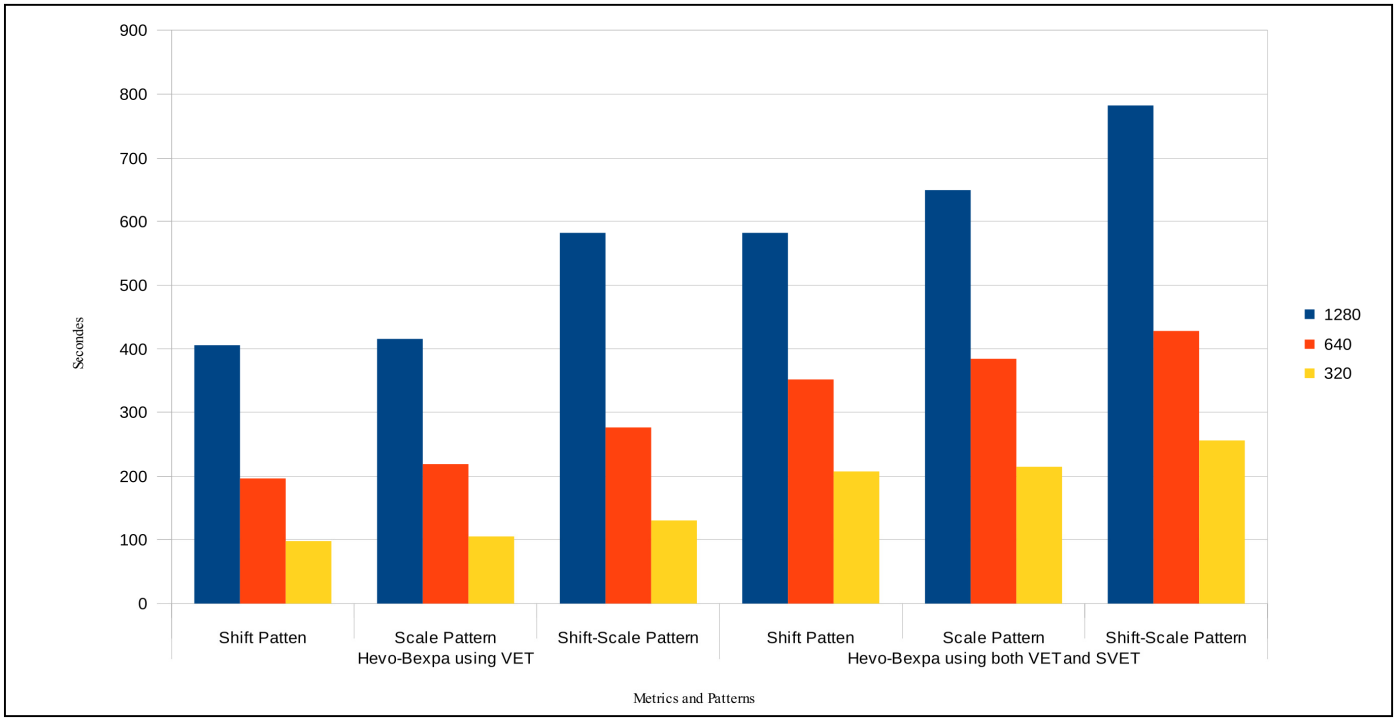


Fig. 2. Mean of HEvo-Bexpa algorithm running times using VET and SVET to find Shift, Scale, and Shift-Scale biclusters.

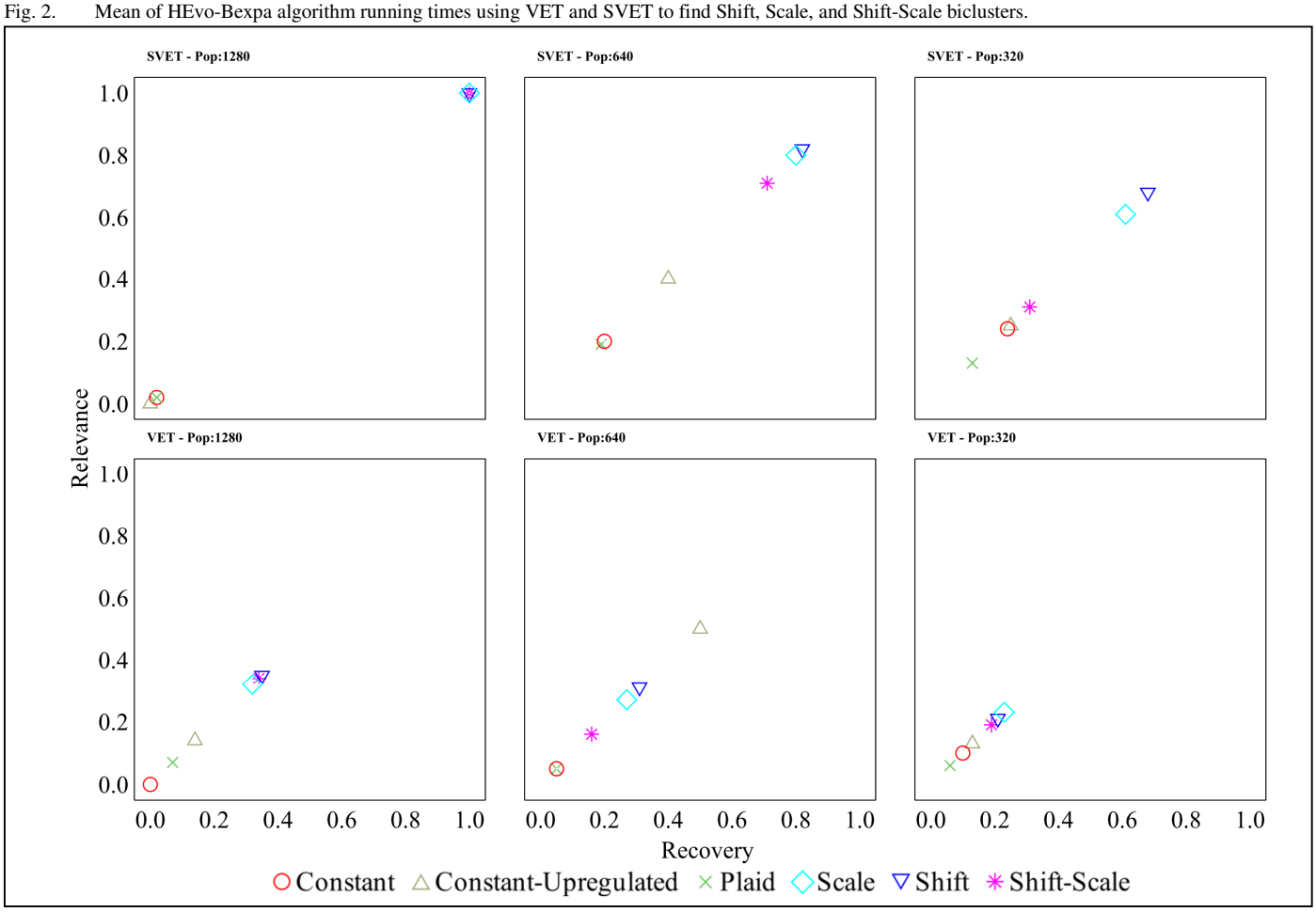


Fig. 3. Different Recovery and Relevance scores of HEvo-Bexpa algorithm, using VET and both VET and SVET metrics with 320, 640, 1280 population size.

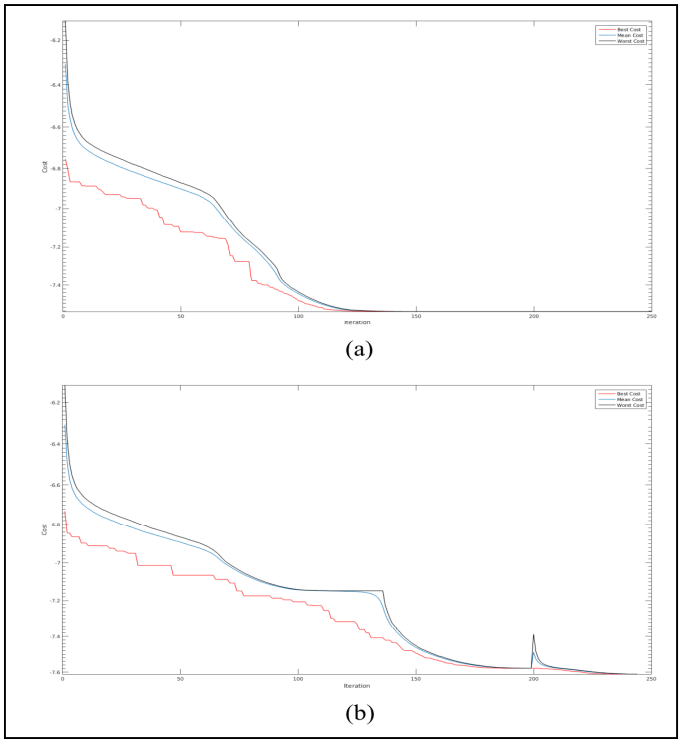


Fig. 4. (a) Cost of finding a Shift-Scale bicluster based on VET, (b) Cost of finding a Shift-Scale bicluster based on both VET and SVET in two-level using HEvo-Bexpa algorithm with 1280 chromosomes.

In the current study based on Eren's reviews, 20 synthetic dataset containing 500 rows and 200 columns were generated for each pattern. Every matrix included an embedded bicluster with 50 rows and 50 columns. The algorithm has been implemented on the MATLAB 8.1. Intel core i7-4710HQ processor and 8 gigabytes of RAM served MATLAB suite under Linux operating system. In each iteration of GA, 10% of the population were mutated. Parent selection method was roulette wheel. Multiple crossovers including uniform crossover, single point and double points were considered and one of them was employed in a random manner when crossover function was called. ARO iteration number was 3. In every iteration, one-hundredth of the length of each chromosome was mutated and also merging probability was assumed 0.7. In this study, biological perspective was not desired, therefor w_{var} was equal to zero. Also, synthetic data does not contained overlapped biclusters; thus, w_{ov} was considered zero, too. The other parameters of fitness function were assumed: $R_{toc} = 1$, $w_{R_{toc}} = 0.08$, $w_s = 8$, w_{gc}=0.4.

VI. Conclusion

The running times are shown in figure 2. Also, the recovery and relevance scores of HEvo-Bexpa algorithm for the previous algorithm and the proposed algorithm based on SVET metrics with different population size are shown in figure 3. In contrast VET, HEvo-Bexpa using the proposed metric found all of the positive and negative correlated rows, with enough population size. The algorithm is very sensitive to the different parameter values. For example, using different parameters for constant pattern against other patterns can provide better results. Since in this study it is used fixed parameters for all patterns, results were not suitable for constant pattern. It would be possible to check the parameter sensitivity analysis for developing an automatic parameter tuning procedure, in future researches. There is also a possibility to achieve some results with the same quality or even better using less population size besides an intelligent auto-configuration.

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A Novel Approach to Improve Recommender Systems Using Support Vector Machine

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***Abstract*— Recommendation plays an increasingly important role in our daily lives. Recommender systems automatically suggest to a user items that might be of interest to her. Collaborative Filtering (CF) technique has proven to be promising for implementing large scale recommender systems but its success depends mainly on locating similar neighbors. Due to data sparsity of the user–item rating matrix, the process of finding similar neighbors does not often succeed. In addition to this, it also suffers from the new user (cold start) problem as finding possible neighborhood and giving recommendations to user who has not rated any item or rated very few items is difficult. In this paper, a support vector machine-based trust-aware collaborative filtering method is proposed to improve the accuracy of the trust-aware recommender systems. Our proposed trust-based recommender system produces valuable recommendations by incorporating a notion of implicit trust between users and selecting a small and suitable neighborhood as a features of training data based on similarity metric. The performance of proposed method is evaluated using two datasets of different sparsity levels Flixster dataset and MovieLens dataset. Experimental results showed the proposed method was better than previous methods in precision, recall and Mean Absolute Error.**

Keyword—Recommender System; Collaborative Filtering; Social Recommender; Support Vector Machine.

I. INTRODUCTION

With the spread of information on the Web, data and characteristics of items and products are one of the most common types of this information. Meanwhile, choosing a favorite product among thousands of products with different characteristics, seems laborious and difficult task for a human user. This difficult task results from the problem of deciding and choosing a product among thousand types. Usually, recommender systems aim to provide high-quality advice available to a large community of users for decision-making [1]. Recommender systems are software tools that help users to select goods or merchandise based on their interests. A lot of research is being done on how to produce effective recommendations [2]. Recently, the social recommender systems that aim to solve information overhead about users of social media, have been considered in many studies. A recent study [3] shows that the information obtained from social networks can improve the accuracy of recommendation.

In general, there are two different approaches of recommendation [4]: content-based and collaborative filtering (CF) recommendation. CF is a successful technique in providing advice to users [5]. Since in the CF algorithms, finding similar users is the key issue in this method, and also, since users have commented on a number of different items and their opinions are different and also opinion overlap of various users are different from each other, finding a similar measure which could properly consider all of these features is difficult. Because of this difficulty, collaborative filtering systems cannot obtain optimum accuracy .

In order to overcome the problems of CF, Trust-Aware Recommender Systems are presented that can involve Social Trust information too [7,8]. Social relationships between users, especially trust relations, can facilitate Social Recommender System [9]. The main idea in these systems, is based on that "trusted users may have similar interests." In fact, researchers in this field have discovered that, there is a direct and strong correlation between trust and user preferences [10]. On the other hand, the Support Vector Machine (SVM) is proposed as one of the efficient machine learning algorithms in data mining [11].This method has been applied in the context of collaborative filtering recommender system [26], However we use trust base information to aforementioned research. In this paper, in order to explore the relationships and trust in recommender systems, SVM algorithm is used. Among the issues to explain innovations of this study are as follows: (1) extraction of implicit trust between users of social networks with using some methods of social network analysis, (2) use of implicit trust rather than explicit trust in the Recommender Systems and comparing the related results, (3) the use of Support Vector Machine learning method that has not still been used in traditional approaches and recommender systems and comparing the new approach with some existing methods that have adequate accuracy.

The rest of this paper is organized as follows, in section 2, a brief overview of research done on Trust-Aware Recommender System will be investigated. In section 3, details of the proposed method involving use of Support Vector Machines for discovery and extraction of implicit trust relationship recommender systems will be presented. In section 4, the details of implementing the method, data collection and tools are presented for recommender systems. Then, the evaluation method will be discussed and the results

of the tests will be given. Finally, in section 5, concludes our work and outlines potential future research.

II. Related Research

As it was mentioned in the previous section, a new perspective on collaborative filtering method is using a measure of Trust. Yan et al., suggested the iTARS [12] system that the implicit trust network is based on the similarity of users. The authors in [13, 14] using Small-worldness of trust network, improved network reliability performance. They also [15] studied (or evaluated) the effect of number of Recommenders, and they were able to improve the prediction accuracy rate by finding the right number of Recommenders. Massa et al. [8] suggest that trust information is more effective in recommender systems set up than information of rating items. They showed that by propagating trust and using it, it is possible to increase the coverage by keeping the amount of MAE generate more recommendations. Also, O'Donovan and Smyth [16] by presenting 2 computational models of Trust showed that using this measure–has increased the efficiency of recommender system.

Papagelis et al., [17] in their proposed method showed that with involving trust measure, we can decrease the negative effect of rates matrix data sparsity. In their proposed method, amount of trust between two users is achieved by interactions between them. They have considered interaction as rates. So with matrix of rates help, provide a relational network between users and by using that, they find the existing trust between users. In general, there are two types of trust: explicit and implicit. In an explicit method, trusted users can manually be entered to the system or through links from social networks. In the implicit approach, that trust can be achieved according to the votes of users [6]. In this area, both explicit trust (stated by user) (eg. [18.16]) and implicit trust (eg. [19, 8]) Has been used. While explicit trust is more accurate than the implicit, but often this information cannot be directly obtained from the user. Therefore, our proposed approach in this study is focused on the implicit trust relationship. In this methods the trust is automatically generated and need not to be taken from users. These methods usually estimate the trust based upon the user's previous scoring behaviours.

The proposed O'Donovan and Smyth algorithms are of this category [16]. The algorithm is based on this fact that users who have provided good recommendations in the past compared to other users with not so good recommendations are more reliable. O'Donovan and Smyth to be able to identify the most reliable users have used two measures of level of trust in the profile and of the item. Profile level shows the overall reliability of "u" user and item level shows reliability level of " u " user with respect to "i" item. These two trust measure are needed for calculating the accuracy of user's " u " recommendations for the target user "a". In particular, $p_{a,i}$ amount of information would be generated to predict the Scoring of " a " user from information of "u" user and then the authenticity of the content would be checked, as in whether $p_{a,i}$ is located within the real score of " a " with ε standard deviation. Measure of profile trust level for " u " user is defined as a percentage of correct suggestions that "u" are involved. This standard is too general, O'Donovan and Smyth in order to make better recommendations with respect to the items, proposed measures of item trust level which shows percentage of correct recommendations for item "i". In methods under this category, the amount of trust is not obtained from aggregation and dissemination of trust, but trust level is specified based upon user's previous ratings. O'Donovan and Smyth use CF just like Mesa et. al algorithms, so that trust levels are used as filters. Therefore, trusted neighbors are considered in the recommendations process. This approach is called trust-based filtering. Equation 2 shows this approach. $w_{a,u}$ Shows the correlation between user " a " and " u ", R^T shows the set of users who rely on " a " user and R^+ shows a subset of users who are similar to " a " user in CF.

$$p_{a,i} = \bar{r}_a + \frac{\sum_{u \in R^{T+}} w_{a,u(r_{u,i} - \bar{r}_u)}}{\sum_{u \in R^{T+}} t_{a,u}} \qquad (1)$$

In other words, only users who have standard trust of profile level and their item level is higher than a certain amount and have a positive correlation with " a ", are handled and placed in the R^{T+} collection. O'Donovan and Smyth also revealed that refining based trust in MAE has better accuracy compared to CF.

A. Support Vector Machine (SVM)

SVM [20] is a method of supervised learning and basis of this classifier is classification of data in linear format. In this method, data are mostly written down so that they could be separated from each other linearly. The purpose of this method is to find a Hyperplane with Maximum media width that can draw a distinction between two categories. SVM approach in the training phase is to try to take a decision in such a way, to expand the minimum distance to each of the categories. This choice makes our decision in practice, to tolerate noisy conditions, and have a good response. This boundary selection method is done based on points known as support vectors. In linear division of data we should try to select a line that has a greater safety margin. Equation to find the optimum line for data is carried out by methods of non-linear programming which are known methods of problem solving with Constraint Satisfaction.

Assuming we have training data consists of n pairs (x_1, y_1), (x_2, y_2) ... and (x_n, y_n) with $x_i \in R^m$ and $y_i \in \{-1, 1\}$.

We want to specify a separating hyperplane as equation (2), that the biggest margin between two classes of 1, -1, can create the distance between the two parallel hyperplane in either sides of the separating hyperplane.

$$\{x : f(x) = x^T w + w_0 = 0\}, \qquad \| w \| = 1 \qquad (2)$$

Set of constraints would ensure that all points are positioned in the minimum distance of C from the Decision Boundary which are determined by W and W_0. We are looking for the greatest C and related parameters.

$$\max_{w,w_0,\|w\|=1} C$$
$$\text{Subject to } y_i(x_i^T w + w_0) \geq C, \quad i = 1,...,n \qquad (3)$$

As previously mentioned, the SVM was used first as a linear classifier. Before linear dividing, we take the data to much higher spatial dimensions by function Φ so that machines can classify the highly complex data. To be able to solve problem with very high dimensions by these methods, we use a simpler function called kernel function which appears as Φ vector function, In fact for classification of non-linear problems, problem could be solved by use of a kernel to find hyperplane with maximum margin.

III. THE PROPOSED METHOD

In previous collaborative filtering systems, finding a similarity measure is one of the most influential factor in performance of the algorithm. As mentioned above, due to data sparseness in vote's matrix, the similarity between users cannot correctly be estimated. Trust-based collaborative filtering methods are a solution to this problem. In cases where there is explicit trust, surely the additional information can compensate for deficiencies of Votes matrix. But in cases, that is supposed to obtain implicit trust from the same Votes matrix, method of calculating trust matters.

In the proposed method, all individuals according to their votes and preferences can help us in process of finding a suitable suggestion. In other words, even an individual who has no similarity to the target user can also have valuable information. Proposed method discovers implicit relations in matrix Votes by using SVM learning algorithm and then use them to propose a good recommendation.

As mentioned, the aim of SVM is to find a unique hyperplane that can maximize its resolution capability. This hyperplane consists of a decision boundary that separates records of one class from another. In this situation the decision level is considered as optimal hyperplane. SVM finds this hyperplane by using support vector and Margins which are defined by support vector. There are many Decision Boundaries to separate data belonging to different classes, but we are looking for Decision Boundary or Separating Hyperplane with maximum margin that separates data with greater accuracy and less errors [20]. Due to use of SVM algorithm, this system is not dependent on a specific formula to find the trust.

The proposed system by using SVM algorithm, discovers the implicit relationships in Votes matrix and then use them for a good recommendation. The system consists of 2 stages: 1) Find *k* the right recommender user, 2) SVM model training to explore the relationships of trust between users for predicting user votes. Fig. 1 shows the details of the proposed system.

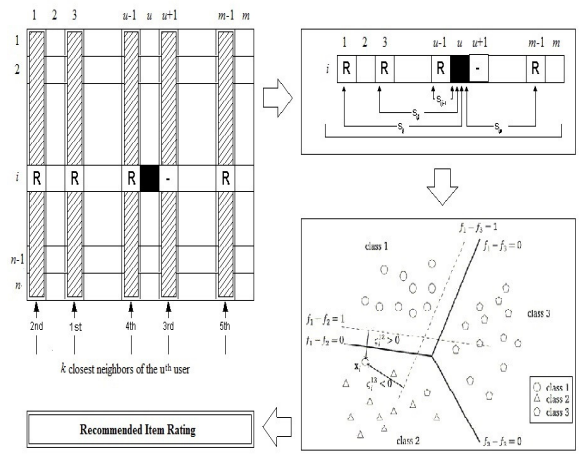


Fig. 1. Components of the proposed system to provide recommendations

As shown in Fig. 1 system selects *k* recommender for each user from the users set. Selection criteria is defined, not only contribution between the two but also the greatest similarity between them. Since user data are input to SVM, we try to choose the most trusted users. In fact, at this stage those users are selected whom having the largest share, and are the most similar so that the machine gets enough training data. Subscription is defined as the number of items that both users have voted on it (regardless of the vote itself). Next, in the SVM algorithm, communication between them are investigated and eventually by using this connections, the rate desired items are presented to the users. Details of this method along with analysis and evaluation of the results are presented in section 4.

IV. TESTING AND EVALUATION OF RESULTS

In this paper, two data sets of Movie Lens and Flixster are used for evaluation of the proposed method. Movie Lens data set is related to the research project of GroupLens at the University of Minnesota. This data set contains a hundred thousand votes by 943 users on 1682 movies, in which each user has voted at least on 20 movies. The mentioned data are collected from the website for 3 months period from 19 September 1997 to 22 April 1998. After data collection, users who have voted on less than 20 movies or have no demographic information were excluded from it. User votes are shown as numbers from 1 to 5 which means 1) bad, 2) medium, 3) good, 4) very good and 5) excellent. For further details you can refer to the respective website. Flixster dataset are also related to a movies social website called Flixster, which like MovieLens dataset includes user IDs, Movie identifiers, given votes and time tag. Rates are actual values with the range of 0.5 to 5.0 with 0.5 Intervals.

The mentioned data must be properly formatted and processed so that they can be used in the proposed method. For this purpose, if "n" is the number of total users and "m" is the total number of items in the dataset and "l" is the number of items that have active users rated them, then a filter must be set on

the main dataset in such way that produces a L × n matrix which contains values of matrix votes that all "n" users have voted to the same item "I" that active user have already rated them. For those neighboring users who didn't vote for any item, zero would be placed in the matrix.

After this step and obtaining the matrix of active users, it's time to find k the recommender user. For this purpose, k=10 users that has minimum distance vector (most similar) to the active users have chosen. Euclidean distance has been used for similarity measure.

Finally, according to the extracted files, we transpose the matrix to produce training and test data for machine learning algorithm. So that the first data column indicates the row numbers. Columns 2 to k + 1 are input variables, and includes selected k user from the previous step which accept a certain amount in each row. The last column of the data, contain output data or tags. The data are ready for SVM learning model for training and testing. In section A create and use of SVM model will be discussed.

A. Creating SVM model

After data presented in the previous section were pre-processing and related characteristics were extracted, feature vector is made which would be given to support vector machine (SVM) for training and testing. SVM is used as predictors of the recommendation system. In training phase SVM uses the data for training purpose and in testing phase use them for recommendations. Based on feature vectors, SVM determines what items and what rate to be offered to the user.

For SVM various implementations have been developed in recent years. Most of these software are designed and implemented in academic environs, but in the meantime, commercial products can also be found. LIBSVM [22] software has been used in the proposed recommender system. In fact, this software was designed to be a library to perform learning by using support vector machine. This software or the library is originally designed by C ++ programming. The most serious issue in SVM method is the choice of kernel function which depending on the nature of data, different kernels can be used. LIBSVM Software supports four different kernel by default including linear kernel, polynomial, radial basis function kernel (RBF) and sigmoid. RBF kernel was selected in the proposed system due to higher performance in outcomes that this function has only one parameter called gamma (γ). Also K is kernel symbol and X_i, X_j contain training data.

$$K(X_i, X_j) = \exp(-\gamma \left\| X_i - X_j \right\|^2) \ , \quad \gamma > 0 \qquad (4)$$

B. The criteria and test results

Assessment of a recommender system is system measuring accuracy in predicting the votes that active user may give to the target item. Considering that proposed system provides a list of the top recommendations, to assess we use the criteria of Precision and Coverage. In the following while introducing each of these criteria, the full process of this assessment is described.

Precision measure, measures the accuracy of the system predictions. This Criterion measures ratio of desirable items to the total proposed items. To calculate the precision the equation (5) is used [23].

$$Precision = \frac{\left| \{\text{Re}commended \text{ Items}\} \cap \{Favorit \text{ Items}\} \right|}{\left| \{\text{Re}commended \text{ Items}\} \right|} \qquad (5)$$

Coverage criterion states the system ability to detect the user's favorite items. A general idea to increase this measure is to add all possible items on the proposed list. The coverage of a recommender system is calculated by equation (6) [23].

$$Coverage = \frac{\left| \{\text{Re}commended \text{ Items}\} \cap \{Favorit \text{ Items}\} \right|}{\left| \{Favorit \text{ Items}\} \right|} \qquad (6)$$

Also, mean absolute error (MAE) has been used as a common measure for evaluating the accuracy of recommender systems. MAE specifies the rate of deviation of predicted votes from the correct votes and is calculated by formula (7).

$$MAE = \frac{1}{N} \sum_{i=1}^{N} \left| pr_i - r_i \right| \qquad (7)$$

Where, N is the number of votes that the system has estimated, Pr_i is estimated votes, and r_i is correct votes. Less MAE, indicates greater accuracy.

In the carried out experiments, 5 Fold Cross Validation algorithm [24] have been applied on Movielens and Flixster datasets . In this series each of the different collections u1, u2... u5 which are randomly built from the original series have separate training and test data. In this way, 0.2 part of the data on each iteration are considered as test data. Also user collaborative filtering algorithms (UCF) [25], algorithm of implicit trust between users (TRS) [16] and algorithm of reconstructed networks (RN) are used, to demonstrate and compare the performance of the proposed method with rival base methods. The results using these algorithms and the proposed methodology, with criteria for Precision, coverage and MAE error are respectively presented in figure 2, 3 and 4. Horizontal axis represents measure of user rating and vertical axis represents the level of Precision, coverage and MAE percentage respectively.

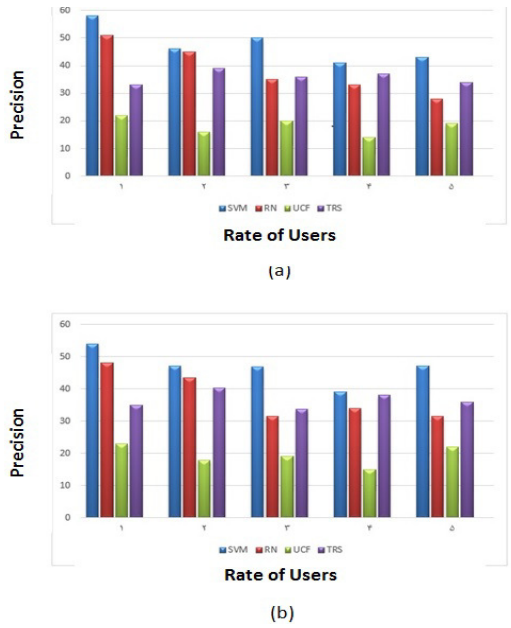


Fig. 2. Comparison of Precision a) Movielens dataset, b) Flixster dataset

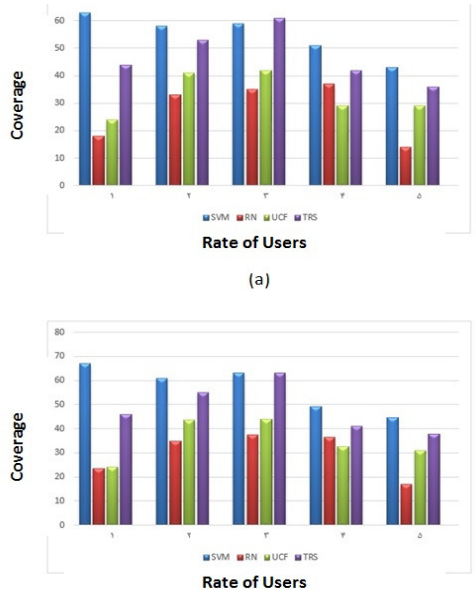


Fig. 3. Comparison of Coverage a) Movielens dataset, b) Flixster dataset

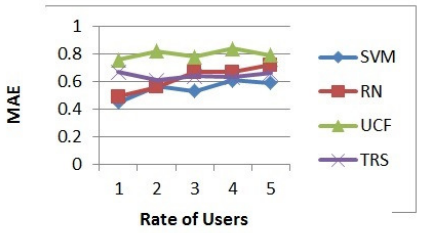


Fig. 4 - Comparison of MAE in Movielens dataset.

(a)

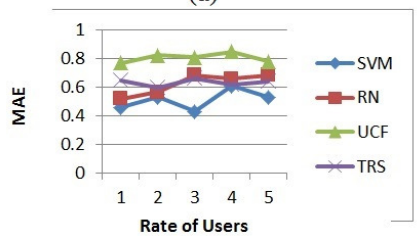


Fig. 4 - Comparison of MAE in Flixster dataset.

(b)

Method / Dataset	SVM	RN	UCF	TRS
MovieLens	0.55	0.62	0.79	0.65
Flixster	0.51	0.62	0.8	0.63

Table.1- Comparison of MAE in Movielens and Flixster dataset.

According to these figures, what is evident is that using the proposed method increases the precision and coverage of the system. Since the CF alone does not consider trust between users, covers only a few of predictable items, and does not offer very high quality recommendations and compared to other methods, it is suffering badly from a cold start. For this reason, trust models are used more to improve quality of recommendations. RN method uses only the user's rates to create forecasts that have many neighbours and a high similarity rate, Also covers a small fraction of items that due to scattering data has an unfavourable performance and does not offer good accuracy. Compared with pure implicit trust method that only directly trusted neighbours are used, TRS method has better performance. But this method works not well for cold users which is due to the dependency that CF method has, to find similar users, prior to trust. In the trust implicit learning method presented in this paper, the value of trust can be obtained from learning algorithm of support vector machine. Using implicit trust network between users, significantly reduces the errors of algorithm predictions in User Based Collaborative Filtering. In addition to the basic algorithm, user similarity is diagnosed much better by implicitly trust network that are available in the data. In other words, SVM learning algorithm can enable communication between user comments and discovers his trusted neighbours and store for later use. Using implicit trust discovered by support vector machine learning algorithm, improves the

system's recommendations and in other words significantly reduces error predictions of recommender system. Therefore machine learning approach can be effective in offering reliable and high quality recommendation.

V. CONCLUSION AND FUTURE PLAN

In this paper, a new method to provide recommendations in Recommender systems aware of the trust, have been proposed. In the proposed method, an approach based on implicit trust and uses of machine learning algorithms was used to solve the problems of Collaborative Filtering method. System for each user, selects k recommender from the user sets. Selection criteria is similarity between the two (most similar). In the next step with the help of support vector machines, communication between them are investigated and eventually by using these connections future predictions are carried out. The proposed approach for all cases that data is likely to have different observation, is a fierce rivals to other methods and flaunts to its high performance. However, in some cases, the proposed method is less efficient than the basic techniques, but in many cases is the best way, and in most cases is one of the best methods. The proposed method tries, without having to find similar users, uses the information contained in data, and is expected to do more accurate predictions. As the results showed, in the proposed approach, accuracy and coverage has increased significantly and the average absolute error considerably reduced.

One of the things that could be considered as future work, is use of the strengths of several classifying methods in combination with the SVM algorithm. To create a variety in classifications which can be used to achieve a better recognition accuracy. Moreover, the use of feature selection techniques to reduce dataset and weighting learning algorithm in SVM algorithm, can be considered as yet another future works. Generally, choosing appropriate features for machine learning algorithms reduces data dimension and algorithm space and thus increases its speed. Also in some cases increases classification accuracy.

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Path Following of an Omni-Directional Four-Wheeled Mobile Robot

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***Abstract*— Navigation of omni-directional four wheeled mobile robot usually is done by trajectory tracking controller. But, in this article two methods of path following have been presented to reach this purpose. Path following is another navigation approach that is solved some of trajectory tracking navigation systems difficulties like *'turning back'*. Path following navigators usually are designed by two different viewpoints, geometrical approaches or control approaches which both are utilized in this paper. The main contribution of this paper is to present tow simple methods with acceptable navigation performance. Based on the simulation results, it is proofed that, the presented methods are able to navigate the robot on desired paths even in hard situations like measurement delay and external disturbance. Also, advantages of each method is presented based on comparison of simulation results. Another contribution of this work is using dynamic model of the robot instead of kinematic model which is usually is used in path following articles. To reach this goal, at the first step, a Linear Quadratic Regulator (LQR) controller is designed as low level controller, then path following navigator is mounted on high level controller. Note that, weighting matrix of LQR controller (matrix Q) is calculated by Genetic Algorithm to achieve the best possible time performances.**

Keywords—Path Following Problem; Omni-Directional Mobile Robot; Linear Quadratic Regulator; Genetic Algorithm

I. INTRODUCTION

Navigation of mobile robot is one of the challenging problem in mechatronic. Designing a trajectory tracking controller for robot is a good suggestion to deal with this problem, but this is not the best and only way to navigate a robot. Path following is another method of navigation that is studied in this research.

Path following and trajectory tracking have the same objective, but with a different look to the navigation problem. In path following, desired robot route, considered as a time independent function of position that is called '*Path*', but in trajectory tracking, it consider as a time dependent function that is called *'trajectory'*. This dependence of trajectory tracking to the time makes some difficulty. for example, it is better that the trajectory started from the robot initial location, If not, it's possible that robot turns back and goes toward the start points of trajectory (*turning back*). This difficulty is solved in path following. In path following, at first step, all of the path is rendered by an algorithm. Then, robot is navigated to the nearest point of the path. Next, robot is navigated to follow the path until the end point. This algorithm must guaranty that the robot reach to the path and stay on it for all the time after reaching.

Path following has been used for many different systems, for example, aircraft [1], [5], [6], and [8], maglev system [2], quadrotor helicopter [3], and manipulator [4]. In [1] and [2], path following problem has been solved by transvers feedback linearization approach that is a control based technique. Also, feedback linearization approach has been used in [3] and an adaptive optimal law has been presented in [8]. Nonlinear Guidance law (NLGL) that is a geometrical approach has been used in [5]. Navigation of omni-directional robot usually has been done based on trajectory tracking methods. For example, in [9] and [10] the model predictive control (MPC) has been used.

In this research, two different algorithms of path following are presented for an omni-directional four-wheeled mobile robot and compared together. *'Carrot-Chasing'* which is a geometrical approach [7] and *'Adaptive Optimal Guidance law'* that is a control approach based on linear quadratic regulator (LQR) with an adaptation law to calculate weighting matrices of LQR [8]. Both methods are simulated in 3 situation that are different in consisting of position measurement delay and position disturbance.

AOGL and Carrot-Chasing consider the robot moves at constant speed in the direction that is called *heading angle*. Both methods, control the heading angle to navigate the robot. In most of path following article, authors, consider the robot has an internal controller to control the heading angle and moves the robot with constant speed [7], [8]. According to this consideration they used robot kinematic as the system model that are almost far from real behavior of robot. In this paper, the robot dynamics are used as the system model. To reach this consideration, at the first step, an internal control loop is designed to control the robot dynamics based on LQR method which is improved by an offline *'Genetic Algorithm'*.

The rest of this article is organized as following. In section II, the mathematical model of omni-directional mobile robot is described. Internal control loop is presented in section III. Section IV describe path following methods. In section V,

simulation results are drawn. At the end, the conclusion is presented in section VI.

II. Mathematical Model

A. Robot's kinematics

Position of the robot is presented in two frames (body fixed frame and earth frame) as it is shown in Fig. 1. Earth frame is mapped to body fixed frame with an orthogonal rotation matrix $R_{(\theta)}$ as following:

$$\dot{\xi} = R_{(\theta)}^{T} \times \dot{\xi}_r \tag{1}$$

$$R_{(\theta)} = \begin{bmatrix} \cos(\theta) & \sin(\theta) & 0 \\ -\sin(\theta) & \cos(\theta) & 0 \\ 0 & 0 & 1 \end{bmatrix} \tag{2}$$

where $\xi = [x_r, y_r, \theta]^T$, x_r and y_r are the location of robot's center of mass (point P) in earth frame, θ is the angular difference between body fixed frame and earth frame, $\dot{\xi}_r = [v, v_n, \omega]^T$ is the robot's velocities vector in body fixed frame which v and v_n are orthogonal components that describe linear velocities of robot's center of mass, and ω is angular velocity of robot.

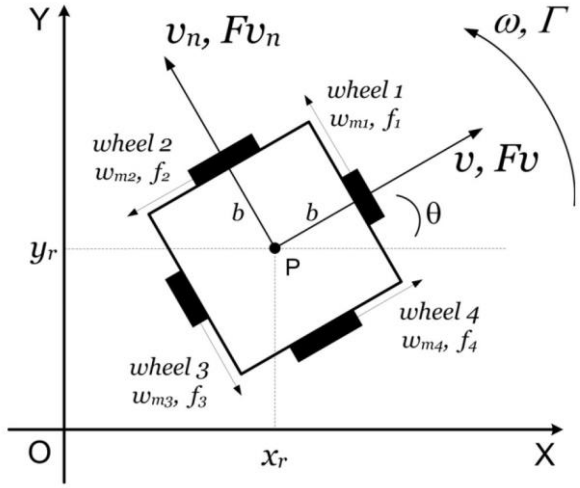


Fig. 1. Robot motion parameters in body fixed frame and earth frame [9]

B. Robot's dynamics

In this section a nonlinear dynamic model of a four wheeled omni-directional mobile robot is presented. This model consists of robot dynamics, motor dynamics, and a nonlinear model of friction.

By using Newton's law of motion in body fixed frame, the robots dynamics of robot is described as following:

$$F_v(t) - B_v v(t) - C_v sgn\big(v(t)\big) = M\frac{dv(t)}{dt} \tag{3}$$

$$F_{v_n}(t) - B_{v_n} v_n(t) - C_{v_n} sgn\big(v_n(t)\big) = M\frac{dv_n(t)}{dt} \tag{4}$$

$$\Gamma(t) - B_\omega \omega(t) - C_\omega sgn\big(\omega(t)\big) = I_n\frac{d\omega(t)}{dt} \tag{5}$$

where,

$$sgn(\alpha) = \begin{cases} 1 & \alpha > 0 \\ 0 & \alpha = 0 \\ -1 & \alpha < 0 \end{cases} \tag{6}$$

In above equations, F_v and F_{v_n} are linear forces in body fixed frame, Γ is the moment around the center of mass. I_n is the inertia moment and robot's mass was shown as M. B_v, B_{v_n}, and B_ω are the viscose friction coefficients. C_v, C_{v_n}, and C_ω are the coulomb friction coefficients.

The robots traction forces are calculated from the wheels' traction forces with following equations.

$$F_v(t) = f_4(t) - f_2(t) \tag{7}$$

$$F_{v_n} = f_1(t) - f_3(t) \tag{8}$$

$$\Gamma(t) = (f_1(t) + f_2(t) + f_3(t) + f_4(t))b \tag{9}$$

with b the distance from center of mass to the wheels and $f_i \quad (i = 1, \dots, 4)$ is wheel's traction force.

The traction force of each wheel is

$$f_i(t) = \frac{T_i}{r_i} \qquad i = 1, \dots, 4 \tag{10}$$

where T_i is the wheel rotational torque.

The DC motors dynamics is defined as

$$u_i(t) = L_{a_i}\frac{di_{a_i}}{dt} + R_{a_i} i_{a_i}(t) + K_{v_i}\omega_{m_i} \tag{11}$$

$$T_i(t) = l_i K_{t_i} i_{a_i}(t) \tag{12}$$

where L_{a_i} is the motor's armature inductance, R_{a_i} is the motor's armature resistance, l_i is the motor's gear ratio, ω_{m_i} is the angular velocity of wheels, K_v is the motor's emf constant, and K_t is the motor's torque constant. Note that, K_t and K_v are equal [9].

To find the value of the above parameters refer to [9].

III. Internal Control Loop

As it mentioned before, an internal control loop is designed based on LQR approach to control the robot dynamics and satisfies the consideration of path following algorithms. Usual LQR is a controller that stabilize the stats to the origin, but in this research a controller is needed to regulate the states to the target values (that are not necessarily equal to zero). So, a *'Linear Quadratic Integral'* (LQI) controller is used.

LQI is a modification of LQR that adds tracking ability to the LQR controller. This modification is done by considering the integral tracking errors ($\bar{e}_i = \int(\bar{y} - \bar{r})dt$) as virtual states ($\bar{e}_i$). To design LQI controller, this new states are adjoined to the real system states ($\bar{x}$) and the LQR controller is designed for this new system ($\bar{x}_{adj} = [\bar{x}, \bar{e}_i]^T$).

State space representation of robot dynamics are presented as following [9]:

$$\dot{x} = Ax + Bu + Ksgn(x) \tag{13}$$

$$y = Cx. \tag{14}$$

This representation of the system is nonlinear, but if the coulomb friction is considered as an external disturbance, then the nonlinear term ($Ksgn(x)$) of the system is canceled and the system equations are becomes linear.

To design the LQI controller for this linear system, the following general infinite-horizon linear regulator problem (LQR) is considered,

$$J = \frac{1}{2}\int_0^\infty \left(x_{adj}^T Q x_{adj} + u^T(t) R u(t)\right) dt \tag{15}$$

where $Q = diag(1, 1, 1, q_1, q_2, q_3)$ is a positive semi definite (PSD) matrix ($Q \geq 0$) and $R = I_4$. Performance of the LQI controller is depend on the weighting matrix Q and R. In this research, to optimize the performance of controller, the matrix R was defined as a constant matrix and matrix Q was calculated by *'Genetic Algorithm'* (GA) with a fitness function as following:

$$f = \int_0^\infty (2e_1^2 + 2e_2^2 + e_3^2)\, dt \tag{16}$$

where $e = [e_1, e_2, e_3]^T$ is the error vector.

The best matrix Q that has been calculated by GA is:

$$Q = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 3330.9 & 0 & 0 \\ 0 & 0 & 0 & 0 & 8234.1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 81.4 \end{bmatrix}. \tag{17}$$

IV. Path Following Methods

Path following is a method to navigate unmanned vehicle such as unmanned aerial vehicle (UAV), autonomous under-water vehicle (AUV), and unmanned ground vehicle (UGV). In this article, two methods of path following is presented for an omni-directional mobile robot that is a kind of UGVs. These methods are Carrot-chasing and AOGL.

A. Charrot-Chasing Algorithm

Consider a robot moves with constant speed in heading angle direction. Also, there is an algorithm that chooses a point on the desired path as a *'Virtual Target Point'* (VTP) and changes the robot heading angle toward this VTP, in each iteration. With this algorithm, as time progresses, distance from robot to the path is decreased and robot asymptotically will follow the path. If the VTP is called carrot, since this algorithm navigates the robot to chase this carrot. Therefore, the algorithm is named *'Carrot-Chasing'*. This algorithm is called the *'Rabbit-Chasing'*, too [7].

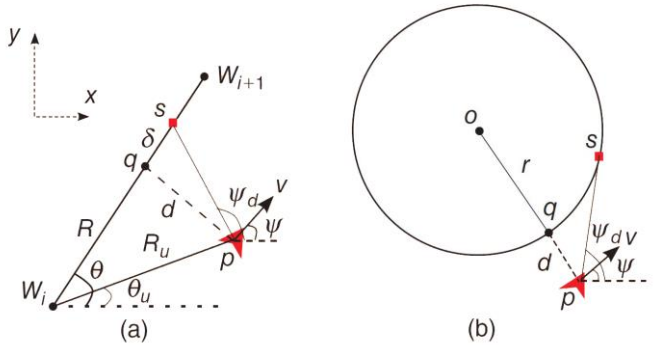


Fig. 2. Carrot-Chasing algorithm geometry (a) straight line path, (b) circular path [7]

1) Straight line path following algorithm

As shown in Fig. 2 (a), this path is defined by two pints, W_i and W_{i+1}. Robot situated at point p with heading angle ψ. q is the projection of p on the path at a distance R from W_i.

Straight line path following algorithm is defined as following. First, the VTP (point s) is calculated at distance δ from point q. Then, this algorithm finds robot's desired heading angle ψ_d toward point s. Finally, this algorithm goes to first step and process is repeated continuously [7]. Note that, in this research $\delta = 0.1m$.

2) Circular path following algorithm

As shown in Fig. 2 (b), the circular path is defined by two parameters, center of circle O and radius r. Robot current location is p with heading angle ψ and q is the projection of point p on the path.

Circular path following algorithm is defined as following. First, the VTP (point s) is calculated at angular distance λ from point q. Then, this algorithm finds robot's desired heading angle ψ_d toward point s. Finally, this algorithm goes to first step and process is repeated continuously [7]. Note that, in this research $\lambda = 0.1rad$.

B. Adaptive Optimal Guidance law

As shown in Fig. 3, robot moves with constant speed v in its heading angle ψ with a position error d from the desired path (dashed line) and a velocity error v_d as following

$$v_d = v.\sin(\psi - \psi_p) \tag{18}$$

where v is robot's speed, ψ is robot heading angle, and desired path angle is ψ_p.

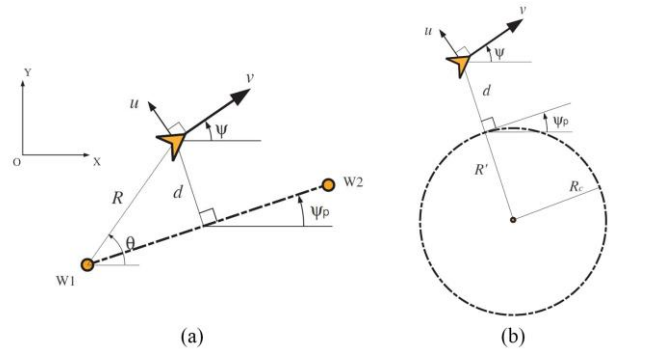


Fig. 3. AOGL algorithm geometry (a) straight line path, (b) circular path [8]

Geometrical dynamic equetions of the path based on d and v_d is defined as following.

$$\dot{d} = v_d = v.\sin(\psi - \psi_p) \tag{19}$$

$$\dot{v}_d = v(\dot{\psi} - \dot{\psi}_p)\cos(\psi - \psi_p) \tag{20}$$

Since the desired path curvature is unknown, variation rate of desired path angle is defined equal to zero ($\dot{\psi}_p = 0$). When the robot following the path, robot heading angle ψ and desired path angle ψ_p have a small difference. So, $(\psi - \psi_p) \to 0$ and $\cos(\psi - \psi_p) \to 1$. According to this approximation, (20) is redefined as following:

$$\dot{v}_d = v\dot{\psi} \tag{21}$$

In this system, lateral acceleration u is defined as the system input (or control signal) where u is calculated as

$$u = v\dot{\psi}. \tag{22}$$

Standard linear state space representation of the system is

$$\dot{x} = Ax + Bu \tag{23}$$

with,

$$x = \begin{bmatrix} d \\ v_d \end{bmatrix},\ A = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix},\ B = \begin{bmatrix} 0 \\ 1 \end{bmatrix}. \tag{24}$$

Consider the cost function of the LQR problem as following:

$$J = \frac{1}{2}\int_{t_0}^{\infty} [x^T Q x + R u^2(t)]\, dt \tag{25}$$

with respect to (23).

Waiting matrices Q and R are defined as following:

$$R = 1 \tag{26}$$

$$Q = \begin{bmatrix} q^2 & 0 \\ 0 & 1 \end{bmatrix} \geq 0 \tag{27}$$

where, q^2 is calculated by an adaptation law based on considering the position error d as a penalty. This adaptation law is

$$q^2 = \left|\frac{d_b}{d_b - d}\right| \tag{28}$$

where, d_b is maximum allowable position error that is a constant number.

Optimal solution of the LQR controller with cost function (25) is given as:

$$u^* = -R^{-1}B^T P x \tag{29}$$

Where, $P_{2\times 2} > 0$ is obtained by solving the following Algebraic Riccati Equation.

$$A^T P + PA - PBR^{-1}B^T P + Q = 0 \tag{30}$$

Using (26) ~ (30), the adaptive optimal guidance law is calculated as following [8].

$$u^* = -\left[d.\sqrt{\left|\frac{d_b}{d_b - d}\right|} + v_d.\sqrt{2 \times \sqrt{\left|\frac{d_b}{d_b - d}\right|} + 1}\right] \tag{31}$$

V. Simulation Results

In this part, two algorithm of path following that were presented in section IV are simulated in three different cases. In first case, simulation is done in an ideal situation (there is no disturbance and delay). A disturbance is applied to the system in second case. This disturbance is an impact (velocity is 0.7 in direction $\pi/4$) that is hit on the robot. In third case, 0.1 second measurement delay is added to previous case conditions.

Simulation is done for two different path. Which are, a straight line with unity slope in X-Y plane and a circle with radius $r = 5m$ and center $O = (0, 0)$.

Simulation results of both algorithms is compared with two criteria that are based on time response. These criteria are ISE and QE, which are defined as following [10]:

$$ISE = \int_0^\infty e^2(t)\, dt \tag{32}$$

$$QE = \int_0^\infty [e^2(t) + 2u^2(t)]dt \tag{33}$$

where $e(t)$ is position error and $u(t)$ is control force.

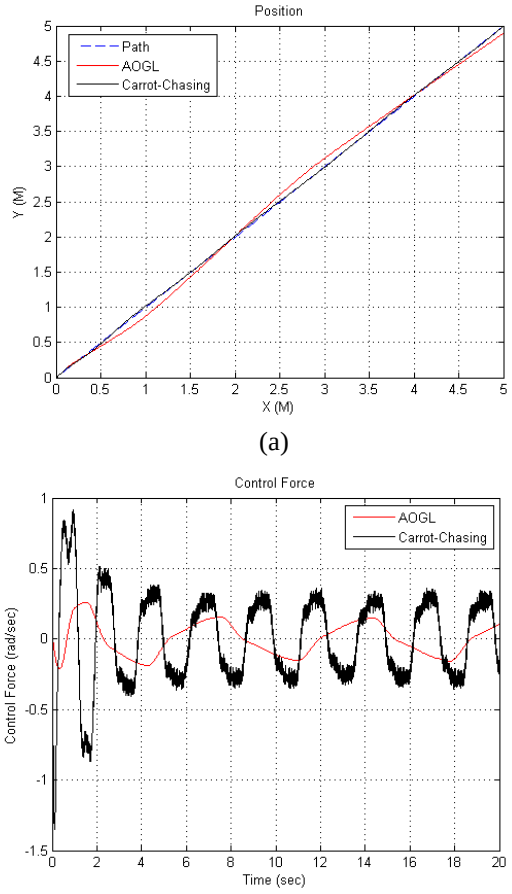


Fig. 4. Straight line path following in case 1. (a) robot position and (b) control force.

As it shown in Fig. 4, both algorithm follow the desired path. But, deviation from desired path with carrot-chasing algorithm is less than AOGL. Maximum deviation in carrot-chasing is less than 0.02m and in AOGL is 0.09m. An important fact that is understood from Fig. 4 (b) is: reaching to less position error with carrot-chasing algorithm extremely increased the control force. Note that, system initial conditions are defined as $[x \quad y \quad \psi] = [0 \quad 0 \quad \pi/4]$ for all simulations which desired path is straight line.

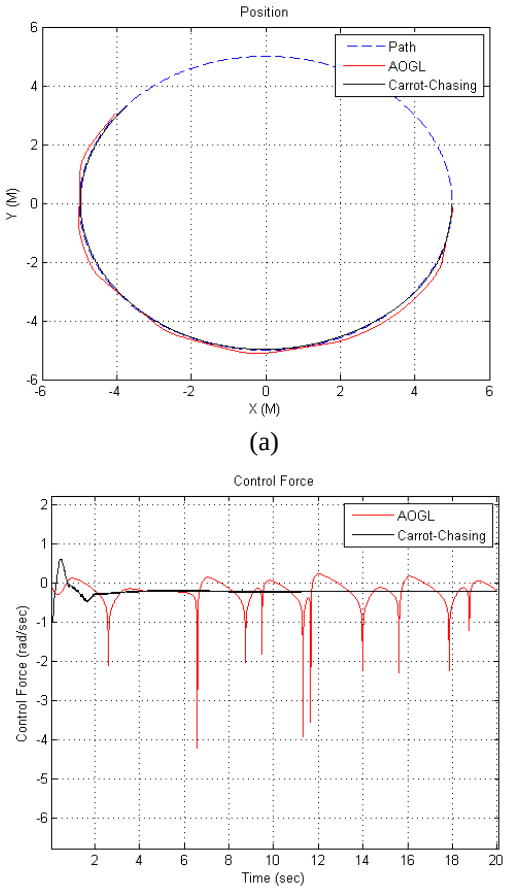


Fig. 5. Circular path following in case 1. (a) robot position and (b) control force.

As it shown in Fig. 5, both algorithms follow the desired path. But, maximum deviation from path in carrot-chasing is less than 0.05m and in AOGL is about 0.17m which mean, deviation with carrot-chasing algorithm is less than AOGL. Note that initial conditions are defined as $[x \quad y \quad \psi] = [5 \quad 0 \quad \pi/2]$ for all simulations which desired path is circular.

TABLE I. VALUES OF ISE AND QE IN DIFFERENT CASES

			Case 1	***Case 2***	***Case 3***
Straight line path	Carrot chasing	ISE	0.0008	0.0046	unstable
		QE	3.9976	17.3816	unstable
	AOGL	ISE	0.0566	0.2473	0.3529
		QE	0.5940	5.1496	7.4703
Circular path	Carrot chasing	ISE	0.0135	0.0328	0.0428
		QE	3.4871	6.4425	70.5658
	AOGL	ISE	0.1609	0.41	0.8495
		QE	5.6568	5.9006	7.9213

TABLE I. consists of the ISE and QE values for all situations. These values are used to compare the algorithms.

Based on TABLE I, It is very hard to say which algorithm is the best. Because, in some cases carrot-chasing has better result and in some cases AOGL. In case 1 (ideal situation), carrot-chasing is absolutely better than AOGL. Because, ISE criteria of this algorithm is much smaller than AOGL. So, in ideal situation deviation from desired path of carrot-chasing is negligible against AOGL. Test of the algorithms in case 2 is showed that, in situation of external disturbance, deviation from desired path for carrot-chasing is less than AOGL but, control force of carrot-chasing is more than AOGL. Therefore, carrot-chasing is better if less deviation from desired path being important and AOGL is better, if less control force being important. Results of test in case 3 are showed that, carrot-chasing algorithm is not reliable in situation of measurement delay. Because, with this algorithm robot could not follow the straight line path. So, AOGL is better algorithm in situation that measurement is done with delay.

VI. Conclusions

In this paper, two different methods of path following for an omni-directional four-wheeled mobile robot have been presented and tested on ideal situation and hard situation like: disturbance happening and measurement delay. Firs method is ‘carrot-chasing’ which is a geometrical approach and second is AOGL which is a control method approach. Based on simulation results it is concluded that, carrot-chasing algorithm has less deviation from desired path until there is no delay in measurements. But, when measurement done with delay, carrot-chasing is not reliable anymore. Therefore, if possible to reject or reduce the measurement delay, it is better to use carrot-chasing otherwise, AOGL is better choice because of its delay tolerant. Note that, in this work all simulations are done with dynamic model of omni-directional four wheeled mobile robot instead of kinematic model which is usually is used in path following articles. So it is concluded that, the presented two layer controller structure could navigate this robot on desired path, well.

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Ranking of Brands Reputation using Sentiment Analysis in Twitter

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Abstract—Social media development and users' upward trends to Publish ideas on web is a valuable opportunity for companies to study customers' preferences and evaluate brand reputations. The main goal of this paper is to propose a new method for evaluate and rank brand reputation using sentiment analysis in Microblogs. In this research, users' opinions and reviews are extracted and classified using hybrid approach and natural language processing techniques. Results show that Naïve Bayes and Support Vector Machine selecting Tri-grams feature and part of speech tagging had best performance among tested models. In addition, we used different values of parameter Penalty in order to overcome the spars matrix problem. The main contribution of this research is evaluating and ranking brands using sentiment analysis in Twitter. Also there is an improvement in evaluation metrics in comparison with previous studies.

Keywords-component; brand reputation ranking, sentiment analysis, opinion mining, microblog, Twitter.

I. INTRODUCTION

Sentiment analysis, also called opinion mining, is the field of study that analyzes people's opinions, sentiments, evaluations, appraisals, attitudes, and emotions towards entities such as products, services, organizations, individuals, issues, events, topics, and their attributes [1]. In this regard researchers try to find and extract statistics and language patterns in textual data and evaluate users' trends using various methods and techniques including information retrieval, natural language processing and machine learning. In recent years, this realm of science has been considered by researchers of different fields due to the numerous applications of sentiment analysis in different domains like business, marketing, news analysis and political approaches [2, 3]. Internet nowadays plays an important role in expression of customers' opinions includes sending messages in weblogs, forums and other webpages. With rapid growth of internet accessibility, more and more customers share their ideas about different subjects online. Considerable number of online comments has become a major source for data gathering about products and services for both customers and companies [4]. Empowered by cutting-edge social media, internet-based social communities have significantly contributed to the success of online businesses. Current online retail commerce is characterized by many to many transactions, instead of the traditional one to one relationship between sellers and buyers, closely tying the parties involved in various social networks that center on a given products [5].

knowledge obtained from social networks such as Twitter and Facebook has been shown to be extremely valuable to marketing research companies, public opinion organizations and other text mining entities [6]. Utilization of this knowledge in different areas include marketing research, business intelligence, stock market prediction and brand monitoring is rapidly expanding. Marketing researches have revealed that online search of products has become an inseparable part of customers' shopping experience [7, 8]. Hence, there is an increasing tendency to understand customers' opinions about products and brands. Monitoring, tracking and analyzing capability of social media is considered as the basis for creation and implementation of brand reputation management strategies [9]. On the other hand, survey-based brand reputation measurement has disadvantages includes lots of efforts and costs. Therefore brand reputation requires techniques and methods that analyze and measure reviews with more speed and ease [10].

Previous studies using opinion mining are mainly limited to evaluate a specific product or service [11, 12]. Evaluation and analysis of users' trends towards brands are among the areas less considered. In evaluation of a product or service, the writer of a review expresses his/her opinion with short and simple sentences in which the product features are bold. Usually there is no sarcastic words and sentences with complex grammatical structures in such texts. Also goods and products mostly has tangible features and constant quality, which makes it relatively easy to evaluate a product at minimal risk [13]. On the contrary, opinion measurement is very complicated in comments with social aspects and customers express their opinions with complex sentences. Moreover, customers' opinions relating to products and services tend to be used on specific features such as a particular model of camera and do not include other products, services and brands [14]. Therefore customer based sentiment analysis systems in which only products or services features are regarded will increase system dependency in a particular field and it causes model generality to faces difficulty [15]. Consequently designing a multi-purpose sentiment analysis system with the least dependency to a specific domain is a necessity to build an automated model for monitoring a brand.

The main goal of this paper is to propose a new method for sentiment analysis in Twitter with the focus on global commercial brands. Using new techniques in the proposed model particularly in natural language processing

techniques and text classification methods with special attention to the different structures of social media are some other objectives of this research. This paper's contributions are as follows:

1. Proposing a new method for classification of commercial brands using hybrid approach in sentiment analysis.
2. Using big lexicons like SentiWord.Net in lexicon based approach and training data with an extensive domain in machine learning model in order to improve model generality in various fields of business.
3. Improving scalability of proposed model using hashing features and penalty parameters in spars matrices.
4. A significant increase in accuracy in classification algorithms in comparison with previous sentiment analysis models.

The main hypothesis of this research is to use sentiment analysis and opinion mining with a focus on English language and using global brands in Twitter. Sentiment analysis and opinion mining in Persian language are undoubtedly the issues that need further study but lack of basic science, fundamental studies and electronic dictionaries in Farsi prevent us from doing the research.

The rest of the paper is organized as follows. Section II outlines existing work on sentiment analysis with focus on twitter sentiment analysis. Section III describes the methods used in our work to develop the prediction system and sentiment classification. Experimental results are fully detailed and discussed in Section IV. Section V presents our proposed approach of using twitter sentiment analysis to evaluate brand related tweets, and rank brand reputation. Finally, Conclusion and future work are covered in Section VI.

II. LITERATURE REVIEW

Knowledge of the benefits of a strong reputation for companies has been an impetus for research investigating what factors may affect this reputation. One of the important factors determining a reputation is the information that consumers receive about these brands. Social media present a new source of information for consumers to assess a brand's reputation [13]. Recently, textual sentiment analysis has garnered a lot of attention from scientific researchers. Sentiment analysis is a prominent and active area of research, spurred particularly by the rapid growth of social media and the opportunity to access the valuable opinions of numerous participants on various business, brands and social issues. [16].

Twitter is a microblogging service that was launched formally on July 13, 2006 [6]. Unlike other social media, Twitter is considered a microblog because its central activity revolves around posting short updates or tweets using the Web or mobile/cell phones. The maximum size of the blog is 140 characters-roughly the size of a newspaper headline. Twitter becomes almost an indefinite source in text classification. In a large scale sentiment analysis study on Twitter, Go, et al. [11] downloaded 1,600,000 tweets and classify them as positive or negative or neutral by looking for specific words or smiley icons that expresses users' opinions. Twitter has many unique attributes, which differentiate it from other social networks and webpages:

- Length: The maximum length of a Twitter message is 140 characters. Sentiment analysis of tweets data is considered as a much harder problem than that of conventional text such as review documents. This is partly due to the short length of tweets and the rapid evolution of language in Twitter [17].
- Language model: Twitter users post messages from many different media, including their cell phones. The frequency of misspellings and slang in tweets is much higher than in other domains.
- Domain: Twitter users post short messages about a variety of topics unlike other sites which are tailored to a specific topic. This differs from a large percentage of past research, which focused on specific domains such as movie reviews [16].

Sentiment Classification techniques can be roughly divided into machine learning approach, lexicon based approach and hybrid approach [14]. The Machine Learning Approach applies the famous Machine Learning algorithms and uses linguistic features. The Lexicon-based Approach relies on a sentiment lexicon, a collection of known and precompiled sentiment terms [3]. The hybrid approach to sentiment analysis combines both, the machine learning and lexicon-based approaches, in a way that exploits the strengths of both approaches, but avoids some of their weaknesses. Broadly speaking, in the hybrid approach, one of the two approaches is used to boost the performance of the other approach. For example, supervised classifier models make use of lexicon-based approaches to lower the dependency on manually annotated training corpora. On the other hand, the machine learning approaches can be used to bootstrap the sentiment lexicons used in the lexicon-based approaches [18].

An extensive literature review suggests that most sentiment analysis applications might be classified into four distinct categories: product reviews, movie reviews, political orientation extraction and stock market predictions [3]. In spite of extensive research background in sentiment analysis and its diverse range of applications, using sentiment analysis techniques with a focus on brands has been less considered [6]. There are hardly any empirical studies on consumers' Twitter use in an organizational setting. An exception is the study conducted by Jansen, et al. [19]. They consider tweets as electronic word of mouth (eWOM), a form of WOM, which is product advice that consumers give to each other. Lexicon based approach is used in Jansen, et al. [19] research to do sentiment analysis. Not all brand-related tweets provide evaluative information about brands. The category of tweets that does provide this information is called sentiment tweets. These sentiment tweets can be regarded as the most important information about brands that other customers may use as input for a brand's reputation. In their content analysis of 50 United States (US) brands, only 20 percent of all tweets about brands were found to be sentiments. More than 80% of the tweets that mentioned one of these brands expressed no sentiment. Jansen, et al. [19] uses a lexicon of 200,000

unigram and bi-grams. Although these models use a large set of features but they have resulted in low prediction accuracy of tweet sentiment [20, 21].

Mostafa [6] also used lexicon based approach in order to analyze and classify some famous brands such as Nokia, IBM, KLM and DHL in twitter. According to the results of analyzing customer opinions, overall trends towards most brands are positive. The lexicon-based approach used in this study can detect basic sentiments, such approach may sometimes fall short of recognizing the subtle forms of linguistic expression used in situations such as sarcasm, irony or provocation [6].

Ghiassi, et al. [20] employed hybrid approach in sentiment analysis. Although this research was more accurate in comparison with previous classifying methods but using only one brand in twitter sentiment analysis decreases model generality. In Ghiassi, et al. [20] research, experimentation on additional brand-related and using general Twitter corpuses to reveal similar findings are considered as future works.

In this paper we aims to contribute to a better understanding of Twitter as one of the most prominently used social media. Specifically, we aims to analyze consumers' Twitter behavior, because tweets have the high potential to affect the reputation of a business. With its interest in the comparison between goods and brands, this study contributes to our understanding of consumers' media use, which may affect brand reputation. Indeed, an important avenue for future research is to design studies that can reliably examine how reading one's Twitter timeline, where brand-related tweets also figure, can have an impact on consumers' reputation of a brand. Although several studies have recently investigated sentiment analysis, no previous studies have focused solely on investigating consumers' sentiments towards major worldwide brands. In this study we aim to fill this void. We believe that by investigating brans' polarity the study adds depth to the knowledge base on text mining.

III. METHODS

This section discusses the methods used in this work to develop the prediction system. The proposed approaches are employed using Python programing language version 3.4 and its machine learning packages [22]. Our approach is to use different machine learning classifiers and feature extractors. The machine learning classifiers are Naive Bayes, Logistic Regression, and Support Vector Machines (SVM). The feature extractors are N-grams, part of speech tags and feature hashing. Fig. 1. shows our proposed framework in sentiment analysis based on hybrid approaches. The rest of section discusses different steps of proposed framework.

A. Data Gathering

In first step Twitter Application Programing Interface (Twitter API) and a web crawler which specifically designed by research model were utilized in order to collect and gather brand related Tweets from Twitter. Social media platforms such as Twitter offer access via an API, so that relevant Tweets can be obtained based on a submitted query. The query in this case needs to include terms related to the brand in question, for example brand name or related products and services.

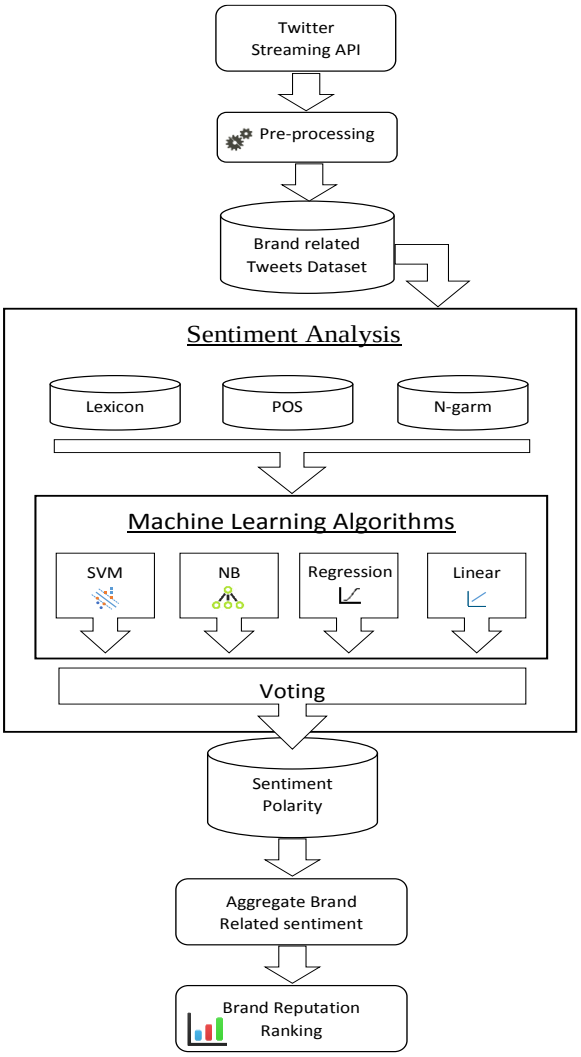


Fig. 1. Proposed framework

B. Data preprocessing

To create the word vector list, the tweets are pre-processed. The following are the steps done in data pre-processing. Tokenize to split the texts of a tweet into a series of words or tokens to remove the 'non-letters' words which will generate single word tokens [23]. Transform the upper case letters to lower case to reduce ambiguity. Then stop words are filtered to remove common English words. Word like these are very noisy unless removed. A stemmer is then used for steaming [24]. Rather than mentioned standard preprocessing we employed some Tweet related Pre-processing in order to better tweets cleaning.

Tweet related Pre-processing:

- Lower Case – converted all the characters in a string to lower case
- URLs – deleted all string that represents links or with hyperlinks

- @username – removed the username and because these are not factors for sentiments
- #hashtag - hash tags can give some useful information, so it is useful to replace them with the exact same word without the hash. E.g. #Apple replaced with Apple.
- Punctuations and additional white spaces - removed punctuation at the start and ending of the tweets [16].

C. Feature Selection

The most important decision to make when classifying documents, is the choice of the feature set. Several features are used in this work include N-grams, part-of-speech data and feature hashing [23].

1) N-grams

This is the classic approach to feature selection, in which each document is represented as a feature vector, where the elements indicate the presence (or frequency) of a word in the document. In other words, the document is represented by its keywords. A word N-gram is a subsequence of N words from a given sequence (e.g. a sentence). This means that the features in the document representation are not single words, but pairs (bigrams), triples (trigrams) or even bigger tuples of words [23]. We use unigram, bigrams and trigrams in this proposed model.

2) Part-Of-Speech Features

Part-Of-Speech features (POS) are common features that have been widely used in the literature for the task of Twitter sentiment analysis [17]. In this work, we build various classifiers trained using a combination of word N-grams and POS features.

D. Feature hashing

In our approach, we make use of feature hashing, which is a relatively new topic for text classification [25]. In traditional document classification tasks, the input to the machine learning algorithm is a free text, from which a bag-of-words representation is constructed — the individual tokens are extracted, counted, and stored as vectors. Typically, in tweets, these vectors are extremely sparse. One can deal with this sparsity by using feature hashing. It is a fast way of building a vector space model of features, which turns features into either a vector or a matrix. Such an approach produces features represented as hash integers rather than strings. Using feature hashing to deal with the high dimensional input space of tweets showed that it can improve the performance of the machine learning algorithms [26].

E. Supervised Machine Learning Algorithms

The machine learning algorithms are employed using Scikit-learn an open source machine learning package in python. Scikit-learn focuses on ease of use, and is mostly written in a high level language, care has been taken to maximize computational efficiency [22]. In our proposed model the machine learning classifiers are Naive Bayes (NB), Logistic Regression, Support Vector Machines (SVM), and Linear Models.

1) Naive Bayes

Naive Bayes (NB) is a simple probabilistic classifier based on applying Bayesian theorem and works well on text categorization. We use a Multinomial NB and Bernoulli NB model. A Multinomial Naive Bayes classifier constructs a model by fitting a distribution of the number of occurrences of each feature for all the documents. In Twitter Classification, class c^* is assigned to tweet d, where

$$c^* = argmac_c P_{NB}(c|d) \quad (1)$$

And

$$P_{NB}(c|d) := \frac{(P(c)\sum_{i=1}^{m} P(f|c)^{n_i(d)})}{P(d)} \quad (2)$$

In Eq.(2), f represents a feature and $n_i(d)$ represents the count of feature f_i found in tweet d. There are a total of m features. Parameters $P(c)$ and $P(f|c)$ are obtained through maximum likelihood estimates, and add -1 smoothing is utilized for unseen features [11]. In the Bernoulli model, features are independent Booleans (binary variables) describing inputs. Like the multinomial model, this model is popular for document classification tasks [27].

2) logistic regression

Logistic regression is a standard technique based on maximum likelihood estimation. The first step in logistic methods is identifying which combination of independent variables best estimates the dependent variable. This is known as model selection. The model is represented by the following:

$$P_{LR}(c|d,\lambda) = \frac{exp\left[\sum_i \lambda_i f_i(c,d)\right]}{\sum_{c'} exp\left[\sum_i \lambda_i f_i(c,d)\right]} \quad (3)$$

In this formula, c is the class, d is the tweet, and λ is a weight vector. The weight vectors decide the significance of a feature in classification. A higher weight means that the feature is a strong indicator for the class. The weight vector is found by numerical optimization of the lambdas so as to maximize the conditional probability. Theoretically, Logistic regression performs better than Naive Bayes because it handles feature overlap better. However, in practice, Naive Bayes can still perform well on a variety of problems [27]. The model is used with default values for classification parameters.

3) Support Vector Machines

Support Vector Machines is another popular classification technique [11]. We use the linear SVC (Support Vector Classification) with L1 and L2-based feature selection. linear SVC Similar to SVC (C-Support Vector Classification) with parameter kernel='linear', but implemented in terms of liblinear (A Library for Large Linear Classification[1]) rather than libsvm library, so it has more flexibility in the choice of penalties and loss functions and should scale better to large numbers of samples [22]. SVM is calculated by Eq.(4).

[1]http://www.csie.ntu.edu.tw/~cjlin/liblinear/

$$\vec{w} = \sum_{i=1}^{n} \alpha_i^* y_i \vec{d_i} \qquad \alpha_i \geq 0 \qquad (4)$$

Where α_i^* are obtained by solving a dual optimization problem. Eq.(4) shows that the resulting weight vector of the hyper plane is constructed as a linear combination of $\vec{d_i}$. Only those examples that contribute to which the coefficient α_i is greater than zero. Those vectors are called support vectors, since they are the only document vectors contributing to $\vec{w}$ [28].

4) Linear Models

The sklearn.linear_model module implements generalized linear models [22]. It includes Perceptron, passive-aggressive and Ridge Classifier. It also implements Stochastic Gradient Descent related algorithms. The Perceptron is another simple algorithm suitable for large scale learning. By default:

- It does not require a learning rate.
- It is not regularized (penalized).
- It updates its model only on mistakes.

The last characteristic implies that the Perceptron is slightly faster to train than SGD with the hinge loss and that the resulting models are sparser. The passive-aggressive algorithms are a family of algorithms for large-scale learning. They are similar to the Perceptron in that they do not require a learning rate. However, contrary to the Perceptron, they include a regularization parameter C. Ridge Classifier is a Classifier which uses Ridge regression. Stochastic Gradient Descent (SGD) is a simple yet very efficient approach to fit linear models. It is particularly useful when the number of samples (and the number of features) is very large. SGD Classifier can optimize the same cost function as Linear SVC by adjusting the penalty and loss parameters. In addition it requires less memory, allows incremental (online) learning, and implements various loss functions and regularization regimes.

F. Penalty Parameters

The main goal of Penalizing in machine learning algorithms is variance reduction to avoid overfitting. It is also a good solution for spars matrix problem. The regularizer is a penalty added to the loss function that shrinks model parameters towards the zero vector. Three types of penalties used in our models include L1 penalty, L2 penalty and Elastic net model. L1 penalized model is often called Lasso, while L2 penalized model is known as Ridge regression. Elastic net model is obtained from a combination of L1 and L2 penalties.

G. Stanford Twitter Sentiment Corpus

Stanford Twitter Sentiment dataset (STS) [11] has 1,600,000 training tweets including product names, companies, and people collected by a scraper that queries the Twitter API. After removing retweets, any tweet containing both positive and negative emoticons, one gets 800,000 tweets with positive emoticons and 800,000 tweets with negative emoticons. We used combination of 1,200,000 positive and negative tweets to train the proposed model. Testing data were manually annotated with a class label includes 2034 tweets from STS gold data sets [29].

H. Voting classifier and Aggregation

The idea behind the voting classifier implementation is to combine conceptually different machine learning classifiers and use a majority vote or the average predicted probabilities (soft vote) to predict the class labels. Such a classifier can be useful for a set of equally well performing model in order to balance out their individual weaknesses. In majority voting, the predicted class label for a particular sample is the class label that represents the majority (mode) of the class labels predicted by each individual classifier. E.g., if the prediction for a given sample is:

- classifier 1 -> class 1
- classifier 2 -> class 1
- classifier 3 -> class 2

The Voting Classifier (with voting='hard') would classify the sample as “class 1” based on the majority class label.

The last step in our proposed frame work is to select algorithms which have best performance for majority voting to conduct final model. This model is used to rank the studied brands. Finally the results of proposed method are compared with some surveys for setup verification purposes.

IV. Experimental Result

The prediction systems are developed using the methods discussed in previous section.

TABLE 1. Classification Algorithems with N-grams and Penalty Parameters

Classifier	Penalty	Uni-gram metrics				Bi-grams metrics				Tri-grams metrics			
		ACC	*PRE*	*RE*	*F1*	*ACC*	*PRE*	*RE*	*F1*	*ACC*	*PRE*	*RE*	*F1*
Bernoulli NB*	None	0.886	0.891	0.886	0.887	0.886	0.891	0.886	0.887	0.943	0.945	0.943	0.943
Multinomial NB*	None	0.874	0.880	0.874	0.875	0.874	0.880	0.874	0.875	0.942	0.945	0.942	0.943
Linear SVC	L2	0.886	0.899	0.886	0.889	0.886	0.899	0.886	0.889	0.932	0.938	0.932	0.933
	L1	0.880	0.896	0.880	0.883	0.881	0.896	0.881	0.884	0.880	0.896	0.880	0.883
Logistic Regression	L2	0.869	0.885	0.869	0.872	0.869	0.885	0.869	0.872	0.893	0.905	0.893	0.895
	L1	0.850	0.872	0.850	0.855	0.850	0.872	0.850	0.855	0.856	0.877	0.856	0.860
	Elastic-Net	0.850	0.872	0.850	0.855	0.850	0.872	0.850	0.855	0.856	0.877	0.856	0.860
Passive-Aggressive	None	0.877	0.887	0.877	0.879	0.873	0.882	0.873	0.875	0.932	0.938	0.932	0.933
Perceptron	None	0.839	0.847	0.839	0.842	0.839	0.847	0.839	0.842	0.922	0.929	0.922	0.923
Ridge Classifier	None	0.867	0.882	0.867	0.870	0.866	0.880	0.866	0.869	0.929	0.935	0.929	0.930
SGD Classifier	L2	0.806	0.853	0.806	0.813	0.806	0.853	0.806	0.813	0.796	0.837	0.796	0.803
	L1	0.740	0.826	0.740	0.750	0.739	0.826	0.739	0.748	0.718	0.816	0.718	0.728
	Elastic-Net	0.796	0.849	0.796	0.803	0.795	0.849	0.795	0.803	0.775	0.826	0.775	0.783

ACC: Accuracy, PRE: Precision, RE: Recall, F1: F-Measure, * Naïve Bayes

The results of our sentiment classification are shown in Table 1 using Unigram, Bigrams, Trigrams, and POS, applied over the STS data set. This Table shows Experimental comparison for the main algorithms under L1, L2 and Elastic Net Penalty regularizer. We used precision, recall, F-measure and accuracy to measure the effectiveness of algorithms. Comparing Uni-gram and Bi-grams features in Table 1 shows that there is no significant improvement in examined algorithms. In contrast, Tri-grams features cussed significant improvement in evaluation metrics and leads to better performance between all models. Selecting L2 Parameter in comparison with L1 and Elastic-Net has better accuracy in all three examined models contains Linear SVC, Logistic Regression and SGD. According to evaluation metrics in Table 1 Most of algorithms have an acceptable performance. All metrics in the models examined are above 80%. The best performances among training classifiers belong to Bernoulli NB, Linear SVC and logistic regression. These three models are used for majority voting in final implementation.

V. BRAND REPUTATION RANKING

To demonstrate the usefulness of the proposed model, we collected user massages and opinions from Twitter of five global brands using the Twitter API. In this paper, tweets related to five global brands in IT sectors including Google, Microsoft, Apple, Sony and Samsung were extracted from Twitter in order to analysis and brand ranking. The data contains 16,267,000 tweets gathered during five month. Table 2 shows collected data and results of tweets classification.

TABLE 2. BRAND RELATED TWEETS CLASSIFICATIONS

Brands	***Tweets****	***Sentiments***	***positive***	***negative***	***POS%****
Apple	4,102,356	604,687	445,775	158,912	73.72
Google	3,597,582	793,627	548,317	245,310	69.09
Samsung	3,193,305	556,912	351,523	205,389	63.12
Microsoft	2,669,225	459,907	276,312	183,595	60.08
Sony	2,704,551	537,665	318,298	219,367	59.20
Total	16,267,019	2,952,798	-------	-------	-------

*Total Number of Tweets, *Percentage of Positive Tweets

Total number of tweets and sentiments in each brand is shown in this table. Total number of classify tweets have been listed as positive and negative classes. The percentage of positive tweets is calculated in the last column.

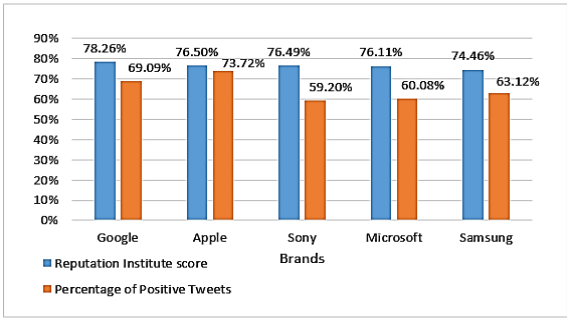


Fig. 2. Brands Score

Generally, percentage of positive tweets in all brands are above 60% that shows users positive trends towards studied brands in this research. Fig. 2. shows scores of our studied brands and results of the survey published by Reputation Instituted in 2015 [30]. This study is done annually using Interviews and questionnaires to measure the reputation of the word 100 most highly regarded and familiar global companies in 15 countries. In this Figure the scores of Reputation Institute are obtained from 61,000 interviews in April 2015. Our proposed model brand scores are estimated based on percentage of total positive tweets. Table 3 compares brands reputation ranking based on scores shown in Fig. 2.

TABLE 3. BRAND REPUTATION RANKING

Reputation Institute	Google 1	Apple 2	Sony 3	Microsoft 4	Samsung 5
Proposed model	Apple 1	Google 2	Samsung 3	Microsoft 4	Sony 5

Although results of brand reputation ranking are not totally same in these two researches but there are many similarities between results obtained from our research and reputation institute survey. Both Google and Apple brands are on the top in Table 3 and Microsoft has same rank in both researches. There is only a little difference between Sony, Microsoft and Samsung considering percentage of positive tweets. Therefore there isn't a big difference between the rankings of these three brands in Table 3.

VI. CONCLUSION AND FUTURE WORK

The massive data published on social media platforms plays an important role in creation and improvements of companies and brands reputation. Brand reputation management is regarded as the first priority in many companies. In spite of this, brand reputation concept has remained as complicated issue and difficult to be measured. In this research we proposed a novel method to evaluate and measure customer trends towards commercial brands in twitter using sentiment analysis with the aim of brand reputation ranking. For this purpose we have examined various supervised classification methods and the most promising strategies like N-grams features, feature hashing and penalty parameters to analyze tweets sentiment. Based on achieved results, best performance belongs to NB and SVM algorithms having Tri-grams with accuracy 94.2% and 94.3% respectively. The best accuracies obtained in previous researches are equal to 87.2% in Go, et al. [11] and 87.6% in Bakliwal, et al. [31] which shows significant improvement and better performance in our method comparing previous ones. Moreover using Penalty parameters and feature hashing in spars matrix leads to increase scalability of the model. Compared to the existing approaches to twitter sentiment analysis which either rely on many features or complicated learning procedure, our approaches are much more simple and straightforward and yet attain comparable performance.

Capturing consumers' opinions and gaining knowledge about consumer preferences has long been a major concern for marketing researchers. However, traditional marketing methods such as focus groups and face-to-face interviewing are both costly and time consuming. In contrast, tweets and blogs are readily available for free. Moreover, consumers

opinion-based expressed qualitatively may easily be benchmarked against objective measures such as sales data, revenues, or stock price. Thus, companies can utilize such online textual content in an effort to gain insight into consumers' opinions regarding commercial brands. Ignoring consumer generated sentiments might put companies in a competitive disadvantage and could also create significant brand image problems. The speed of social media might also render companies' advertising and publicity using traditional media useless.

Evaluation and measurement of brand reputation in company and brands are generally conducted using surveys and focus groups. Similarities of brand reputation ranking results in this research and Reputation Instituted studies demonstrate the efficiency and usefulness of our proposed method. Designing and developing real time sentiment analysis methods in social media have been hot topics in recent researches. Extension of existing sentiment analysis models to real time systems are also our feature aims for monitoring brands. In this research we have focused on the use of traditional classifiers, like Naive Bayes, SGD classifier, and Support Vector Machines to solve Twitter sentiment problems. In future work, we will explore use of more ensembles of multiple base classifiers, like Random Forest classifier in order to improve the accuracy of tweets sentiment classification.

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Experimental Stability Study of an Octorotor Using an Intelligent Controller

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***Abstract*— In this paper, the attitude stabilization problem of an Octorotor with coaxial motors is studied. To this end, the new method of intelligent adaptive control is presented. The designed controller which includes fuzzy and PID controllers, is completed by resistant adaptive function of approximate external disturbance and changing in the dynamic model. In fact, the regulation factor of PID controller is done by the fuzzy logic system. At first, the Fuzzy-PID and PID controllers are simulated in MATLAB/Simulink. Then, the Fuzzy-PID controller is implemented on the Octorotor with coaxial motors as online auto-tuning. Also, LabVIEW software has been used for tests and the performance analysis of the controllers. All of this experimental operation is done in indoor environment in the presence of wind as disturbance in the hovering operation. All of these operations are real-time and telemetry wireless is done by network connection between the robot and ground station in the LABVIEW software. Finally, the controller efficiency and results are studied.**

Keywords*— *Octorotor, Attitude Stabilization, Fuzzy-PID controller, Experimental, Online Tuning

I. INTRODUCTION

Freshly, Vertical Take Off and Landing (VTOL) Systems and Unmanned Aerial Vehicles (UAVs) Such as Quadrotor has become as significant and interest issue among of researcher in the field of control. This popularity is obvious in literature, [1-5]. These systems are used for several applications. With a view to the high maneuverability of this UAV, they can use as rescue in natural disasters for impassable area where it is Risky for humans, [6]. Also, from civilian vision, it can be noted to the traffic monitoring, inspection of forest areas and even nowadays in some parts of the world as a postman. In addition, military applications such as border patrol and spy on the enemy information during a war, currently represent as part of the unmanned aerial vehicle market, and this industrial section is speedily developing. Some clear characteristics of these discussed rotorcrafts are high nonlinear dynamic, time-varying behavior and continuously being under the influence of disturbances, [7]. These features are resulted in the usage of some nonlinear control methods by researchers in this field. For example, an adaptive backstepping controller was provided in [8] which it was designed for the position trajectory tracking of a quadrotor. In addition, this controller which is based on an adaptive controller, uses the usual nonlinear model of quadrotor. Also in [9], author emphasized on the ability of sliding mode control procedure, this controller is an appropriate selection for stabilizing under-actuated systems such as the quadrotor which has the nonlinear dynamic model. Also, comparison between backstepping and sliding mode techniques is investigated by Samir Bouabdallah, [10]. As mentioned, the quadrotor is sensitive to the disturbance. That is why in [11], a nonlinear adaptive state feedback controller is used for the stabilization of quadrotor system and the full guaranty tracking even in the presence of invariant force disturbances. The coaxial quadrotor flying robot is kind of VTOL system that consists of eight rotors. Also, mechanical configuration of coaxial quadrotor is exactly the same of quadrotor and motors are located on the coaxial axis as two by tow, [12]. For achieving the more trust and stability in rotorcrafts, some approaches are available. One of these methods is to add motors to the system structure. This increasing of motor numbers can be done in the two ways. In the classical kind of Octorotor with eight arms, the motors set as star configuration. The weight of this structure is its disadvantage. Analogous to the Quadcopter, the Coaxial Quadcopter has six Degree of Freedoms (DOFs) with four inputs. Control implementation of coaxial quadrotor is greatly similar to the quadrotor. Since, dynamic model of this UAV is high nonlinear, variety controllers are applied for the position and attitude control, [13]. In the meantime, Proportional Integral Derivative (PID) controllers are still popular in industrial and robotic systems because of the implementation of this controller is too simple, [14]. For sample, papers [15-19] are evidence of this claim. Also, to improve the PID controller performance, some methods are used which includes increment of control loop speed and combining PID controller with intelligent controller such as fuzzy intelligent systems. To this reason, for the attitude control, the self-tuning fuzzy PD application on a quadrotor is expressed in [20]. Also, a Fuzzy PID hybrid control is consequently designed for an eight-rotor Micro Aerial Vehicle (MAV) and a Quadrotor in [13] and [21] respectively.

In this paper, to provide more realistic results for the real-time tasks, a hardware-in-the-loop experimental system has been set up. To this end, the dynamic modelling of the coaxial

quadrotor is studied. Next, the controller design procedure is described which includes classical and fuzzy PID controllers. Simulation results of the both controllers are explained. After that, the implementation test of designed Fuzzy-PID controller with its results is expressed for the hovering manoeuvre on a real rotorcraft using the LabVIEW software. Finally, the results are studied.

II. OCTOROTOR CONCEPT

Before the study of controller design procedure, the dynamic model of system must be explained. The structure of coaxial quadrotor is completely similar to the quadrotor which Figure (1) shows this robot.



Fig. 1. Considered Octorotor Helicopter frame

The only deference in the coaxial quadrotor is two motors are installed at the end of each arm in one axis and apposite of each other, [21]. Figure (2) shows dynamic sense of this coaxial Octorotor.

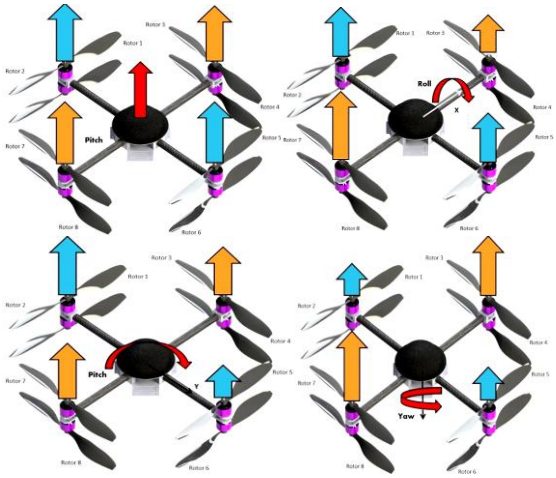


Fig. 2. Concept of Octorotor with coaxial motors

This type of flying robot consists of eight angular velocities ($\omega_1,\omega_2,\omega_3,\omega_4,\omega_5,\omega_6,\omega_7,\omega_8$) and the overall angular velocities is, [22]:

$$\omega_r = -\omega_1+\omega_2-\omega_3+\omega_4-\omega_5+\omega_6-\omega_7+\omega_8 \qquad (1)$$

where the angular speed of forward direction propellers are ω_1 and ω_2, right direction propellers are ω_3 and ω_4, backward direction propellers are ω_5 and ω_6, and left direction propellers are ω_7 and ω_8. Also, the rotation matrix is described as, [13]:

$$\mathbf{R}=\begin{bmatrix} C\theta C\psi & S\varphi S\theta C\psi - C\varphi C\psi & S\varphi S\psi + C\varphi S\theta C\psi \\ C\theta S\psi & S\varphi S\theta S\psi - C\varphi C\psi & C\varphi S\theta S\psi - S\varphi C\psi \\ -S\theta & S\varphi C\theta & C\varphi C\theta \end{bmatrix} \qquad (2)$$

where C and S are abbreviation of Cos and Sin functions. In addition, control inputs of system are presented as

$$\begin{aligned} U_1 &= b\left(\omega_1^2+\omega_2^2+\omega_3^2+\omega_4^2+\omega_5^2+\omega_6^2+\omega_7^2+\omega_8^2\right) \\ U_2 &= lb\left(-\omega_3^2-\omega_4^2+\omega_7^2+\omega_8^2\right) \\ U_3 &= lb\left(-\omega_1^2-\omega_2^2+\omega_5^2+\omega_6^2\right) \\ U_4 &= d\left(-\omega_1^2+\omega_2^2-\omega_3^2+\omega_4^2-\omega_5^2+\omega_6^2-\omega_7^2+\omega_8^2\right) \end{aligned} \qquad (3)$$

where U_1,U_2,U_3,U_4 defines Throttle, Roll, Pitch and Yaw respectively. Furthermore, b and d are the thrust factor and drag factor correspondingly. Moreover, l is the length from the centre to the rotor based. So, motion equations of system for this Octorotor can be extracted. As regards to six DOFs of this nonlinear system, equations include rotation and transition motion. $\ddot{\varphi},\ddot{\theta},\ddot{\psi}$ are rotation accelerations and $\ddot{X},\ddot{Y},\ddot{Z}$ are transition accelerations. So, it yields:

$$\begin{cases} \ddot{\varphi} = \left(\frac{I_y-I_z}{I_x}\right)\dot{\theta}\dot{\psi} + \frac{J_{TP}}{I_x}\dot{\theta}\,\omega_r + \frac{U_2}{I_x} \\ \ddot{\theta} = \left(\frac{I_z-I_x}{I_y}\right)\dot{\psi}\dot{\varphi} - \frac{J_{TP}}{I_y}\dot{\varphi}\,\omega_r + \frac{U_3}{I_y} \\ \ddot{\psi} = \left(\frac{I_x-I_y}{I_z}\right)\dot{\varphi}\dot{\theta} + \frac{U_4}{I_z} \\ \ddot{x} = \frac{1}{m}\left(c\varphi\, s\theta\, c\psi + s\psi\, s\varphi\right)U_1 \\ \ddot{y} = \frac{1}{m}\left(c\varphi\, s\theta\, s\psi - s\varphi\, c\psi\right)U_1 \\ \ddot{z} = \frac{1}{m}\left(c\theta\, c\varphi\right)U_1 - g + D_z \end{cases} \qquad (4)$$

where D_Z is the wind disturbance on the robot.

III. CONTROLLER DESIGN

This section will present two control strategies for the stability of coaxial Quadrotor. These controllers are Proportional Integral Derivative (PID) and Fuzzy-PID controller.

A. *Classical Controller Strategy*

When a PID strategy is used as a controller, success in the stability can be resulted in success at finding the best gain for P, I and D of the controller. In fact, if these gains have the suitable magnitude, much of the stability problem would be obtained. Considering that, the rotational and translational equations of the Octorotor are independent, so each angle has a separate PID controller. As a result, the control rules are defined as:

$$\begin{aligned} U_2 &= K_{p\varphi}\, e_{\varphi}(t) + K_{i\varphi}\int e_{\varphi}(\tau)d\tau + K_{d\varphi}\frac{de_{\varphi}(t)}{dt} \\ U_3 &= K_{p\theta}\, e_{\theta}(t) + K_{i\theta}\int e_{\theta}(\tau)d\tau + K_{d\theta}\frac{de_{\theta}(t)}{dt} \\ U_4 &= K_{p\psi}\, e_{\psi}(t) + K_{i\psi}\int e_{\psi}(\tau)d\tau + K_{d\psi}\frac{de_{\psi}(t)}{dt} \end{aligned} \quad (5)$$

where e is the difference between the desired angle and real angle. Also, the block diagram of this PID controller is shown in Figure (3).

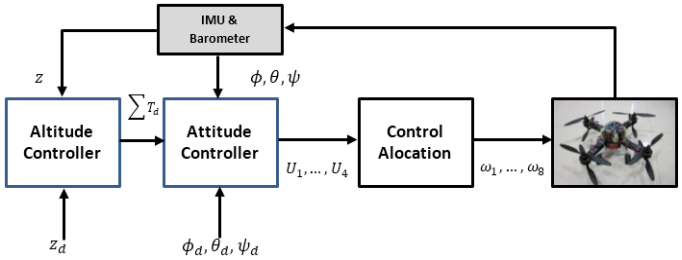


Fig. 3. Block diagram for PID controller of Octorotor

B. *Fuzzy-PID Controller*

One of the most popular controllers in intelligent ones is the Fuzzy-PID controller. For Increasing the performance of PID controller output, coefficients of P, I and D regulates during the operation by Fuzzy controller as online. Also, the block diagram of Fuzzy-PID controller is shown in Figure (4).

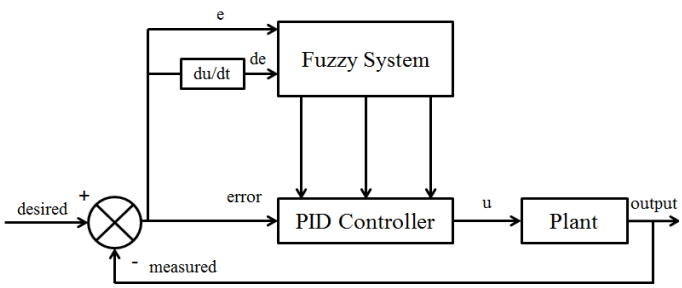


Fig. 4. Block diagram of Fuzzy-PID controller

Based on the PID algorithm and the error computing o and the error changes of the system, the Fuzzy Inference system is carried out. Also, fuzzy rules and PID parameters are tuned by look-up fuzzy matrix, [23]. Incremental method is one of the approaches in tuning the coefficients of K_P, K_I and K_D using fuzzy intelligent controller, [24]. Formula of this method can be described as:

$$\begin{aligned} K'_p[K] &= K_p + K_1 CV(e[K], \Delta e[K]) \\ K'_I[K] &= K_I + K_2 CV(e[K], \Delta e[K]) \\ K'_D[K] &= K_D + K_3 CV(e[K], \Delta e[K]) \end{aligned} \quad (6)$$

where K'_P, K'_I and K'_D are new coefficients that tuned using this equation. Also, K_P, K_I and K_D are current coefficients which should be added with the output of Fuzzy Inference system which is shown as $CV(e[K], \Delta e[K])$. Also, K_1, K_2, K_3 are constant coefficients that determine the range of rates in every one of coefficients. For tuning the P, I and D parameters, the Fuzzy rules is defined by the system behavior and available knowledge. Various rules of auto-tuning is extracted using the error (e) and rate of changing error (ec). Fuzzy rule tables for K_P, K_I and K_D are shown in Tables I, II and III respectively.

TABLE I. FUZZY ROLE FOR K_P

e \ ec	NB	NM	NS	ZO	PS	PM	PB
NB	PB	PB	PM	PM	PS	ZO	ZO
NM	PB	PB	PM	PS	PS	ZO	NS
NS	PM	PM	PM	PS	ZO	NS	NS
ZO	PM	PM	PS	ZO	NS	NM	NM
PS	PS	PS	ZO	NS	NS	NM	NM
PM	PS	ZO	NS	NM	NM	NM	NB
PB	ZO	ZO	NM	NM	NM	NB	NB

TABLE II. FUZZY ROLE FOR K_I

e \ ec	NB	NM	NS	ZO	PS	PM	PB
NB	NB	NB	NM	NM	NS	ZO	ZO
NM	NB	NB	NM	NS	NS	ZO	ZO
NS	NB	NM	NS	NS	ZO	PS	PS
ZO	NM	NM	NS	ZO	PS	PM	PM
PS	NM	NS	ZO	PS	PS	PM	PB
PM	ZO	ZO	PS	PS	PM	PB	PB
PB	ZO	ZO	PS	PM	PM	PB	PB

Fuzzy roles tables include symbols that represents specific concept. So, NB is (Negative Big), NM (Negative Medium), NS (Negative Small), Z (Zero), PS (Positive Small), PM (Positive Medium) and PB (Positive Big). Also, the membership function of PID parameters for the attitude controller is shown in Figure (5).

TABLE III. FUZZY ROLE FOR K_D

ec / e	NB	NM	NS	ZO	PS	PM	PB
NB	PS	NS	NB	NB	NB	NM	PS
NM	PS	NS	NB	NM	NM	NS	ZO
NS	ZO	NS	NM	NM	NS	NS	ZO
ZO	ZO	NS	NS	NS	NS	NS	ZO
PS	ZO	ZO	ZO	ZO	ZO	ZO	ZO
PM	PB	NS	PS	PS	PS	PS	PB
PB	PB	PM	PM	PM	PS	PS	PB

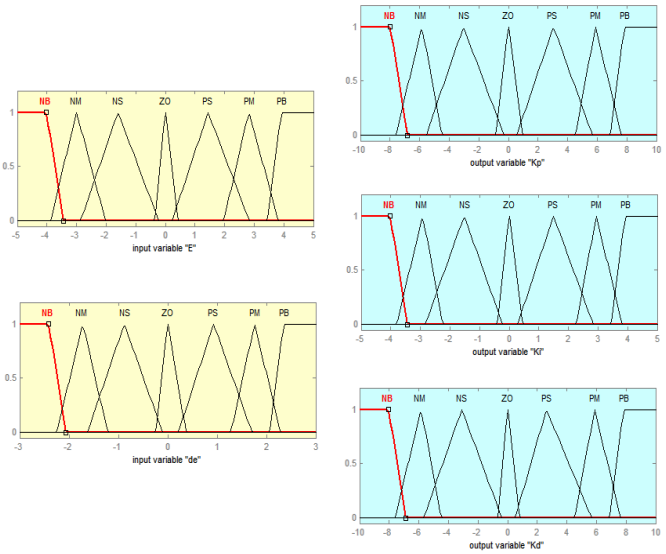


Fig. 5. Membership function of PID parameters

IV. SIMULATION RESULTS AND DISCUSSION

This section is discussed about the Fuzzy-PID controller simulation for the coaxial Octorotor. Purpose of this simulation is the performance investigation of Fuzzy-PID controller in compared to the PID controller. To specify the Roll-Pitch changing domain, a new method is tested. In this method, at first a position input is determined until the robot move to the position with changing in the Roll and Pitch angles. Then, regulator output sets directly in the PID equation. In this step, membership function domain changes constantly until the minimum changing rate of parameters is achieved. Also, the minimum error is attained in the output. Obtained results in Figures (6), (7) and (8) show that the Fuzzy regulator for Roll and Pitch angles are placed in the good mode performance. Also, as shown in these figures, the Fuzzy-PID controller adapted very faster than the PID controller.

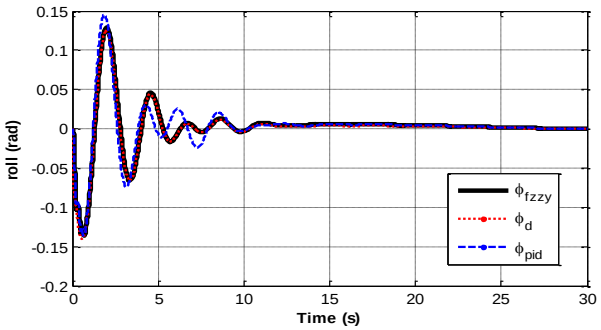


Fig. 6. Roll angle control by PID and Fuzzy-PID controller

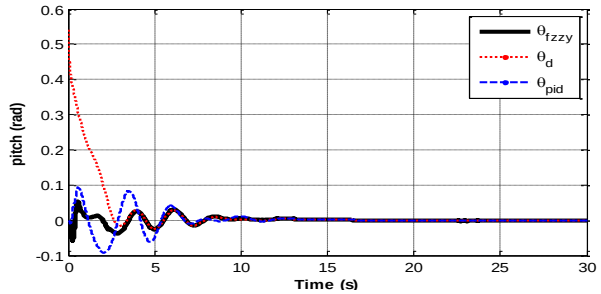


Fig. 7. Pitch angle control by PID and Fuzzy-PID controller

Also, as shown in Figure (8), no specific changes are observed for the Yaw angle.

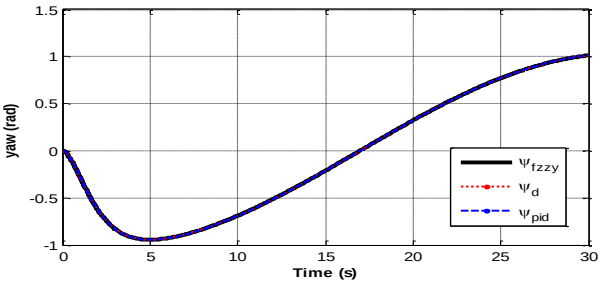


Fig. 8. Yaw angle control by PID and Fuzzy-PID controller

V. EXPERIMENTAL STUDY AND DISCUSSION

In this section, first the Fuzzy-PID controller is implemented and tested on the robot in presence of the disturbance. It should be noted that the implementation of Fuzzy-PID controller is done as auto-tune, at first process of test and then finally, experimental results is expressed in LabVIEW software.

A. Setup Assembling

For online tuning the parameters of K_P, K_I and K_D, a Fuzzy controller is designed in the ground station which plays a role of PID parameter regulator. As shown in Figure (9) for more validity of test, the robot is placed in the presence of disturbance as uncertain model condition. In this Figure (9), data of attitude such as Roll, Pitch, and Yaw inputs, equilibrium points and current parameters of PID controller are sent to the PC ground station. Then, PC sends new PID

parameter to the robot. As a result, these new parameters cause more stability.

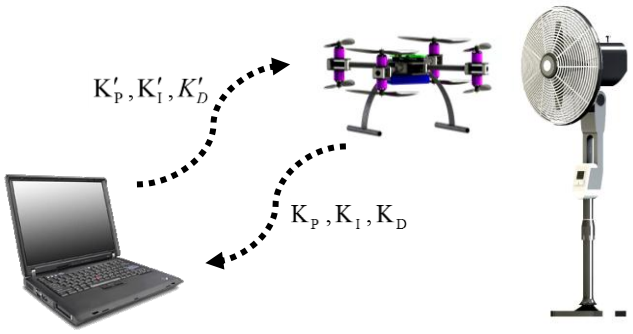


Fig. 9. Implementation scenario

One of the most important problems in this regard is the structure of loop speed in during the task. Connection between software and hardware should not have a negative effect to each other. To this end, a wireless commutation between the Octorotor in flying status and the PC in ground station is set up. For contacting this connection, an access point is used to connect the PC by USB. Also, a RN-171 module has been used on the Octorotor. This module which is shown in Figure (10-b), works with 115200 Kbit/s in this implementation. Also, the utilized access point is shown in Figure (10-a).

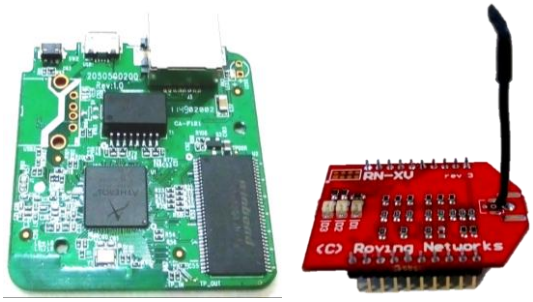


Fig. 10. a) Access point b) Network module

Also, network wireless communication setting in active condition is depicted in Figure (11).

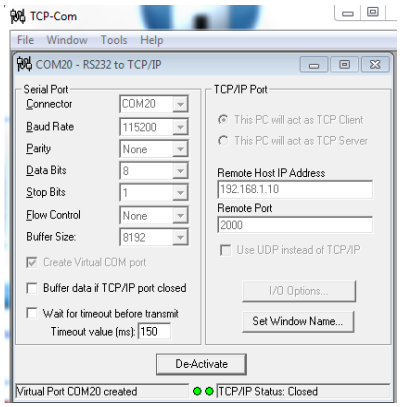


Fig. 11. Network wireless communaction setting

B. *Results of Attitude Control*

After preparing the condition of test and scenario definition for experiment, the Octorotor is put in front of the wind in the real hovering flight. Now, the PID parameter regulator in ground station is turn on. This regulator is the same of Fuzzy controller. When the Octorotor is in the flying status, P, I and D coefficients are constantly changing. TO have the stable flight in front of the wind as disturbance, the Octorotor has to tune its PID coefficients as online. Also, tuning of PID coefficients is available as online monitoring. Figure (13) illustrates the real experimental in the flying robot laboratory. Moreover, time history of obtained results has been shown in Figure (14) for Roll and Pitch angles. In Roll status, created error is attained from different between the Roll angle input and Roll angle output. This different is tried to diminishing and reason of this reduction is that the Fuzzy regulator is turned on. Also, variations of controller coefficients that is written based on the Fuzzy rules is shown in Figures (12) and (13).

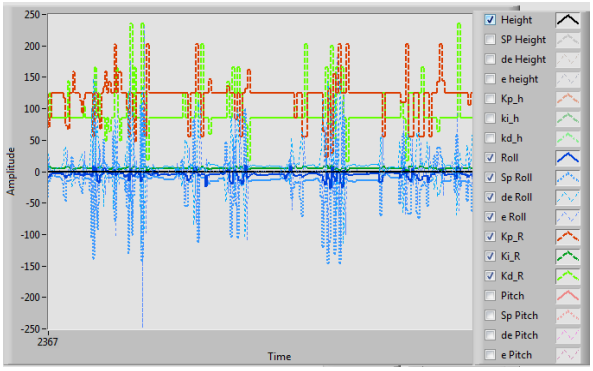


Fig. 12. Implementation of Roll angle control using Fuzzy-PID

On the other hand, the creation of this constant error is inevitable between the input angle and real angle and this issue can be impress the performance of designed Fuzzy regulator.

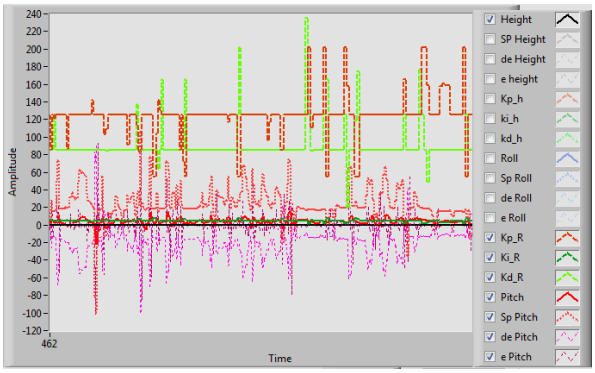


Fig. 13. Implementation of Pitch angle control using Fuzzy-PID

But this constant error is neutralized since its most important reason is the high-speed sampling which is determined the error variations. Processing of implementation of Octorotor in presence of disturbance in real flight is illustrated in Figure (14).



Fig. 14. Implementation processing of Octorotor in presence of disturbance

VI. CONCLUSION

In this paper, a Fuzzy-PID controller for the attitude control of an Octorotor was studied. To improve the PID controller performance, a Fuzzy controller was utilized as an intelligent controller. At first, in order to describe the Fuzzy-PID system, MATLAB/Simulink software was used. Next, simulations on the dynamic model of Octorotor were expressed whereas the Fuzzy-PID controller rapidly adapt to the desired angle relative to the PID controller. Also, for verification of this intelligent controller, an experimental test was performed in presence of the disturbance in an indoor environment. Implementation presented the online tuning of PID parameters by the Fuzzy controller which creates more stability. Finally, with comparing of these results controller, the Fuzzy-PID controller has the better performance rather than the PID one.

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Improving the Heart Disease Diagnosis by Evolutionary Algorithm of PSO and Feed Forward Neural Network

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***Abstract*—This The considerable growing of cardiovascular disease and its effects and complications as well as the high costs on society makes medical community seek for solutions to prevention, early identification and effective treatment with lower costs. Thus, valuable knowledge can be established by using artificial intelligence and data mining; the discovered knowledge makes improve the quality of service. Until now, different researches have been carried out in order to predict heart disease based on data mining methods such as classification and clustering methods; however, what has been less noticed is the exact diagnosis of disease with the lowest cost and time. In the present paper, by using feature ranking on effective factors of disease related to Cleveland Clinic Dataset (UCI) and by using Particle Swarm Optimization (PSO) ae well as Neural network Feed Forward backpropagation, 13 effective factors of it changed to 8 optimized features in terms of cost and accuracy. The assessment of selected features of classified methods also showed that PSO method along with neural networks of feed forward back-propagation has the best accurate criteria of the rate of 91.94% on these optimized.**

Keywords—Data analysis, Categorization, Artificial intelligence, PSO algorithm, Feed Fowrad back-propagation, Feature ranking

I. INTRODUCTION

Cardiovascular diseases are being to become the main cause of death in most countries of the world [1]. For example, in a country such as the United States cardiovascular diseases are considered the main cause of death. According to the reports of the America Heart Association, about 525,000 people suffer an early heart attack and about 210,000 people suffer repeatable ones, each year [2]. According to the reports of CDC1, almost more than half of the deaths in 1999, occurred before any emergency services and hospital treatments to be done on the patient [3]. Cardiovascular disease is a condition of the heart in which the patient may suffer a heart attack, angina, heart failure and so on. In the past, epidemics and infectious diseases were a major cause of human death, but today non-communicable diseases have become more dangerous factors. Figure (1) shows ten main factors have led to the deaths over the past decade [4]

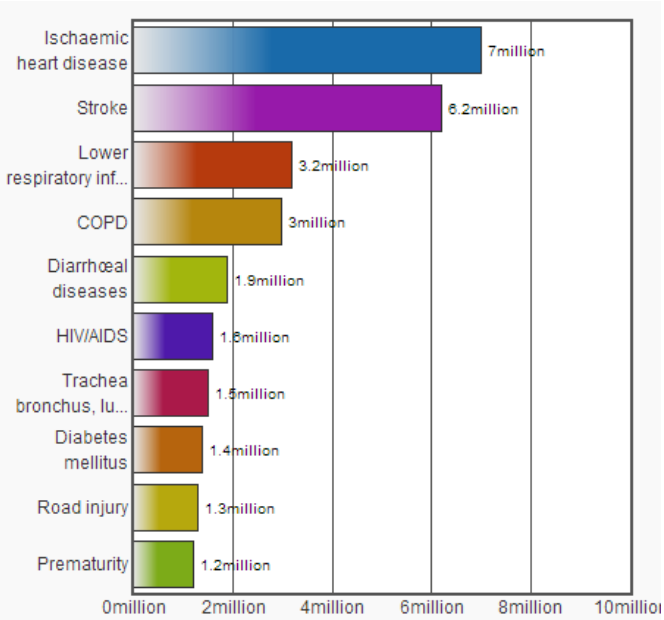


Fig. 1. The 10 leading causes of death in the world by percentage

Although the risks of infectious diseases are more immediate due to their contagion nature of them but the complications from chronic diseases such as cardiovascular disease, are more lasting, costly and debilitating, but there are ways to prevent cardiovascular disease. By applying these methods and practices the development of cardiovascular disease can be prevented or at least delayed them.

II. RELATED WORKS

There have been a large number of researches conducted on datasets of cardiovascular diseases based on data-mining methods. Prabhat Panday and Nirmal Godara have proposed the using of neural networks and the improved model of MLP in 2012 [5]. Ayda, Taha and Soroor Rashidi have proposed a model for diagnosing heart disease using neural networks methods in 2010 [6]. Jasmine Nahar, Tasadduq Imam, Yi-Ping Phoebe Chen and Kevin S Tickle have utilized from classification method to diagnose [7]. Milan Kumari and Sunila Godara have compared some data-mining methods

[1]. Center For Disease Control and Prevention

such as classification and artificial intelligence which are used to prevent heart disease [8]. Srinivas, Kavihta Rani and Goyrdhan used statistical methods (such as Naïve Bayes) in order to predict heart disease [9]. Abdullah and Rajalaxmi have proposed another model to predict heart disease by using the Random Forest Classifier method, in 2012 [10]. In 2011, Soni Ansari and Sharma have proposed the Weighted Associative Classifiers method among the Affiliation Rules to predict the disease [11]. Khemphila and Boonjing have utilized from two methods of Multi-Layer Perceptron (MLP) with Back-Propagation and classification in a combined form to predict heart disease [12]. Ramesh Subbalakshmi and Chinna Rao have used two methods Decision-making Tree and Naïve Bayes statistical methods to predict heart disease in 2011[13] .

The most common methods used by researchers for diagnosis and monitoring of cardiovascular disease are classification and clustering methods. However, what has been less into the attention so far is the investigation of the issue by several types of methods and reaching a consensus in order to diagnose heart disease with highest precision and availability in the shortest time and the lowest cost as possible. Therefore, the purpose of the present study was to select the best features with the lowest costs and shortest times and highest precisions using the PSO evolutionary algorithm. To gain this measurement Feature Ranking and then Neural Networks of Feed Forward, Back Propagation on the PSO algorithm have been proposed which the classified data were evaluated in the database by the Cross-Validation method with Fold = 10 of. In this research other classifying methods such as C4.5,Feed Forward back-propagation, SMO and MLP have been selected to learn the classifiers. The results of the evaluation indicated that using the Feed Forward back-propagation Neural Network has the highest accuracy in the factors resulting in disease .

Further in this study, dataset of the Cleveland Clinic related to the UCI database has been introduced in section III, and then the proposed method has been introduced in section IV. In section V, the evaluation results of the mentioned method have been provided and then compared with the results of other studies in section VI. Finally in section VII, the conclusion has been carried out and future works were stated .

III. FEATURES AND DATASET

Used data for conducting the data-mining actions, are usually data collected for other purposes. In field of data-mining in health, the data is mostly extracted from the client files at health centers. To conduct this research the data related to Cleveland Clinic existing in UCI machine learning repository were used. This dataset has collected the data related to 303 healthy and sick people from which 138 were sick and 165 were healthy .

This database contains 76 attributes, but all published experiments refer to using a subset of 14 of them, which 13 are related to disease factors and 1 case is related to the presence or absence of heart disease in people who underwent 13 previous tests. It must be noted that these factors are in fact the most important and most basic factors ever identified to diagnose heart attacks; therefore the investigation on these factors can be considered quite precise and important. It must also be noted that each and every one of these features can cost the patient something. Choosing features that can contribute the lowest price and shortest time along with highest precision and availability is of great importance in diagnosing a heart attack. The factors related to UCI are as the following:

In table I given features are shown along with their types.

TABLE I. 13 MAIN FEATURE FOR HEART ATTACK DIAGNOSIS

S.N	AttributeName	Description
1	Age	Age in years
2	Sex	Male=1, Female=0
3	Cp	Chest pain type
4	Trestbps	Resting Blood pressure upon hospital nadmission
5	Cholestrol	Serum Chol
6	FBS	Fasting blood sugar>120 (true=1,false=0)
7	RestingECG	Resting Electrocardiographic Results
8	Thalach	Maximum Heart Rate
9	Exang	Does the patient experience angina as a result of exercise (value 1:yes, value 0:no)
10	Old peak	ST depression indeced by exercise relative to rest
11	Slope	Slope of the peak exercise
12	Thal	Value 3: Normal, value 6: fixed defect, value 7: reversible defect
13	CA	Number of major vessels colored by fluoroscopy (value 0-3)
14	ConceptClass	Angiographic disease status

IV. PROPOSED METHOD – IMPROVEMENT IN DIAGNOSIS OF CARDIOVASCULAR DISEASES USING EVOLUTIONARY ALGORITHM OF PSO AND FF BACK PROPAGATION

In this section, the proposed solution to predict heart disease with the lowest cost and highest precision is introduced. It should be noted that the cost does not only mean the final price but it means the general price meaning testing time, availability of the given test and the risk. In order to obtain the best set, Framework of Figure 1 was used.

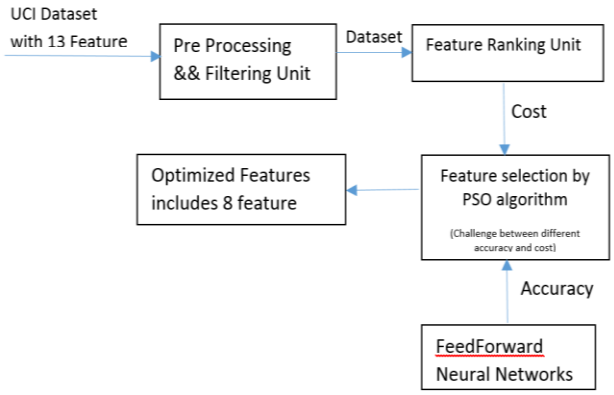


Fig. 2. Proposed Framwork for heart disease pridict

A. *Preprocessing Unit*

In the preprocessing step two main activities are performed: 1) noise-elimination and 2) determining training and testing data samples. Noise elimination of disease cases is the replacement of missing data. Noise and outliers always makes a bad influence on classifying results which is why our selected dataset (C level and Clinic data (UCI dataset) has 303 records from which 7 records are missing data which were removed in order to prevent bad impact on the results. After eliminating the noise, the training and testing data were determined. Cross Validation method with Folds=10 was used to determine the data in which data is classified into 10 equal sections and the algorithm is performed on them 10 times and each time %90 of the data are selected as training sets and %10 as testing sets randomly. From the total of the data %46 were se sick and %54 healthy.

B. *PSO Algorithm*

The PSO Algorithm or Particle Swarm Optimization is the algorithm to optimization of particles used for feature selection and their optimization. In this algorithm each subset of 13 features is considered as particles, the particles are optimized to achieve local and global optimization in the end. To achieve this optimization a fitness indicator is used to subset the features that have the highest fitness, are selected. Fitness in the case is obtained from the formula (1) where the particles are trying to achieve the best Fitness. Features or subset that have the highest Fitness are then selected.

$$\text{Fitness}=\text{Accuracy}-\text{Cost} \quad (1)$$

Feed Forward back propagation classifier has been used to achieve the accuracy which the algorithm is explain in next parts .Feature Ranking unit has been used in order to obtain the cost so that the PSO algorithm will try to choose the best causes of the disease with the lowest cost and highest accuracy. Figure 3 shows the flowchart and Figure 4 shows the Pseudo Code for the algorithm of particles/PSO.

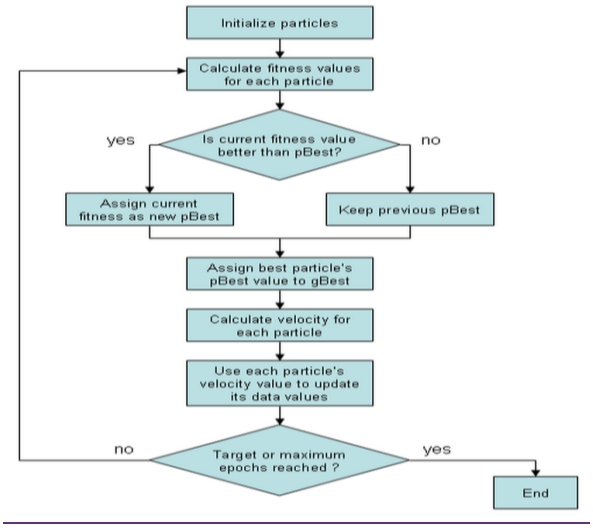


Fig. 3.Flow diagram illustrating the particle swarm optimization algorithm

```
For each particle
 {
   Initialize particle
 }
Do until maximum iterations or minimum error criteria
 {
   For each particle
   {
     Calculate Data fitness value
     If the fitness value is better than pBest
     {
       Set pBest = current fitness value
     }
     If pBest is better than gBest
     {
       Set gBest = pBest
     }
   }
   For each particle
   {
     Calculate particle Velocity
     Use gBest and Velocity to update particle Data
   }
 }
```

Fig. 4. PSO Pesudo code

C. *Feature Ranking and Feel Forward Back-Propagation Network*

As mentioned before, PSO algorithm uses feature rating or feature ranking to gain cost in the proposed method.

From the 13 mentioned features, each has its own costs. It should be noted that the cost is not too high as to obtain the proper characteristics of the 13 patients. For Feature Ranking and obtaining the costs for each feature, after consultation with doctors, the first of these features is divided into 4 divisions and a weight is also considered for them according to the costs (in terms of price, time spent on testing, the accessibility, the venture) have been attributed. In this division, some features in the category free of charge, some at least cost, average cost some categories and some other categories are costly. The cost in terms of time required for testing, the accessibility and venture. In this division, features are put in the Free of Charge, Least Cost, Average Cost and Costly categories. The costs are in terms of required time for testing, the accessibility, venture and price.

The Feature Ranking is shown in table II and figure 5

TABLE II. FEATURE RANKING

free of charge features	at least cost features	average cost features	Costly features
Age	Chol	Slope	Thal
Sex	fbs	Oldpeak	CA
	trestbps	Thalach	
	restECG	Exang	
		CP	

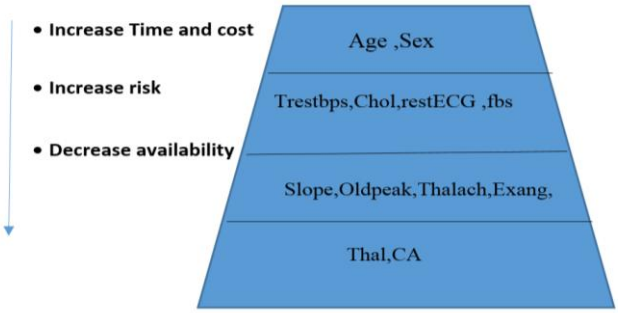


Fig. 5. Feature ranking pyramid

D. Feedforward Back-propagation (FFBP)

The Feedforward Backpropagation is one of the most studied neural network by the scientific community and the most common used in many medical applications. The feedforward, back-propagation architecture was developed in the early 1970's by several independent sources (Werbor; Parker; Rumelhart, Hinton and Williams) [14]. This independent co-development was the result of a proliferation of articles and talks at various conferences which stimulated the entire industry. Currently, this synergistically developed back-propagation architecture is the most popular, effective, and easy to earn model for complex, multi-layered networks[15]

This network is used more than all other combined. It is used in many different types of applications. This architecture has spawned a large class of network types with many different topologies and training methods. Its greatest strength is in non-linear solutions to ill-defined problems [16,17].

The typical back-propagation network has an input layer, an output layer, and at least one hidden layer. There is no theoretical limit on the number of hidden layers but typically there is just one or two [18]. Some work has been done which indicates that a minimum of four layers (three hidden layers plus an output layer) are required to solve problems of any complexity. Each layer is fully connected to the succeeding layer, as shown in Figure 1[19].

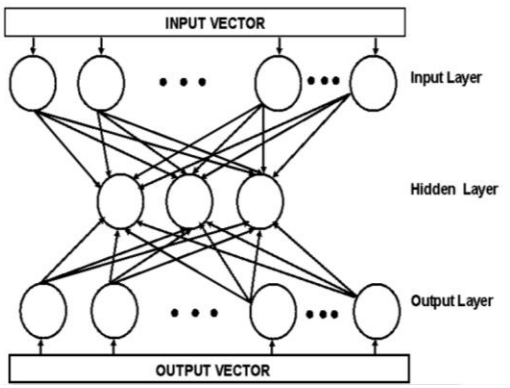


Fig. 6. An example of Feedforward Backpropagation Network

The in and out layers indicate the flow of information during recall. Recall is the process of putting input data into a trained network and receiving the answer. Back- propagation is not used during recall, but only when the network is learning a training set. The number of layers and the number of processing element per layer are important decisions. These parameters to a feedforward, back -propagation topology are also the most ethereal. They are the art of the network designer. There is no quantifiable, best answer to the layout of the network for any particular application. There are only general rules picked up over time and followed by most researchers and engineers applying this architecture of their problems[20][21]. Typical feedforward, back-propagation applications include speech synthesis from text, robot arms, evaluation of bank loans, image processing, knowledge representation, forecasting and prediction, and multi-target tracking. Each month more backpropagation solutions are announced in the trade journals[22].

After pre-processing and Feature Ranking, minimizing the features and selecting the best attributes with lowest costs and highest precision is achieved by evolutionary algorithm of PSO. As noted above, PSO algorithm is to calculate costs through Feature Ranking and to accurately calculate them the Feed Forward Back Propagation Network is used .

In this step of the proposed method, choosing the characteristic is from a subset of data. The number of referrals is calculated by taking 13 effective factors in heart disease and using the 2^n formula which here from the 8192 subsets the best features are chosen using evolutionary algorithm of PSO. The purpose of this step is to investigate all subsets of the database with the data given by two healthy and sick labels in order to find the highest accuracy and lowest cost. Then, for each subset of data, a classifier is learned (Feed Forward back propagation Network) and the diagnosis of the disease is done by examining and voting between the categories. In order to find the best feature or in the Feature Selection, ranked features listed in the previous step and the accuracy of the Feed Forward back propagation Classifier are mixed by PSO algorithm and the most optimized set of particles in terms of time, accessibility, venture and precision is found.

Finally, the selected best set through PSO algorithm, has the following features:

Age, Sex, Chol, fbs, restECG, Exang, Old peak, slope

These 8 features selected by the PSO algorithm are the best set in terms of costs and highest accuracy, in other words, the most effective tests with high accuracy.

V. EVALUATION CRITERIA AND EVALUATION THE PROPOSED METHOD

To assess the effectiveness of PSO algorithm (where 13 features choices altered to 8 optimize features) accuracy, recall and precision criteria of Feed Forward back-propagation was used. These criteria are calculated using the results of applying this method on test data. In these relations ((2),(3) and (4) formula) TP means the number of samples that are healthy and properly diagnosed. FP indicates the number of samples that

are healthy and have been diagnosed wrongly. FN indicates the number of samples that were sick but healthy wrongly diagnosed. TN contains a number of examples that have been patient and the patient is properly diagnosed.

$$\text{Accuracy} = (TP+TN)/(TP+TN+FP+FN) \quad (2)$$

$$\text{Recall} = TP/(TP+FN) \quad (3)$$

$$\text{Precision} = TP/(TP+FP) \quad (4)$$

In this section, the proposed method is evaluated using the Cleveland dataset introduced in section III. In the above-mentioned dataset 165 samples for healthy people and 138 other data have been announced for people with heart disease. In this method, the sample data for training and testing are determined. The method of Cross Validation with Fold = 10 was used to do so. Finally, evaluation of the methods applied indicated the Feed Forward Neural Network classifying approach resulted in standard precision, recalling and accuracy and error rates. The results of this assessment can be seen in Table III. It is also observed that the method has been able to significantly improve accuracy.

TABLE III. ASSESSMENT OF DIFFERENT CLASSIFICATION METHODS

	SMO	C4.5	MLP	FFBP
Accuracy	0.764	0.756	0.687	0.9194
Recall	0.764	0.757	0.686	0.930
Precision	0.764	0.756	0.686	0.919

On the other hand, considering the feature selection and measurement of 8 factors from 13 factors, reducing the cost and time improved the diagnosis which resulted in improving the acceleration of test, accessibility and venture. Another significant point about the selected feature is that here, unlike other methods, the values of accuracy and recall measures increase together and one will not be another's victim. Usually most of the classification methods are accurate or have a good recalling and to raise a criterion, they sacrifice another[23]. But this method along with Feature Selection is free of this error.

VI. COMPARING WITH SIMILAR WORKS

In conducted investigations, many studies have been done to increase the accuracy of prediction of heart disease. As mentioned in section III, this study has been evaluated using the specific data information from the Cleveland Clinic. In this section the results of other studies on the same data are compared with available survey data.

So far, the three approaches of neural networks, clustering and classification are used in the diagnosis of heart disease.

In the Related Works section, articles and researches with the UCI dataset activities were identified. In this section the accuracy of each along with comparing those with results of this research are presented in Table IV

As shown in Table IV, from the various methods, proposed method (PSO with FFBP + Feature Ranking), not only reduces the cost (13 features to 8 optimized features) but by far has had the greatest amount of scale accuracy. This paper has been able to increase accuracy standards by %2.38 by combining feature selection approach and artificial intelligence algorithms using particles swarm optimization(PSO) .

TABLE IV. TABLE STYLES

Authors	Algorithm	features	accuracy	feature ranking
Panday and Godara [5], 2012	Improve MLP	13	%82.8	No
Subbalakshmi., et al [13] ,2011	Naïve bayes	15	%81	No
Nahar., et al [6], 2012	SMO	13	%٨٦	No
Kumari and Godara[7],٢٠١١	SVM	13	%٨٤,١٢	No
Srinivas., et al [8], 2010	ODANB	13	%٨٣,٧٠	No
El-Rashidy., et al [9], 2012	Fuzzy clustering	13	%٦٣,١٥	No
Abdullah and Rajalaxmi [10], 2012	Decision tree	13	%٦٣,٣٣	No
Soni [11] ., et al, 2011	Association rules	13	%٨١,٥١	No
Khemphila و Boonjing [12],٢٠١١	Back-propagation MLP	8	%٨٩,٥٦	Yes
Our work	PSO+feedforward back-propagation	8	%٩١,٩٤	Yes

VII. CONCLUSION AND FUTURE WORKS

Diagnosis of heart disease by using machine learning methods is one of the challenges in the health field. In this research the work has been provided on a particular dataset using classification and feature selection approach. In the mentioned method, first, instruction set is divided into two groups of healthy and sick people, then in the second stage 8192 subsets were extracted from the total features with clear cost for any subset (cost gain from feature ranking) which in the third stage by PSO algorithm for all the subsets a learning classifier (feed forward back-propagation neural network) is given for all subsets to find best subset with the highest accuracy and accessibility and the lowest cost and time. We Four learning classifier methods are used in this approach, SMO, C4.5, MLP and FF back-propagation that the assessments results carried out in Section V of this study suggest that the use of Feed Forward Back -Propagation Neural Network and feature selection in PSO algorithm is more efficient. With a choice best subset includes eight characteristics of age, sex, exercise tests (Slope, Oldpeak, and Exang), blood pressure and cholesterol by the PSO algorithm, accuracy have been improved by %2.38 and the accuracy has reached 91.94%. Also, the costs (including price, time, and

accessibility) have reduced due to considering Feature Ranking and Feature Selection.

As a future work in this area, it is recommended that in addition to Feature Selection being based on accuracy and costs (in terms of accessibility, venture, testing time and price), the features are selected in such a way that the order of choosing or in fact, the tests are mentioned as well.

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Memetic algorithm based on genetic algorithm and improved cuckoo search algorithm for Dynamic Environment

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***Abstract*— In Many real-world optimization problems, optimization goals, the problem instances or some restrictions may change over time. One of the famous problems in the dynamic environments optimization is moving peaks benchmark function or the moving maximum that behavior is similar to dynamic problems in real-world. In this paper, Memetics algorithm based on genetic algorithm and improved cuckoo search to optimize in dynamic environments is proposed. In the proposed method, we combining genetic algorithm and improved cuckoo search algorithm for dynamic environment has been tested in the moving peaks benchmark as a popular standard dynamic environment with different frequencies and multiple peaks in environment and compared with other algorithms. Experiment results shown that algorithm performance is improved.**

Keywords—component; Memetic algorithm, dynamic environment, cuckoo search, moving peaks.

I. INTRODUCTION

Considering the fact that the majority of existing problems in the real world are dynamic, that is the existing change over time. As result in these environments, algorithms are required, which in addition to finding optimum, they could follow them efficiently. So, in these environments, algorithms will be efficient, that have the lowest mean error for the best solution found at any moment of time. So far, different methods have been presented for solving dynamic problems using evolutionary computing techniques and swarm intelligence [1-3]. Two main problems of evolutionary computing techniques which function as barrier in using these methods directly for optimizing in these environments are outdated memory and diversity loss. When the environment changes, the solutions obtained in the memory are not valid any longer and they should either be forgotten or should be assessed again. Also, since the majority of evolutionary computing methods and swarm intelligence are converged at one point due to their features, thus, the population diversity is lost and in the case of change in the environment, convergence at new optimum point, if possible it will take too much time. One of the methods of maintaining diversity is the diversity maintenance at the time of execution approach. In this group of approaches, the population convergence is always prevented and given this work, it is expected that the dispersed population to be able to be adapted in a more simple way with the environmental changes. Given the existing attractions in the presented method in this group, steady concentration on creating diversity in the population members Will makes the optimizing process slower [4, 5].

Up to now, the combinative evolutionary and swarm intelligence methods have been used for optimizing in dynamic environments. Noroozi et al proposed an algorithm based on DE and the concept of Cellular PSO and called CellularDE[6]. Hashemi and Meybodi combined particle swarm optimization and Cellular Automata (CA) into an algorithm, called Cellular PSO. The search space has been partitioned into equally sized cells using cellular automata. Then, particles of the swarm are allocated to different cells according to their positions in the search space[7].Kamosi et al. presented multi-swarm algorithm for dynamic environments, which consists of a parent and child swarms. Parent swarm to explore the search space and a varying number of child swarms to exploit promising areas found by the parent swarm. this method called mPSO[8].Genetic algorithm is an inspiration of Davin's evolution theory and is based on the survival of the best or natural selection. Although some studies or actions have been conducted in the field of evolutions modeling in the biologic systems in 1960 big a biologist, Fraser, genetic algorithm for engineering application in its todays form was suggested by John Holland, a computer science expert in Michigan university in 1975 [9, 10].

Cuckoo optimizing algorithm is one of the new optimizing algorithms. Cuckoo optimizing algorithm is based on cuckoo ovule laying and the life of this bird. This clever bird uses the strategies of other birds around own impel to participate in its own survival and survives with the least attempt [11, 12].

Moving peaks problem (MPB) introduced by Brank was in fact an artificial producer dynamic environment. MPB is a dynamic environment with a D-dimensional landscape consisting of N peaks, where the height, the width and the position of each peak is changed slightly every the time a

change occurs in the environment Also, the frequency and the intensity of environment changes in adjustable[5, 13]. In this paper, Memetics algorithm based on genetic algorithm and improved cuckoo search to optimize in dynamic environments is proposed.

The rest of the paper is organized as follows. In Section 2, related works on dynamic environments are reviewed. Improved Cuckoo Search algorithm is presented in section 3. In section 4, the proposed algorithm is presented. In Section 5, presents the experimental results of the proposed algorithm along with comparison with alternative approaches from the literature. Finally section 6 includes the conclusion of the present paper.

II. EASE OF USE

In Many real-world optimization problems, optimization goals, the problem instances or some restrictions may change over time. In this case the optimal solution of the problem may change as well. If each of these unclear events are considered in the process of optimizing, this problem is called dynamic.

There is a benchmark function known as moving peaks for dynamic environments[3]. In this benchmark function, the peaks vary steadily over time. This function was recommended with the aim of creating connection between high complexity and the difficulty of perceiving real world problems. Problem in a multi-dimensional environment consists of several peaks and whenever a change occurs in an environment, the location, height and the width of the peaks changes slightly. This problem is explained here. The benchmark function of moving peaks consists of m peaks in space n along with parameters with real value. The fitness of the environment is defined equal to the maximum amount among peak functions and this problem could be formulated as following:

$$F(\vec{x},t) = \max\left(B(\vec{x}), \max_{i=1\ldots m} P(\vec{x}, h_i(t), w_i(t), \vec{p}_i(t))\right) \quad (1)$$

Where B($\vec{x}$) is the base amount of the environment which is independent of time and P is the function that defines peak and each one of the m peaks have the time variable parameters of height (h), width (w) and position (p). In every ΔE assessment of height, width and position or place of each peak varies. The height and width of all peaks varies through adding one random variable of Gaussian to it and the location of each of the peaks moves along the V vector and length S. So, the parameter S controls the severity rate of changes, and ΔE determines the frequency of the changes.

$$\begin{aligned} \sigma &\in N(0,1) \\ h_i(t) &= h_i(t-1) + height_{severity}. \\ w_i(t) &= w_i(t-1) + width_{severity}. \\ \vec{p}_i(t) &= \vec{p}_i(t-1) + \vec{v}_i(t) \end{aligned} \quad (2)$$

This equation could be created considering the previous changes in it where vector V is the position peak changes toward previous changes or it could be created randomly which at results in the random change of peaks and has not been dependent on any kind of previous changes [14].Please do not write or print outside of the column parameters. Margins are 3.5 cm on the sides, 2.5 on the top, and 4.5 on the bottom, Gutter is 0 (zero) cm and multiple pages is normal.

III. IMPROVED CUCKOO SEARCH

Cuckoo optimization algorithm is one of the newest and strongest evolutionary optimizing algorithms [12]. CS started with the primary population similar to other evolutionary algorithms. A population of cuckoos is created and these populations of cuckoos have some eggs that they should put the eggs in the nests of some hosts birds.

Each egg in a nest introduces a solution and a cuckoo egg introduces a new solution. The Goal is to apply the new and better potential solutions which are to replace the solutions in the nests which are not satisfactorily good. In the simplest state, each nest has one egg. This algorithm could be developed into more complicated states in each nest with several eggs which introduce more solutions. CS is based on three ideal principles. Each cuckoo lays an egg in each period and stores it in a random selective nest. The best nests with high quality eggs are transferred to the next position. The number of accessible host nests is fixed, and a host can discover an outside egg with the probability of P $\in$ [0, 1]. In this case, the host bird can either throw the egg away or leave the nest in order to build a fully new nest in a new place.

For the purpose of simplification, the last hypothesis could be approximately estimated by a fraction of Pa from n nests which are replaced by new nests. Through new random solutions for an optimizing problem, the quality or fitness of a solution could be simply proportionate to target function. Other forms of fitness could be defined in a similar way through the fitness function in genetic algorithms. Based on above mentioned rules, the basic steps of cuckoo search algorithm could be summarized as following:

Pa parameter and α defined to help the algorithm for finding local and global improved solutions correspondingly. Pa and α parameters are very important in reinforcing the solution vectors and could be potentially used in adjusting the convergence rate of the algorithm. Cuckoo search algorithm assigns fixed amounts for Pa and α parameters. If the value of Pa is small and α is large, the performance of the algorithm will be poor and results in significant increase in the number of iteration. If the value of pa is large and value of α is small, the speed of convergence is high but it may not be capable of searching the best solution. The key difference between the ICS and CS is in the way of adjusting α and Pa. The values of Pa and α are dynamically changed with the number of iterations and expressed in Equations 2-4.

```
begin
  Objective function f(x),  x = (x_1,.....,x_d)^T
  Generate initial population of
     n host nests x_i (i = 1,2,...,n)
  While (t < MaxGeneration) or (stop criterion)
    Get a cuckoo randomly by Lévy flights
     evaluate its quality / fitness F_i
    Choose a nest among n (say, j) randomly
    if (F_i > F_j),
       replace j by the new solution;
    end if
    A fraction (p_a) of worse nests
       are abandoned and new ones are built;
    Keep the best solutions
       (or nests with quality solutions);
    Rank the solutions and find the current best
  end while
  Postprocess results and visualization
end
```

$$P_a(gn) = P_{amax} - \frac{gn}{NI}\left(P_{amax} - P_{amin}\right) \quad (3)$$

$$\alpha(gn) = \alpha_{max}\exp(c.gn) \quad (4)$$

$$c = \frac{1}{NI} Ln\left(\frac{\alpha_{min}}{\alpha_{max}}\right) \quad (5)$$

Where NI and gn are the number of total iterations and the current iteration, respectively [12, 15].

IV. The Proposed Algorithm

In this article, the combination of genetic and improved cuckoo search algorithms has been presented as a mimetic algorithm for optimization in dynamic environments. Genetic algorithm like other evolutionary algorithms in the first steps of performing algorithms identifies of the problem state space where general and local optimal are located but in the rest of the route toward the global optimal move too slowly.

Another defect which these algorithms face is the instability of them. That is, the quality of the solutions from different execution of the algorithm may be too different and unreliable. Among the methods presented for solving meta-heuristic problems, the combinative strategy is importance.

Combinative strategy results from applying different techniques in the problem solving process. Memetic algorithms are among the most famous members of this family which is results from connecting genetic algorithms with a local searching heuristic like hill climbing and in these algorithms, a local search algorithm improves fitness after genetic operators (imitation) and then population evaluation and replacement is conducted. The method applied for performing a Memetic algorithm and local searching depends on the type of the problem and the results will be very different but in many problems, especially problems with discrete environment require a new local search method. Different types of Memetic algorithms have been introduced of which Memetic algorithms based on Lamarckian and Baldwinian theories could be referred to[16].

To maintain diversity, the diversity maintenance strategy throughout the run in a way that in each run to 10 percent of population remains unchanged And the rest are replaced in the primary population if they have high fitness, has been used. The genetic algorithm starts global searching in the environment using the primary population, then after the mutation stage, a local searching around the chromosomes is conducted using improved cuckoo search algorithm that its parameters have been adjusted for local searching, then in the next stage, chromosomes with higher fitness are selected and these stages continue until iterations of genetic algorithm is completed. This method has four important parameters that Pa and α is for improved cuckoo search algorithm, two other parameters is crossover and mutation rate for genetic algorithm. Adjusting these parameters has a large impact on performance of algorithm.

The use of improved cuckoo search algorithm in genetic algorithm raises the accuracy and speed of genetic algorithm. Table 1 demonstrates the parameters of genetic and improved cuckoo search algorithm [12, 17]. Figure 1 shows pseudocode of proposed algorithm.

TABLE1. Improvedcuckoo search and genetic algorithm parameters

	parameters	value
Improved Cuckoo Search	Population size	6
	Pa	1
	α	0.05
Genetic	Population size	25
	Crossover rate	0.8
	Mutation rate	0.3

Function *CuckooMem*

Initialize *population*

Evaluation *population*

While *population size do*

Crossover

Mutation

Local search for each individual (using Improved Cuckoo Search)

Selection

End while

Population = New pop

Best fitness=max (Evaluation population)

Local Search *(individual)*

Generated *neighbor from individual using Improved Cuckoo Search*

Compare *each individual with neighbors*

For *size of neighbors*

If *fitness (neighbor (i))>fitness (individual)*

Lamark or Baldvin method {(Replace best by neighbor and fitness) or (Replace fitness of best neighbor)}

End if

End for

Return *new Individual*

FIGURE1. pseudocode of proposed algorithm

V. RESULTS AND DISCUSSIONS

These experiments aim to study and compare the Apso, mPso, CPSOL, Hmso, mQSO Multi-swarm PSOCDEPSO and the proposed algorithm in dynamic environments using the moving peaks benchmark[8, 18-20]. Since in dynamic environments the best solution founds is not a useful criterion for assessment and reporting, the criteria of CURRENT ERROR and OFFLINE ERROR have been used for comparing and concluding. Table 2 shows the standard adjustments for moving peaks benchmark.

TABLE 2. Standard adjustments for moving peaks benchmark

Amount	Parameter
10	Number of peaks (m)
7.0	Height severity
1.0	Width severity
cone	Peak shape
5	Number of dimensions (D)
[30.0 70.0]	Height range (H)
[1.0 12.0]	Width range (W)
50.0	Standard height (I)
[0.0 100.0]	Search space range (A)
5000	Frequency of change (f)
1.0	Shift severity (s)
[0.0,1.0]	Correlation coefficient (λ)

In the experiments the size of the population was assigned fixed 6. Tables 3 to 6 obtained based on averaging from 10 different runs and the standard error criterion has been computed and it shows the algorithms efficiency and approves their results. The less size of this index, the algorithm will be better in terms of adapting to the environment. Figure 2 shown offline errors for standard adjustments infrequency of 5000.

TABLE 3: Offline error along with the standard error of different algorithms based on the number of different peaks in frequency of 500

mQSO(5,5q)	Hmso	CPSOL	Multi-swarm PSO	AmSO	APSO	CDEPSO	Proposed Algorithm	Peaks
33.67±3.42	8.53±0.49	8.29±0.55	5.46±0.30	3.02±0.32	4.81±0.14	3.62±0.03	**2.5373±0.30**	1
11.91±0.76	7.40±0.31	6.29±0.21	5.48±0.19	5.77±0.56	4.95±0.11	6.07±0.02	**2.8860±0.20**	5
9.62±0.34	7.56±0.27	5.45±0.17	5.95±0.09	5.37±0.42	5.16±0.11	6.57±0.01	**3.6733±0.23**	10
9.07±0.25	7.81±0.20	5.47±0.19	6.45±0.16	6.82±0.34	5.81±0.08	6.88±0.02	**3.4365±0.30**	20
8.80±0.21	8.33±0.18	5.59±0.12	6.60±0.14	7.10±0.39	6.03±0.07	7.50±0.03	**3.1970±0.27**	30
-	8.45±0.18	5.63±0.16	6.85±0.13	-	-	7.61±0.01	**3.8424±0.25**	40
8.72±0.20	8.83±0.17	5.74±0.11	7.04±0.10	7.57±0.32	5.95±0.06	7.14±0.02	**4.1218±0.24**	50
8.54±0.16	8.85±0.16	5.45±0.07	8.54±0.16	7.34±0.31	6.08±0.06	7.12±0.01	**4.6439±0.37**	100
8.19±0.17	8.85±0.16	5.79±0.10	8.19±0.17	7.48±0.19	6.20±0.04	7.06±0.01	**5.5277±0.40**	200

TABLE 4. Offline error along with standard error of different algorithms based on the number of different peaks in frequency of 1000

mQSO(5,5q)	Hmso	CPSOL	Multi-swarm PSO	AmSO	APO	CDEPSO	Proposed Algorithm	Peaks
18.60±1.63	4.46±0.26	4.74±0.32	2.90±0.18	2.33±0.31	2.72±0.04	**1.98±0.01**	2.0310±0.22	1
6.56±0.38	4.27±0.08	3.95±0.21	3.35±0.18	2.90±0.32	2.99±0.09	3.41±0.00	**2.7231±0.18**	5
5.71±0.22	4.61±0.07	3.20±0.20	3.94±0.08	4.56±0.40	3.87±0.08	4.00±0.00	**2.5770±0.19**	10
5.85±0.15	4.66±0.12	3.52±0.17	4.33±0.12	5.36±0.47	4.13±0.06	4.18±0.01	**3.3767±0.12**	20
5.81±0.15	4.83±0.09	3.96±0.12	4.41±0.11	5.20±0.38	4.12±0.04	4.85±0.01	**3.8066±0.23**	30
-	4.82±0.09	4.21±0.17	4.52±0.09	-	-	4.90±0.00	**3.8404±0.32**	40
5.87±0.13	4.96±0.03	3.98±0.11	4.57±0.08	6.06±0.14	4.11±0.03	4.58±0.00	**3.9276±0.17**	50
5.83±0.13	5.14±0.08	**4.13±0.12**	4.77±0.08	4.77±0.45	4.26±0.04	4.34±0.01	4.2263±0.34	100
5.54±0.11	5.25±0.08	**4.15±0.01**	4.76±0.07	5.75±0.26	4.21±0.02	4.47±0.01	4.4618±0.30	200

TABLE 5. Offline error along with standard error of different algorithms based on the number of different peaks in frequency of 5000

mQSO(5,5q)	FMSO	Hmso	CPSOL	Multi-swarm PSO	CDEPSO	Proposed Algorithm	Peaks
0.34±3.81	0.11±3.44	0.87±0.05	1.02±0.14	0.56±0.04	**0.41 ±0.00**	0.7612±0.02	1
0.14±1.90	0.07±2.94	1.18±0.04	**0.99±0.15**	1.06±0.06	0.97 ± 0.00	1.0897±0.01	5
0.10±1.80	0.06±3.11	1.42±0.04	1.75±0.10	1.51±0.04	1.22 ± 0.00	**1.1742±0.01**	10
0.12±2.96	0.06±3.36	1.50±0.06	1.93±0.11	1.89±0.04	1.54 ± 0.00	**1.2644±0.03**	20
0.12±3.36	0.05±3.28	1.65±0.04	2.28±0.10	2.03±0.06	2.62 ± 0.00	**1.3017±0.2**	30
0.14±3.70	0.04±3.26	1.65±0.05	2.62±0.09	2.04±0.06	2.74 ± 0.00	**1.3209±0.1**	40
0.14±3.76	0.05±3.22	1.66±0.02	2.74±0.10	2.08±0.02	2.20 ± 0.00	**1.3508±0.4**	50
0.14±4.12	0.04±3.06	1.68±0.03	2.84±0.12	2.14±0.02	1.54 ± 0.00	**1.3928±0.4**	100
0.13±4.09	0.03±2.84	1.71±0.02	2.69±0.08	2.11±0.02	2.11 ± 0.00	**1.4230±0.5**	200

TABLE 6. Offline error along with standard error of different algorithms based on the number of different peaks in frequency of 10000

mQSO(5,5q)	Multi-swarm PSO	AmSO	APSO	Proposed Algorithm	Peaks
1.90±0.18	0.27±0.02	**0.19±0.02**	0.25±0.01	0.3781±0. 1	1
1.03±0.06	0.70±0.10	**0.45±0.04**	0.57±0.03	0.5871±0. 1	5
1.10±0.07	0.97±0.04	0.76±0.06	0.82±0.02	**0.6500±0. 1**	10
1.84±0.08	1.34±0.08	1.28±0.12	1.23±0.02	**0.5685±0. 2**	20
2.00±0.09	1.43±0.05	1.78±0.09	1.39±0.02	**0.7857±0. 1**	30
-	1.47±0.06	-	-	**0.9657±0. 2**	40
1.99±0.07	1.47±0.04	1.55±0.08	1.46±0.01	**1.1897±0. 3**	50
1.85±0.05	0.03±1.50	1.89±0.14	1.38±0.01	**1.2219±0. 3**	100
1.71±0.04	0.02±1.48	2.52±0.10	**1.36±0.01**	1.4310±0. 4	200

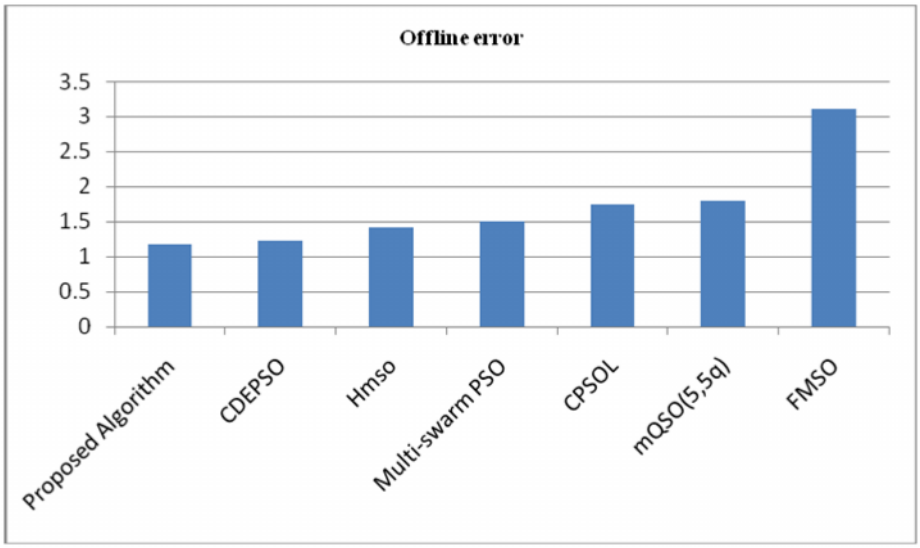


Figure 2. Offline errors for standard adjustments in frequency of 5000

VI. CONCLUSION

In this article a new Memetic algorithm for optimizing based on the combination of two algorithms, that is, genetic and cuckoo search is suggested. Genetic algorithm has ability to fast global search in search space but it is sluggish for local search because improved cuckoo search has been added. Improved Cuckoo search has very fast convergence to local optimum. The algorithm suggested consists of increasing the speed and accuracy of convergence compared to Apso, mPso, CPSOL, Hmso, mQSO Multi-swarm PSOCDEPSO, this algorithm has shown an acceptable efficiency, however, it is still possible to raise the convergence speed. Through using the methods such as search space partitioning for keeping diversity and comparative algorithms, we can increase the speed of convergence.

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An Extension of multinomial choice Model for Customer Purchase Behavior Analysis

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***Abstract*—nowadays customers with various preferences and needs are interested in online shopping but companies with variety of services and products have limited space to present their products in internet pages. So choosing the order of showing products to customers is one of the difficult challenges in e-commerce websites. Although several successful models to analyze customers' behavior have been proposed, most of them have not paid attention to purchase variety, time between purchases and primacy and recency between different purchase categories. In this paper a new hybrid method based on hidden Markov model and multinomial choice model is proposed to analyze customer choice behavior. To justify the proposed method we applied it on the retail storedata set.**

Keywords— Customer Relationship Management, Customer choice model, Hidden Markov Model.

I. INTRODUCTION

Nowadays customers with various preferences and needs are interested in online shopping but Companies with variety of services and products have limited space to present their products in internet pages. So choosing the order of showing products to customers is one of the difficult challenges in e-commerce websites. Companies should know what customers think, need and way of serving them to present the best strategy [1].To meet these goals firms needto track their customers' behavior over time byapplying customer relationship management (CRM) [2]. CRM refers as set of processes that build business strategies to make a long-term and profitable relationship with special customers [3].To build this relationship we can design longitudinal modelof customer's choice behavior and increase customer value [2]. One of the important part of customer behavior analysis is customerchoice modeling.

Choice modeling has been an important part of marketing research over the past decades [4]. A firm can Improve customer acquisition, customer loyalty, competitiveness and sales by predicting customer behavior [5]. By analyzing customer choice,the researcher can obtain better view of customer behavior [2].Reference [2] Divides choices in CRM context to 2 part. 1. Firm's choices (which customers are important for firm, when and with which products or services they should serve their customers); 2. Customers' choices (which products or services, when and where to buy). Customer choice modeling is predicting which customer will buy which product using customer features [1].

There are several model for customer choice modeling. Discrete choice models means selecting a certain product through several items andthat is very important in purchasing decision [6]. Oneof the discrete choice model that proposed for customer purchase behavior modeling isMultinomial choice model [4].But this choice model is limited in order to analyze customer behavior over time. It calculates one accumulative pattern from customerpurchase since first transaction until now. But customerpurchase pattern is not same in different timeperiods.To overcome this limitation in thispaper we proposed a new methodbased on combination of hidden Markov model (HMM) and multinomial distribution to sectional analysis of customer purchase behavior. We applied HMM to show primacy and recency of customer purchase and multinomial distribution to determine product category purchase probability. We justified our model by using a retail store data set and results show our model outperform multinomial choice model.

This paper is organized as follows. Section II presents a review of literature in choice model and Hidden Markov model. In section III we introduce our proposed method for choice model using HMM. Our experimental results on retail store data set and evaluation metrics are illustrated in section IV and our conclusion and further research are presented in section V.

II. LITERATURE REVIEW

Since our proposed method is in probabilistic and statistical models that shows customer behavior over time, at first we review relativemodels ofcustomer behavior modeling and analysis in CRM context. Then we review application of HMM in CRM context for various purposes and for different industries.

One of the powerful model for customer behavior analysis is Pareto/NBD [7]. Many researcher have improved this model for various purposes [8, 9]. Reference [8] improved Pareto/NBD model by combination with Gamma-Gamma model for customer segmentation purpose and reference [9] is a powerful model to predict customer lifetime value (CLV) by combination of HMM and Pareto/NBD model. So HMM is

very powerful in customer behavior modeling over time.Pareto/NBD model just focus on thenumber of purchase but our model pays attention to which product category. It is one of our model differences in comparison to pareto/NBD model. So firm can get better information about their customers'purchase behavior.

Anotherfamous model of customer choice modeling is multinomial logit model [11, 12]. Reference[11] solve assortment problem by a mixture of multinomial logit model to obtain upper bounds on the optimal expected revenue. Reference [12] apply multinomial logit model to clustering customer which clusters are homogenous in term of customer product choice. Another model is conditional logit model. Reference [13] Apply conditional logit model to build a multiple discrete choice model to analyze the subscription behavior of the Korean mobile telephony market.These two logit models have 'independence of irrelevant alternatives (IIA)' property [14]. This property may not be suitable in some marketing application [4].Logit models don't pay attention to purchase sequence,primacy and recency between purchases. They just suppose external variables to analysis customer behavior. But our proposed method models customer behavior using transactional data. Although our model applies simple data comparison to logit models, but we should consider information gathering in logit models is not simple and many customers are sensitive about their personal information. This action is unlike CRM goals. So our contribution is our model is nonintrusive and simpler than logit models, because our model apply just transactional data and each company has this data in its data bases.

There are other way for customer choice modeling. Reference [15]Proposed a new approach for brand choice modeling by probabilistic neural network and data preprocessing,reference [1] proposed ensembles methods for predicting customer choice (bagging and boosting). Another famous model applied in customer choice context isMultinomial choice model [4]. Multinomial choice model calculates one accumulative pattern from customers purchase since first transaction until now. But Customers purchase pattern is not same in different time periods.In this paper we propose a new method for sectional analysis of customer purchase behavior and we show our model is outperform multinomial choice model.

Markov chain and HMM have strong theory and they have been used in various CRM and marketing context in recent years. Markov chain has been used in fields such as direct marketing [16]; customer loyalty [17, 18]; CLV measurement [19,20,21] and market share analysis [22]. As we said before HMM is powerful model too and has been used indifferent CRM fields such as CLV measurement [10, 23]; modeling firm and customer relationship [24]; customer requirement analysis [25]; customer loyalty [26] andpredicting customer migration pattern [27]. HMM has been used in various industries for different purpose such as retail industry [10] and alumni gift giving data [24].In this paper we apply HMM for customer choice model and we show it outperform multinomial choice model.

III. PROPOSED MODEL

Since our method is a hybrid method based on HMM and multinomial choice model, first we illustrate the fundamentals of Markov chain, HMM and multinomial choice model then we introduce our method.

A. Markov Chain

Markov chain is powerful model that has been applied in various research. Markov chain is a set of random variables that have the following conditions [28]:

S_t: independent and discrete random variables and they are finite or infinite and countable. The index space is infinite and countable. $S_t=i$ means the process is in state i at time t. when the process is in state i, p_{ij} is probability from state i to state j. random process (1) is known as Markov chain.

$$p\{S_{t+1}=j|S_t=i,S_{t-1}=i_{n-1},\dots,S_1=i_1,S_0=i_0\}=p_{ij} \quad (1)$$

$$p_{ij}\geq 0, \qquad i,j\geq 0,\sum_{j=0}^{\infty}p_{ij}=1\,,i=0,1,\dots$$

The conditional probability distribution ina process at the next step (S_{t+1}) by known all past states$(S_{t-1}, \dots , S_0)$ and present state S_t is independence from past states and depends only on present state. This property is known as a Markov property. Suppose p is first order transition probability. P is like (2).

$$p=\begin{Vmatrix} p_{00}p_{01}p_{02}\cdots \\ p_{10}p_{11}p_{02}\cdots \\ \vdots \\ p_{i0}p_{i1}p_{i2}\cdots \\ \vdots \end{Vmatrix} \quad (2)$$

Where p_{01} is the probability that the individual is in state 0 at time t and in state 1 at time $t+1$.

As we said before Markov chain has been used a lot in marketing and CRM context especially in customer lifetime value measurement [29]. Reference [30] is one of the first study on the application of Markov chain in marketing context.

B. Hidden Markov Model

Another important stochastic model is HMM. The Fig. 1 shows the general architecture of HMM[28].As Fig. 1 shows$S_t$is a random variable thatshows hidden state at time t and $O_t$is a random variable that shows observation at time t. oneHMM can be established by determining the following parameters. 1.The initial state distribution, the transition matrix and the emission matrix [31].

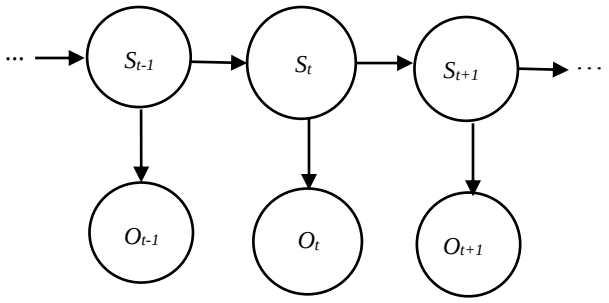


Fig. 1. HMM structure

- The Initial state distribution: Equation (3) shows that initial state probability isπ_i.

$$\pi = \{\pi_i\} \quad , \pi_i = p\{S_1 = i\} \tag{3}$$

- The state transition matrix: Equation (4) shows that HMM process at time *t* is in state *i* and at time *t+1* is in state *j* with probability a_{ij}.*N* is total number of states.

$$a_{ij} = p\{S_{t+1} = j | S_t = i\}, \ 1 \le i, j \le N \tag{4}$$

Where $a_{ij} \ge 0, \ 1 \le i, j \le N$

And $\sum_{j=1}^{N} a_{ij} = 1, \ 1 \le i \le N$

- The emission matrix (the distribution of observation):

$$B = b_j(k) \tag{5}$$

$$b_j(k) = p\{O_t | S_t = j\} \tag{6}$$

Where $b_j(k) \ge 0$

C. Multinomial Choice Model

Two popular customer choice models are binomial and multinomial models. When there are two situations we should use binomial choice decision. For example when we want to know if an individual buys something or not, an individual denotessomething or not or an individual buys brand A not b we should apply binomial choice model [14].But sometimes an individual should chooses something between more than two categories or brands [14]. In this situation we should apply Multinomial choice model which defined as choosing between n alternatives [4]. So whenever the dependent variable has more than two choices we call it multinomial choice model.

Reference[4] denoted the multinomial choice model in a multi-brand market.In this model brands are shown by *j=1,…,n*; customers by *i=1,…,I*; an individual buys*j* with probability π_j and the number of times each brand is purchased is y_j. So multinomial choice model is like (7):

$$p(Y_1, \dots, Y_n = y_1, \dots, y_n = \binom{T!}{y_1!, \dots, y_n!} \prod_{j=1}^{n} {\pi_j}^{y_j} \tag{7}$$

But thisMultinomial choice model calculates one accumulative pattern from customers'purchase since first transaction until now.

D. Proposed Model

As we introduced multinomial choice model in previous section, here we propose a method in order to extend multinomial choice model based on combination of HMM and this model for analyzing customer purchase behavior over the time.In our model we supposed the quantity and type of customer purchase are depend on customer's state in each time period. Since this states are not visible, we supposed that they are hidden Markov model states. Fig. 2 shows our model. Primarily we performed data preprocessing. The output of preprocessing is the table that divides the number of customer purchase based on category and week.Then we apply our model on this data.

At first we performed data preprocessing. As we show in table I the original data set was a flat file with 6 field (customer id, date of transaction, product id, product category, number of purchase and product price). In preprocessingwe divided customers purchase to different groups using category label (luxury, expensive and cheap product) like Table II and data week by week then count all purchase in a week.Afterward we count all purchase in each group for each customer id. We suppose total purchases in different group follow multinomial distribution.

Our model is combination of HMM and multinomial choice model. We appliedHMM to show primacy and recency of customers' purchase and multinomial distribution to determine product category purchase probability. By our model firms can analyze their customer purchase behavior.

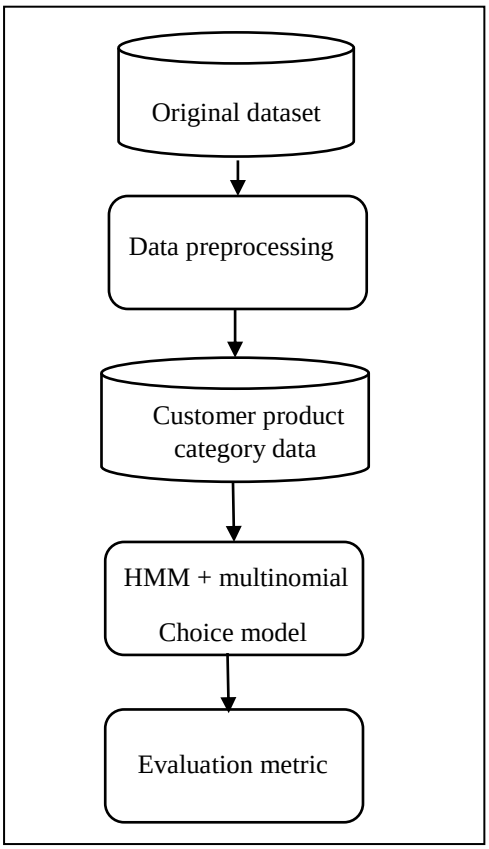


Fig. 2. Proposed method

TABLE I. ORIGINAL DATA

TABLE II. CUSTOMER CATEGORICAL AND WEEKLY PURCHASE ITEM

Customer id	*Categoryproduct*	*Week 1*	*…*	*Week end*
⋮	⋮	⋮	⋮	⋮
id	Luxury	The number of purchase	⋯	The number of purchase
id	expensive	The number of purchase	⋯	The number of purchase
id	cheap	The number of purchase	⋯	The number of purchase
⋮	⋮	⋮	⋮	⋮

IV. EXPERIMENT AND RESULTS

In this section primarily the data we applied to justify our model are explained, then our evaluation metrics and the results we obtained are presented.

A. Data set

In order to justify our model we applied an e-commerce website transactional datawhich sales different product. Our data set has 2095 customer with 61000 transaction over 23 monthand 3 product categories (luxury, expensive and cheap). The website is in retail industry and sales various product with various price and 3 product categories. By our model firm can understand which customer buy which product in which category.

B. Evaluation metrics

In this section we illustrate our evaluation metrics. Our primary metric is log-likelihood. We estimated log-likelihood for both our proposed method and multinomial choice model. Another metric we applied is the difference of two methods' log-likelihood for each customer. Our two last famous metrics which they are useful for over fitting (AIC and BIC) were applied to compare our proposed method with multinomial choice model.

Our first metric is log-likelihood. We applied this metric for both our proposed method and multinomial choice model. Whatever the log-likelihood value becomes larger the model is better.Equation(8)and (9) arethe log-likelihood of our proposed model. Where λ is decay parameters, T is total number of weekend and n number of HMM states.

$$\begin{aligned} log-likelihood &= log\, p(O_1, O_2, \dots O_t|\lambda) \\ &= log \prod_{t=2}^{T} p(O_t|O_1^{t-1}, \lambda) p(O_1|\lambda) \\ &= \sum_{t=2}^{T} log\, p(O_t|O_1^{t-1}, \lambda) + log\, p(O_1|\lambda) \\ &= \sum_{t=2}^{T} log\, p(O_t|O_1^{t-1}, \lambda)\, p(S_t|O_1^{t-1}) \end{aligned} \quad (9)$$

customer id	*product id*	*product category*	*date*	*Number of purchase*	*Product price*
id	id	Luxury	date	number	price
id	id	expensive	date	number	price
id	id	cheap	date	number	price

Where

$$p(S_t|O_1^{t-1}) = \sum_{i=1}^{n} p(S_t|S_{t-1} = i) p\,(S_{t-1}|O_1^{t-1})$$

Equation(10) is multinomial choice model log-likelihood. In multinomialchoice model log-likelihood According to the independence of each purchase at any time interval log-likelihood is:

$$logp(O_1, O_2, \dots O_3) = log \prod_{i=1}^{T} p(O_i) = \sum_{i=1}^{T} logp(O_i) \quad (10)$$

Where

$$\sum_j \sum_i O_i^j = n \quad (11)$$

Where n is total number of purchase for each customer.

$$p_j = \frac{\sum_i O_i^j}{n} \quad (12)$$

$$p(O_i) = \binom{\sum_j O_i^j}{O_i^j} p_j^{O_i^j} \quad (13)$$

In order to evaluate goodness of fit better,our second evaluation metric is observation distance log-likelihood and it was calculated between two model per each customer.

$$\begin{aligned} &Distance\ loglikelihood\ per\ each\ customer \\ &= proposed\ model\ loglikelihood \\ &- multinomial\ loglikelihood \end{aligned} \quad (14)$$

In addition to the goodness of fit metric, BIC [32] and AIC [33] were computed for over fitting.

$$BIC = -2loglikelihood + klogn \quad (15)$$

$$AIC = -2loglikelihood + 2k \quad (16)$$

Where k is number of free parameters and n is number of observations. Whatever the AIC and BIC values become smaller the model will be better. As we said in BIC metric we need to define model parameters. Our proposed model has 7 parameters and multinomial choice mode has two parameters. In multinomial choice model each category has a probability like (17):

$$p_a + p_b + p_c = 1, p_c = 1 - p_a - p_b \quad (17)$$

Where a, b and c are names of categories. So it has two parameters. In our proposed model we considered two hidden states, one initial state and in each of two hidden states we considered multinomial distribution with three product categories. So our proposed model has 7 parameters.

method	*Mean*	*Min*	*Max*
Proposed method – multinomial choice model	0.68	-0.2402	12.2369

C. Results

In this section we present the results of our analysis. Our proposed model was built based on 2 hidden states and 3 product categories (Luxury, expensive and cheap). In Table IIIwe illustrate mean, max, min and sum log-likelihood of customers for both models. As we said before the bigger value of log-likelihood is better so our experiment results show proposed model log-likelihood is bigger than multinomial choice model Therefore our proposed model outperform multinomial choice model and fits better. In table IV we present the difference of log-likelihood between proposed model and multinomial choice model and it shows positive value for mean of two models' log-likelihood differentiation. In Table V we illustrate BIC and AIC for both models.As we said before the smaller value of AIC and BIC is better so our experiment results show proposed model AIC and BIC is smaller than multinomial choice model. Therefore our proposed model outperform another model.

(8)

I. Conclusion and Further Research

Since analysis of customer behavior and choices is essential for firms,to recognize valuable customers to developsuitable marketing strategies, CRMresearchers have been proposedvarious solution to analysis customer behavior and one of them is multinomial choice model [4]. In this paper we propose a new method to extendmultinomial choice model toanalysis customer category purchase behavior. Our proposed methodis hybrid method based on multinomial distribution and HMM.We appliedHMM to show primacy and recency of customers' purchases and considers the customer behavior over time and we appliedmultinomial distribution to determine product category purchase probability. In order to evaluate the proposed method we used a retailer data set.We show our model outperform pure multinomial choice model by log-likelihood metric and we analyze other metrics such as AIC, BICand the difference of log-likelihood between two methods.Therefore our proposed method is suitable to model customer purchase behavior and firms canhave an analysis of their customer behavior over time.

For further research our model can be completed in several ways. We considered week for time periodbut we didn’tstudyon details to choose week but certainly different time periods has direct impact on model performance. For further research other time period such as month and year could be considered. We apply retail data set to justify our model but another industry could be used. We use product category in order to analyze purchase behavior but it can be modeled by product itself.

TABLE III. COMPARISON LOG-LIKELIHOOD

method	*Mean Log-likelihood*	*Min Log-likelihood*	*Max Log-likelihood*	*Sum Log-likelihood*
Proposed method (HMM + multinomial distribution)	-9.7059	-93.0097	2.0650e-14	-20334
Multinomial distribution	-10.3859	-97.2321	0	-21758

TABLE IV. THE DIFFERENCE OF LOG-LIKELIHOOD BETWEEN PROPOSED METHOD AND MULTINOMIAL CHOICE MODEL

TABLE V. THE COMPARIOSN OF AIC AND BIC

method	*BIC*	*AIC*
Proposed method (HMM + multinomial distribution)	40700	40682
Multinomial distribution	43526	43521

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A Hierarchical Feature Learning for Isolated Farsi Handwritten Digit Recognition Using Sparse Autoencoder

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Abstract—In recent years, the recognition of Farsi handwritten digits is drawing increasing attention. Feature extraction is a very important stage in handwritten digit recognition systems. Recently deep feature learning got promising results in English handwritten digit recognition, though there are very few papers in this area for Farsi handwritten digits. The contribution of this paper is to propose a new framework utilizing a two layer sparse autoencoder for feature learning directly from data and using the learned weights for feature extraction. In the classification stage of our proposed framework Softmax regression is applied. This recognition method is applied to Farsi handwritten digits in the HODA dataset. The experimental results support our claim that use of deep feature learning as feature extraction stage improves the performance compared with conventional methods.

Farsi Handwritten Digit Recognition; Feature Learning; Deep Representation Learning; Sparse Autoencoder

I. INTRODUCTION

Handwritten digit recognition is an attractive branch of optical character recognition (OCR) which has some of important real-world applications such as bank checking process, postal mail sorting and reading different forms [1]. In the last few decades, research on more popular languages such as English, Japanese and Chinese have long been a focus of study and high promising results are reported. Although Farsi is the main language in Iran, Tajikistan, and Afghanistan, and it is spoken by more than 110 million people [2] but very few studies have been reported for Farsi language.

For handwritten character/digit recognition, three main stages typically should be considered: preprocessing, feature extraction, and classification [2]. Preprocessing is applied to improve image quality for further processing and feature extraction. Some options for preprocessing include normalizing the size and aspect ratio of image, the interpolation technique of pixel values, histogram equalization, blurring, and other techniques. In classification step, a large number of new classifiers have been recently proposed and tested on various OCR databases.

0	1	2	3	4	5	6	7	8	9
۰,۰	۱	۲,۲	۳	٤,۴	۵,۵	٦,۶	۷	۸	۹

Figure 1. Printed samples of Farsi digits

Among the various stages in pattern recognition (PR) systems such as OCR, Feature Extraction (FE) process is one of the most critical stage so that the PR system accuracy mainly relies on an efficient FE process. For Farsi handwritten digit recognition, this stage is more challenging than other languages, because in Persian digits, there are two types of writing for the digits 0, 2, 3, 4, 5, and 6 (Fig. 1).

Recently, feature learning and deep feature learning algorithms have been applied on handwritten digit recognition and got more promising results than human-crafted features approaches [3, 4]. The goal of deep feature learning algorithms is to automatically learn feature hierarchies with features from higher level abstraction being learned from the lower level ones directly from data, without completely depending on human-crafted features. This ability is especially important for higher level abstractions, which human often do not know how to specify explicitly in terms of raw sensory data [5].

In this paper, we proposed a multi-level feature learning architecture based on sparse autoencoder as its building block to perform FE for Farsi handwritten digit recognition. This model is applied directly to raw sensory data, without any complicated preprocessing such as noise reduction, bounding box extraction and etc. We just remove the average pixel value per data point for contrast normalization. Learned features have been used to train a Softmax regression classifier. Empirical results with the largest handwritten Farsi dataset have shown the effectiveness of the proposed method.

The rest of the paper is organized as follows: Section II reviews the related works in this area. Section III describes deep feature learning. Section IV describes needed preliminaries consist of single-layer sparse autoencoder as well as Softmax regression classifier. Section V discusses our proposed method. Section VI shows the experimental results and finally section VII draws a conclusion and future works.

II. RELATED WORKS

Several recognition techniques for Farsi handwritten digits had been published; for instance, as feature extraction methods; Characteristic Loci [6, 7], fractal code [9], moment [10], profiles [11], structural feature (points, primitives) [12], segmentation and shadow code [13, 14], template [15] and wavelet [16] have been proposed.

For classification, different types of Neural Networks [7, 8, 10, 13], SVM's [16], Nearest Neighbor [12] and SVD [2] have been applied.

Although recently feature learning and deep feature learning got promising results on English handwritten digit recognition [3, 4], there are very few papers in this area for Farsi handwritten digits.

Lack of using feature learning methods as feature extractor in Farsi handwritten digit recognition literature was our motivation for this paper.

III. DEEP FEATURE LEARNING

The success of machine learning algorithms generally depends on feature extraction or data representation. For this reason, much of the actual effort in deploying machine learning algorithms goes into the design of feature extraction. Feature engineering is labor-intensive and rely on human intelligence and prior knowledge. In order to expand the scope and ease of applicability of machine learning, it would be highly desirable to make learning algorithms less dependent on feature engineering i.e. feature learning. Among the various ways of learning features, the focus is on those that can yield more non-linear abstract features, such as deep learning. A deep architecture is formed by the composition of multiple levels of features which higher level features being learned from the lower level ones [17]. One method that has achieved some success in training a deep architecture is the greedy layer-wise training method. The main idea is first, pre-training one layer at a time in a greedy way using an unsupervised learning algorithm and second, fine-tuning the whole network with respect to the ultimate criterion of interest.

IV. PRELIMINARIES

A. SINGLE-LAYER SPARSE AUTOENCODER

Reference [18] have shown that the single-layer sparse autoencoder (single-layer SAE) can achieve high performance with less parameters to tune. We use it as building blocks of a multi-layer architecture to extract appropriate features automatically with low computational cost.

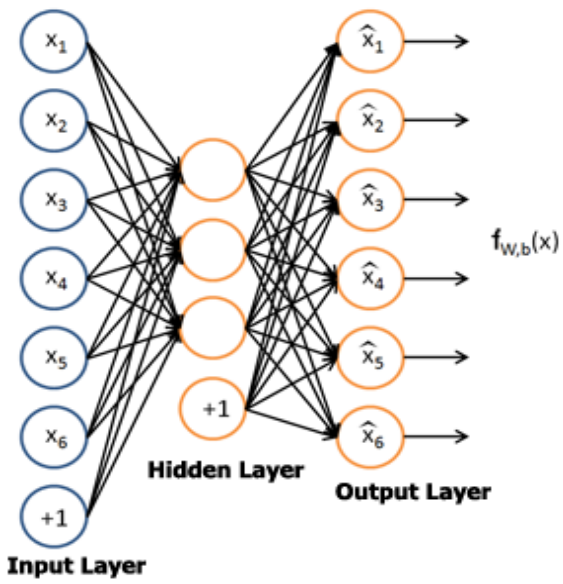


Figure 2. A single-layer sparse autoencoder

Suppose we have only a set of unlabeled training examples $X=\{x^1, x^2, ..., x^m\}$, where $x \in R^n$, a single-layer SAE, like a multi-layer perceptron (MLP) is a feedforward, non-recurrent neural net with an input layer, an output layer and only one hidden layer that has the sparsity constraint. But in contrast to MLP, in single-layer SAE the output layer has the same number of nodes as the input layer and it tries to learn an approximation to the identity function i.e. $f_{w,b}(x) \approx x$. So, a single-layer SAE neural network is an unsupervised learning algorithm that applies back-propagation, setting the target values to be equal to the inputs (Fig. 2). In fact, an autoencoder encodes an input data to a representation (activation values of hidden layer) by the following encoding function:

$$h(X)=g(W_1X + b_1), \quad (1)$$

Where $g(z)=1/(1+\exp(-z))$ is the non-linear sigmoid activation function applied component-wise to the vector z. In this function, $h(x) \in R^k$, $W_1 \in R^{k \times n}$ and $b_1 \in R^k$ are respectively the activation values of hidden layer, parameters (or weights) associated with the connections between input layer and hidden layer, and biases of hidden layer.

After that, a decoding function decodes obtained features to original input data by the following function:

$$f(X)=W_2h(X)+b_2, \quad (2)$$

Where $f(x) \in R^n$ is output values of the output layer nodes. In this function, $W_2 \in R^{n \times k}$ and $b_2 \in R^n$ are the weights associated with the connections between hidden layer and output layer, and biases of output layer, respectively.

The training of the single-layer SAE aims at finding optimal values of W1, b1, W2, b2 by minimizing the following cost function:

$$J=J_{recon}+J_{wd}+\beta\sum_{j=1}^{k}KL(\rho\|\hat{\rho}_j), \quad (3)$$

Where the first term is a squared reconstruction error, J_{recon}, can be denoted as

$$J_{recon}=(1/2)\sum_{i=1}^{m}\|x_i-\hat{x}_i\|. \quad (4)$$

The second term is a weight decay term that tends to decrease the magnitude of the weights, and helps prevent overfitting. It can be denoted as

$$J_{wd}=(\lambda/2)(\|W_1\|^2+\|W_2\|^2), \quad (5)$$

Where λ is the weight decay parameter that controls the relative importance of the terms.
Based on the good result given by [19], we can obtain a better features by imposing a sparse constraint on the activation values of autoencoder's hidden layer. Sparsity in autoencoder (with sigmoid function as activation functions of hidden layer) means we want the hidden neurons to be inactive most of the time i.e. their activation values close to 0. Based on [20], we add a regularization term i.e. $\sum_{j=1}^{k}KL(\rho\|\hat{\rho}_j)$ to constraint the expected activation of the hidden nodes, such that most values of hidden units are much smaller than the sparsity parameter ρ and only a few of them are bigger than it. This sparsity term can be denoted as

$$KL(\rho\|\hat{\rho}_j)=\rho\log\left(\rho\|\hat{\rho}_j\right)+(1-\rho)\log(1-\rho)/(1-\hat{\rho}_j), \quad (6)$$

Where $\hat{\rho}_j=(1/m)\sum_{i=1}^{m}h_j(x_i)$ is the average activation of hidden unit j (averaging over the training set) and β controls the weight of the sparsity penalty term.

B. SOFTMAX REGRESSION CLASSIFIER

Softmax regression or multinomial logistic regression is a probabilistic, linear classifier which generalized logistic regression to the case where we want to handle multiple classes. In this learning model, the probability that an input x is a member of a class k, a value of a stochastic variable ω, is modeled as

$$P(\omega=k|x,\{\theta_{ki}\})=\frac{\exp(\sum_i\theta_{ki}x_i)}{\sum_j\exp(\sum_j\theta_{ji}x_i)}, \quad (7)$$

Where the parameters $\{\Theta_{ki}\}$ are learned from the training data X by minimizing the cost function (8).

$$J(\theta)=-\frac{1}{m}\left[\sum_{i=1}^{m}\sum_{j=1}^{k}1\{\omega^{(i)}=j\}\log\frac{\exp(\sum_i\theta_{ki}x_i)}{\sum_j\exp(\sum_j\theta_{ji}x_i)}\right], \quad (8)$$

Where $1\{.\}$ is the indicator function, so that, $1\{$a true statement$\}=1$ and $1\{$a false statement$\}=0$.
The model's prediction ω_{pred} is the class whose probability is maximal, specifically:

$$\omega_{pred}=\text{argmax}_k\left(P(\omega=k|x,\{\theta_{ki}\})\right). \quad (9)$$

Intuitively, classification is done by projecting an input data point onto a set of hyperplanes, each of which corresponds to a class. The distance from the input to a hyperplane reflects the probability that the input is a member of the corresponding class.

V. THE PROPOSED FRAMEWORK

The proposed framework consists of two main steps: feature extraction and classification. In the feature extraction step we train a stacked autoencoder with two hidden layers using greedy layerwise approach. First, we train a SAE on the raw inputs $x^{(i)}$ to learn primary features $h^{(1)(i)}$. After that, we discard the decoding layer in the first SAE and feed the raw input data into this trained SAE to obtain the primary feature activations $h^{(1)(i)}$ for each of the inputs $x^{(i)}$. Then we use these primary features as the "raw input" to train another SAE to obtain secondary features $h^{(2)(i)}$. Finally we treat these secondary features as "raw input" to a Softmax regression classifier, train it to map secondary features to digit labels. For this purpose we discard the decoding layer of second SAE and link the last hidden layer to the Softmax regression classifier. For fine-tuning, the gradients from the Softmax classification error will then be backpropagated into the encoding layers to tune the parameters of all layers all together.

VI. EXPERIMENTAL RESULTS

To evaluate the performance of the proposed method, we train the model on 60,000 training samples (6,000 samples per class) and evaluate our model on 20,000 test samples (2,000 samples per class) from HODA dataset [21]. The HODA dataset is a very large dataset of Farsi handwritten digits which extracted from 11,942 forms filled by senior high school and bachelor students registered in the Iran's nationwide university entrance exam.
Selected hyper-parameters for training first layer and second layer SAEs are shown in TABLE I. We used 5-fold cross validation scheme for selecting them. The model were chosen by an efficient architecture search [22].
In this work, limited-memory Broyden–Fletcher–Goldfarb–Shanno (L-BFGS) is utilized to complete parameters optimization of the single-layer SAE model [23].
In TABLE II, the recognition rates of proposed framework are listed. The comparison of the results with those of other methods showed the efficiency of our framework. Also, the influence of second layer and fine-tuning on accuracy rate are shown in this table. As it is shown, the accuracy of proposed framework decreases about 6 percentage without fine-tuning. Furthermore, adding second layer SAE on top of the first layer SAE increases accuracy rate.

TABLE III shows the confusion matrix of the recognition results of the mentioned model. As it can be seen, the major confusions were amongst 2, 3 and 4. This happened because 2, 3 and 4 look like each other.

TABLE I. SELECTED HYPER-PARAMETERS

Hyper-parameter	value
Size of images	32 × 32
Input Size	32 × 32
Number of features of first layer	350
Number of features of second layer	500
Weight decay parameter (both layer)	0.003
Weight of sparsity penalty term (both layer)	3
Maximum of iterations	250

TABLE II. COMPARISON OF DIFFERENT ALGORITHMS

Algorithm	Data size		Accuracy	
	Train	*Test*	*Train*	*Test*
M. H. Shirali-Shahreza, K. Faez, and A. Khotanzad [13]	2600	1300	--	97.80
H. Soltanzadeh and M. Rahmati [11]	4979	3939	--	99.57
A. Harifi and A. Aghagolzadeh [14]	230	500	--	97.60
M. Ziaratban, K. Faez and F. Faradji [15]	6000	4000	100	97.65
A. Mowlaei and K. Faez [16]	2240	1600	100	92.44
S. Mozaffari, K. Faez, and H. Rashidy Kanan [9]	2240	1600	98.00	91.37
S. Mozaffari, K. Faez and M. Ziaratban [12]	2240	1600	100	94.44
R. Ebrahimpour, and S. Hamedi [1]	60000	20000	-	97.99
H. Salimi and D. Giveki [2]	60000	20000	-	97.30
M J. Abadi, H. Salimi [6]	60000	20000	-	97.1
M. M. Javadi, F. Sharifizadeh [7]	60000	20000	-	98.16
M. A. Shayegan, Chee Seng Chan [8]	60000	20000	-	95.7
Proposed framework (2 layer – with fine-tuning)	60000	20000	-	98.22
Proposed framework (1 layer – with fine-tuning)	60000	20000	-	97.56
Proposed framework (2 layer - without fine-tuning)	60000	20000	-	92.39

TABLE III. CONFUSING MATRIX OF THE RESULT

Class no.	0	1	2	3	4	5	6	7	8	9
0	1962	8	1	1	4	15	1	2	0	0
1	13	1984	4	0	2	0	3	4	3	17
2	0	1	1965	49	7	1	2	6	0	1
3	0	0	16	1918	28	0	1	0	0	0
4	4	1	6	29	1951	9	4	0	1	2
5	13	0	0	1	3	1969	4	1	1	1
6	1	4	4	0	2	0	1966	4	0	15
7	5	0	2	1	1	1	1	1983	0	0
8	1	0	1	0	0	5	1	0	1989	8
9	1	2	1	1	2	0	17	0	6	1956

VII. CONCLUSION AND FUTURE WORKS

In this paper, a new framework has been proposed for Farsi handwritten digit recognition. We utilized a stacked sparse autoencoder with two encoders or hidden layers for direct automatic feature learning from data without the need of complex preprocessing. Evaluation of proposed method on a very large Farsi handwritten dataset showed the efficiency of it.

In the proposed framework we didn't take advantage of specific characteristics of data such as major confusions among some Farsi digits due to their similarities. We plan to investigate more adapted approaches based on feature learning which leverage specific characteristics of Farsi hand written digits in the future.

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Real-Time Speech Emotion Recognition by Minimum Number of Features

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***Abstract*— Speech emotion recognition is an aspect of equipped robots with the human capabilities. The need to trade-off between computational volume and performance accuracy is the main challenge of real-time processes. Application domain of this paper is robotic; therefore both mentioned factors are important. Selecting distinguishing factor with low dimension and high resolution is the optimal solution for both decreasing computational volume and increasing performance accuracy. In this paper a feature vector by minimum number of elements is proposed for recognizing emotional states of speech. The elements of proposed feature vector are selected from both prosodic and frequency features. The result of evaluation realizes the desired performance in the real-time processes.**

Keywords—Speech Emotion Recognition; Real-time Processing; Prosodic Features; Cepstral Featurs

I. INTRODUCTION

There are wide ranges of features in the voice. Feature selection is directly related to the process in which we tend to do it. Selecting inappropriate features lead to both low performance and overload processing. Overload processing in the real-time applications such as robotic has no justification. Feature selection is a challenging step of the recognition processes. All features of voice play role in the speech style. The values of these features are varied from one person to another [1]. On the other side, the accuracy of classification algorithm is influenced by distinguishing factors [3].

Changing the value of features has different impact on the emotional states [4]. Although considering all features of voice and using dimension reduction algorithms is useful option for increasing the accuracy; however the computational volume should be reasonable for real-time processing [10]. Mentioned option is useful for the offline application. Additional processing load is the last option for real-time applications. The optimal solution is selecting features in which simultaneously produce both high performance and also do not require to the large amounts of computation [4].

The rest of the paper is organized as follows: section II contains previous works, section III presents feature extraction, the result is located in the section IV and conclusion and future work are presented in section V.

II. PREVIOUS WORKS

The features of voice are classified into two categories of prosodic features and frequency features [2]. Distinguishing power and computational volume are important points of feature selection step. Some of significant features are introduced in the follow [5]. Prosodic feature: This type of feature is the base of suprasegmental features in which the human hearing perceived them directly. Prosodic features include: energy, duration, pitch, etc. [11].

Energy of voice and its statistical parameters are the most attractive features of the speech emotion recognition [5, 13]. This feature is known as a short term feature [15, 17]. The loudness, the volume and the intensity are energy equivalent terms. The vocal cords vibration is introduced as fundamental frequency. This feature is known as pitch or tone. Fundamental frequency refers to the pitch of voice and almost all previous studies were used it [10]. Duration is the amount of time spent for building blocks of speech such as vowel and words. On the other side speech rate refers to the spent time to expressing the whole sentence.

Despite prosodic features, the frequency features are not comprehensible by human hearing. Some of the most important frequency features are explained below. There are set of coefficients in the voice named as cepstral coefficients. Cestrum coefficients are used in the voice processing such as fundamental frequency estimation.

Mel Frequency Cepstral Coefficient (MFCC) is one of linear wavelet. These coefficients are able to capture important characteristics of the speech signal such as dynamic features [18]. Time domain information and frequency domain information are included in the MFCC. Human hearing is sensitive to some of sub-band frequencies. These sub-band frequencies are modeled in the Mel filter [7]. Despite Linear Prediction Cepstral Coefficients (LPCC), MFCC is less sensitive to the noise [8]. MFCC is frequently used in the previous speech emotion recognition research activities [6,9,11]. Table 1 illustrates comparison between MFCC and prosody features.

Using all features of voice does not provide high accuracy. In contrast, due to the high dimension of feature vector, using dimension reduction algorithm is necessary in which it is overload processing [3]. Some other features such as Harmonic, Signal to Noise Ratio (SNR) and Harmonic to

Noise Ratio (HNR) are used in the course clustering. Classified features of voice are presented in the table 2 and 3.

TABLE I. COMPARISON OF MFCC AND PROSODY FEATURES

Parameter	*MFCC*	*Prosody Features*
Duration	Depend on vowel duration	Depend on speech model
Features set	Using standard and small set	Using long term features
Features type	Using cepstral features	No cepstral features
Reliability	High	Low
Filters	Using filter-bank	No filter
Recognition /Identification	Both	Only recognition
Chanel impact	Low	High
Performance	High	Low
Speech samples	No need to high volume	Need to high volume

TABLE II. LIST OF FEATURES INTO 4 GROUPS [13]

Feature Group	*Nature*	*Features*
1	Frequency -Based Features	1-20: mean, max, min, median value and the variance of F0 and first 3 formants
2	Energy-Based Features	21-23: mean, max, min values of energy 24: energy ratio of the signal below 250 Hz 25-32: mean, max, median and the variance of the values and duration of energy plateaus 33-36: mean, max, median and variance of the gradient of rising slopes of energy contour 37-40: mean, max , median and variance of the duration of raising slopes of energy contour 41-44: mean, max , median and variance of the gradient of failing slopes of energy contour 45-48: mean, max , median and variance of the duration of failing slopes of energy contour 49-50: number of rising and falling slopes of energy contour per second
3	Harmonic Features	51-62: mean, variance and normalized variance of the 4 areas 63: max value of the area 1 64-66: the ratio of mean values of areas 2~4 to area 1
4	Zipf Features	67: entropy features of inverse Zipf of frequency coding 68: resamples polynomial estimation Zipf features of UFD coning

TABLE III. LIST OF CANDIDATE FEATURES USED FOR EMOTION RECOGNITION [7]

Feature number	*Base Feature(s)*	*Supplementary Features*
1-6	Pitch frequency (F0)	Variance (VF0), mean of derivative (MdF0), max (MaF0), min (MiF0), difference between max and min (DMF0)
7-21	Formant Frequencies (F1-F3)	Variance (VF1-VF3), mean (MF1-MF3), max (MaF1-MaF3), min (MiF1-MiF3), difference between max and min (DMF1-DMF3)
22-36	Derivative of Formant Frequencies (dF1-dF3)	Variance (VdF1-VdF3), mean (MdF1-Mdf3), max (MadF1-MadF3), min (MidF1-MidF3), difference between max and min (DMdF1-DMdF3)
37-42	Logarithm of Energy (LE)	Variance (VLE), mean (MLE), mean of derivative (MdLE), max (MaLE), min (MiLE), difference between max and min (DMLE)
43-46	Derivative of Logarithm of Energy (dLE)	Variance (VdLE), max (MadLe), min (midLE), difference between max and min (DMdLE)
47-52	MFCCs (first and second coefficients: C1 and C2)	Average (MC1, MC2), max (MaC1, MaC2), min (MiC1, MiC2)

III. FEATURE EXTRACTION

Speech signal is continuous signal and its features are changed over the time. Speech signal is divided into several segments to deal with non-stationary. Behaviour of feature has no change over time in the small segments. It is the main assumption of segmentation. In order to prevent data loss, segmentation is done by overlapping. To reduce the effect of overlap, the hamming window function is used. See (1).

$$\omega(n)=\begin{cases}0.54-0.46\ \cos(\frac{2\pi n}{N}),\ 0\le n\le N\\ 0\quad ,\ n>N\end{cases} \qquad (1)$$

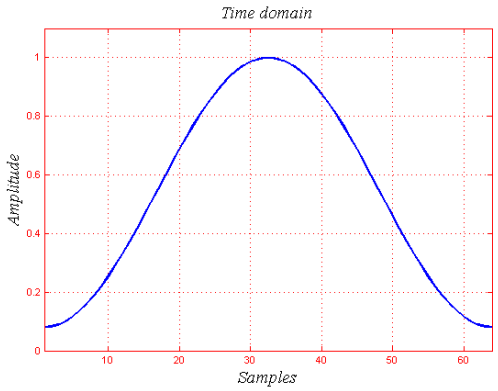


Fig 1: Hamming window – Time domain

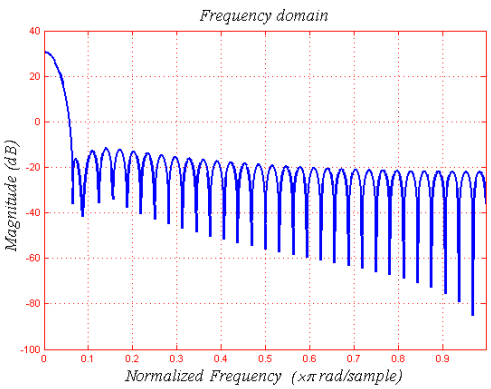


Fig 2: Hamming window – Frequency domain

Loudness is defined as the number of samples in the frame. See (2).

$$E=\sum_{n=0}^{N-1}\left|x(n)\right| \qquad (2)$$

In which *x(n)* is *n*-th sample in the frame and *N-1* is the volume of frame. The loudness is calculates according to (3) in decibel.

$$E=10*\log\frac{1}{N}\sum_{n=0}^{N-1}\left|x(n)\right|^2 \qquad (3)$$

There are different methods for F0 calculation. Auto Correlation Coefficient is one of them.

$$\varphi(k)=\sum_{n=0}^{n-1}x(n)x(n+k) \qquad (4)$$

$$k=0\ ,\ \varphi(k)=\sum_{n=0}^{N-1}x^{2}(n) \qquad (5)$$

K = 0 is the maximum value of the autocorrelation function.

$$\forall\ k>0\ ,\ \varphi(k)\le\varphi(0) \qquad (6)$$

In this case three first candidates contain F0 information.

$$F0=Max\{\varphi(0),...,\varphi(k)\}-\varphi(0) \qquad (7)$$

Another method for F0 calculation is using cestrum coefficients. (Fig 3)

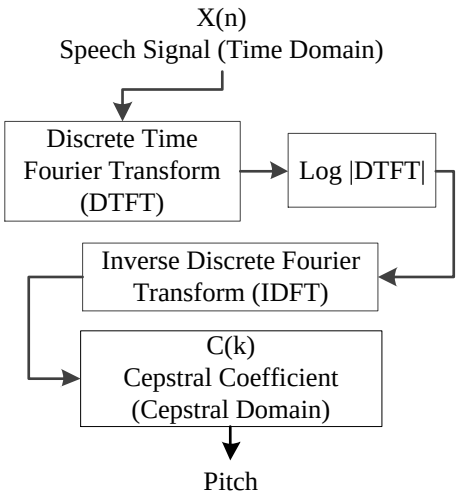


Fig 3: Pitch and Cepstral Coefficients Calculation

MFCC calculation steps are shown in Fig 4.

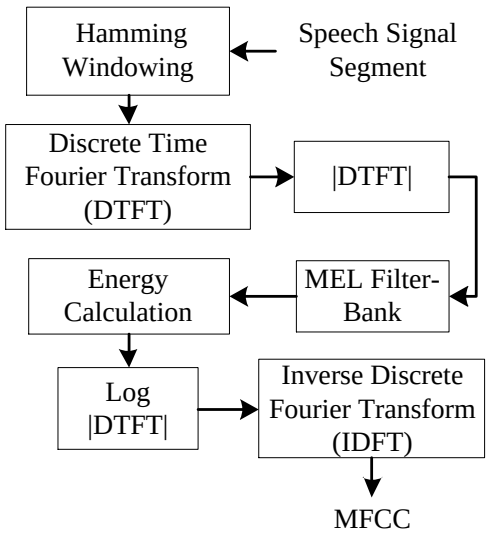


Fig 4: MFCC Calculation

Sub-band frequency division is done according to (8).

$$H_m(k)=\begin{cases}0\ , & k<f(m-1)\\ \dfrac{k-f(m-1)}{f(m)-f(m-1)}, & f(m-1)\le k\le f(m)\\ \dfrac{f(m+1)-k}{f(m+1)-f(m)}, & f(m)\le k\le f(m+1)\\ 0\ , & k>f(m+1)\end{cases} \qquad (8)$$

In which $H_m(k)$ is *m*-th sub-band frequency of *k*.

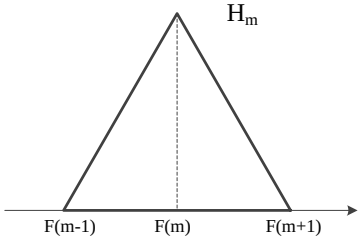


Fig 5: Sub-band Frequency of Mel Filter

According to (8) for all sub-band frequencies we have Mel filter-bank. (Fig 6)

$$f(m)=\frac{N}{f_s}B^{-1}\left[B(f_l)+m\frac{B(f_h)-B(f_l)}{M+1}\right] \qquad (9)$$

In which f_s is sampling rate, f_l is low level of the first filter, f_h is high level of the last filter and $f_l=\frac{1}{2}f_s$. *M* is the number of all filters and *m* is their index and *N* is the number of all samples.

$$B(f)=125Ln(1+\frac{f}{700}) \qquad (10)$$

$$B^{-1}=700\left[\exp(\frac{b}{1125})-1\right] \qquad (11)$$

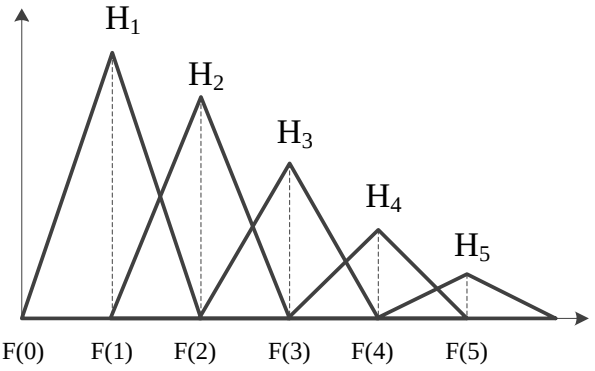


Fig 6: Mel Filter-bank

Cepstral coefficient and MFCC contain short-term information, while emotional states information is located in the long-term information. It is the main challenge if these coefficients. In this case the amount of change should be considered. Equation (12) shows the first derivative of cepstral coefficient.

$$\Delta c(i) = \sum_{\tau=1}^{2} \left[\frac{c_{t+\tau}(i) - c_{t-\tau}(i)}{2\sum_{\tau=1}^{2} \tau^2} \right] \qquad (12)$$

In which *i* is the number of cepstral coefficient. In order to calculate the second and higher derivation $\Delta c(i)$ should be replaced in (12).

IV. Results

The proposed feature vector contains fourteen elements as follows: fundamental frequency, energy and first twelve Mel frequency cepstral coefficients. In order to evaluate the proposed feature vector, it was used by two separate classifiers [19] on the Berlin dataset [12] for recognizing emotional states of speech. The results are shown in fig 7 and fig 8.

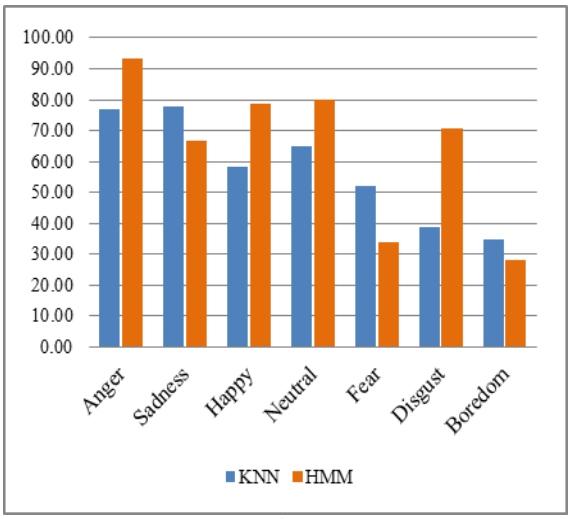


Fig 7: Classification Result

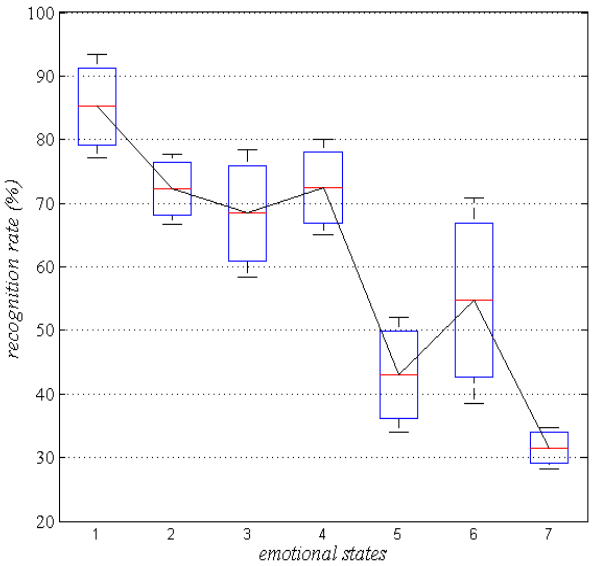


Fig 8: Comparison Result . 1: Anger, 2:Sadness, 3: Happy, 4: Neutral, 5: Fear, 6: Disgust, 7:Boredom

Without considering classification algorithm, the proposed feature vector has desired performance for recognizing happy, sadness, anger and disgust emotional state. In contrast, the proposed feature vector shows weak performance to recognizing fear and boredom emotional state. Fig 9 illustrates descending order of recognized emotional states.

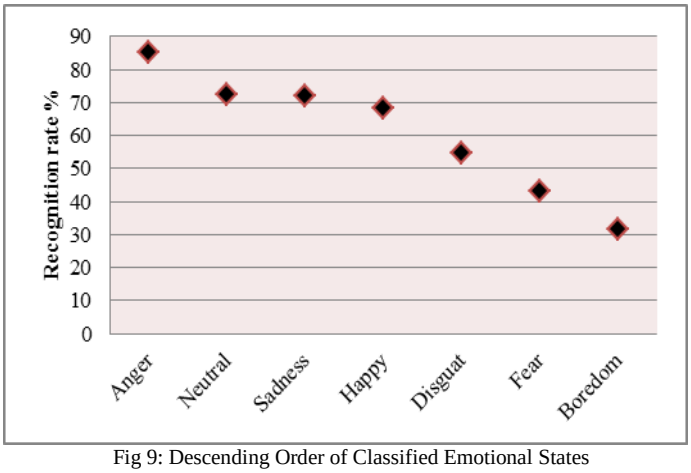


Fig 9: Descending Order of Classified Emotional States

V. Conclusion and Future Work

This paper proposed feature vector for speech emotional state recognition by minimum number of features. Few numbers of elements and the low volume processing and distinguishing elements with high resolution take advantages of proposed feature vector in which lead to usability in real-time processing such as robotic. The proposed feature vector resolves the overload processing of dimension reduction algorithms. As the future work we plan to combine voice and facial features by minimum number of elements for real-time emotion recognition.

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Using Parametric Regression and KNN Algorithm With Missing Handling For Software Effort Prediction

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Abstract— Estimating the software development costs, budget and resources such as the time and effort is one of the most important activities in the software project management. The error rate, at the estimating costs, has a sizable portion in success or fail of a project .In general, it is used from similar project histories for project estimation. One of the challenges in this approach is missing values. in this research, first, for handling missing values the K nearest neighbor (KNN) algorithm and Mean Imputation has been used, then for effort prediction, the parametric model based methods, the non-linear and polynomial regression(quadratic) is used. The proposed method is performed on the CM1 dataset and the results show that the combination of KNN and nonlinear regression (quadratic) has the best response, signifying accuracy improvement and relative error reduction, in comparing with other approaches.

Keywords—effort estimation , regression , missing value.

I. INTRODUCTION

Software cost estimation is a complex process where the quality of outputs heavily depends on the quality of inputs[13] .Generally, during life time of a software development , project team evaluates required sources before starting a project. This evaluation has great importance due to two reasons: First, the project costs is mentioned before starting it, and, also economic considerations determined. Second, important decisions are made based on the information acquired through evaluation process. For example, the taskmaster may not be willing to start a project due to economic reasons or not being able to afford financial sources of the project needs.

A common approach for estimating cost and another project issues is that it is used from precedents and similar projects. Unfortunately, the number of projects, of which information is recorded in a codified form, is not large and in this term, the point that is in table is the lack of information of some project attributes, projects of which information is much valuable. On the other hand, using knowledge-base, in which recorded old project attributes and precedents for estimating required resources,at first, project attributes is adapted with information included in the database an desirable estimation is computed based on this information . Regardless of the importance of this issue, estimating the cost of software is not a simple matter because:

- The datasets are almost noisy [1].
- The rapid changes in information technology and software development methodologies occurs causes we do not have a fixed cost estimate. Measuring the effects of new advanced technologies is difficult [8].
- There are factors that affect the amount of work and time required for software development. Such as the complexity of the product, the ability of developers to identify. And initialize action of these factors is difficult [4].
- Because the projects do not have the same sample (the production line of current work and operational organization) series of activities occur during execution that have not been anticipated .
- Probably none of the aforementioned aspects has as large an impact on the difficulty of software production as does the abstract character of software products[5].

According to the cause ,Estimate is with errors [15].

The remainder of this paper is organized as follows: Sections II, III ,IV introduces some preliminaries to understand the paper. Section V proposes K nearest neighbor (K-NN) algorithm and Mean Imputation for handling missing values when using parametric for software effort prediction. Section VI conducts experiments to examine regression for effort prediction as well as the KNN and Mean in handling missing data. Section VII concludes the paper.

II. *RELATED WORK*

Software Cost Estimation (SCE) is a process of predicting the efforts and cost in terms of money, schedule and staff for any software system.

The history of SCE begin early in 1960 when Frank Freiman develop the concept of parametric estimation models that's leads to the development of PRICE model for hardware, in 1970 the researchers in this field analyze[13].

During the last 30 years, a number of formal models for software effort estimation have been proposed such as Cocomo[4],CocomoII[12].These model shave some advantages , providing a formulaic underpinning of software effort estimation[4].

More recently, formal models are being superseded by a number of data intensive techniques originating from the data mining literature [4]. These include various regression techniques which result in a linear model [15], nonlinear approaches like neural networks [10], tree/rulebased models such as CART [14], and lazy learning strategies (also referred to as case-based reasoning (CBR)). Data mining techniques typically result in objective and analyzable formulas which are not limited to a specific set of attributes, as is the case with formal models such as Cocomo I.

On the other hand, many studies on incomplete data management software project estimation is done.Missing data is one of the problems which are to be solved for real-time application. Traditional and Modern Methods are there for solving this problem. The variables may be of Missing Completely at Random(MCAR), Missing at Random(MAR), Missing not at Random(NMAR)[24].

Many researches have been conducted on handling missing data in software effort prediction. Recently some authors have tried to estimate how many missing value needed to noticeably harm the prediction accuracy in classification [4]. Usually the treatment of missing in Dataset be handled in three different ways [4]. (1)The first approach is to discard the examples with missing value in their attributes .Therefore deleting attributes with elevated levels of missing value is included in this category too.(2)Another approach is the use of maximum likelihood procedures , where the parameters of a model for the complete portion of the data are estimated, and later used for imputation by means of sampling. (3)Finally, the imputation of missing value is a class of procedures that aims to fill in the missing value with estimated ones[4][24].

Song and Shepperd propose a new imputation method called MINI to handle missing data in effort prediction. New extensions and experiments of this method are also proposed in their recent work[39].

Strike et alevaluate ten usually adopted techniques for handling missing data: listwise deletion (LD), mean imputation (MI) and eight different types of hot-deck imputation techniques [1].

Myrtveit et al. conduct an empirical evaluation of imputation methods and likelihood-based methods including LD, MI, similar response pattern imputation (SRPI) and full information maximum likelihood (FIML).

Khoshgoftaar and Hulse also report that BMI technique outperforms other techniques using NASA data. They point out that the amount of missing data and the missingness mechanism are important factors in missing imputation process [40].

in this paper We will focus our attention on the use of imputation methods. The innovation of this research is using K nearest neighbor (K-NN) algorithm and the missing data replacement technique with mean data in the non-linear and linear polynomial regression, rectifying missing data and improving the estimation accuracy of the software projects in parametric methods.

III . IMPUTATION TECHNIQUES

The independent missing imputation techniques we discus in this paper include MI (Mean Imputation) and KNN(K nearest neighbor)[1].

Table 1
The historical effort dataset of software projects

	x_i	…	x_j	…	x_{mn}	j_{i1}
D_1	x_{11}	…	x_{1j}	…	x_{1n}	j_1
…	…	…	…	…	…	
D_i	x_{i1}	…	x_{ij}	…	x_{in}	j_n
…	…	…	…	…	…	…
D_m	x_{im}	…	x_{mj}	…	x_{mn}	j_m

MI imputes each missing value with the mean of observed values . MI imputes each missing value with the mean of observed values. Assuming we have a historical project D_S and its value on attribute x_j. i.e. x_{ij}. Then, MI will use to impute x_{ij}. $D_{obs,j}$ is the set of projects whose values on attribute x_j are observed.

$$\overline{x_{ij}} = \frac{1}{D_{obs,j}} \sum_{D_i \in D_{obs,j}} X_{ij} \quad (1)$$

This method is very simple and easily to implement but the variance of imputed values will be underestimated because all the missing values of an attribute x_j will be imputed using the same value $\overline{x_{ij}}$.

In the k-NN method, missing values in a case are imputed using values calculated from the k nearest neighbors, hence the name. The nearest, most similar, neighbors are found by minimising a distance function, usually the Euclidean distance, where:

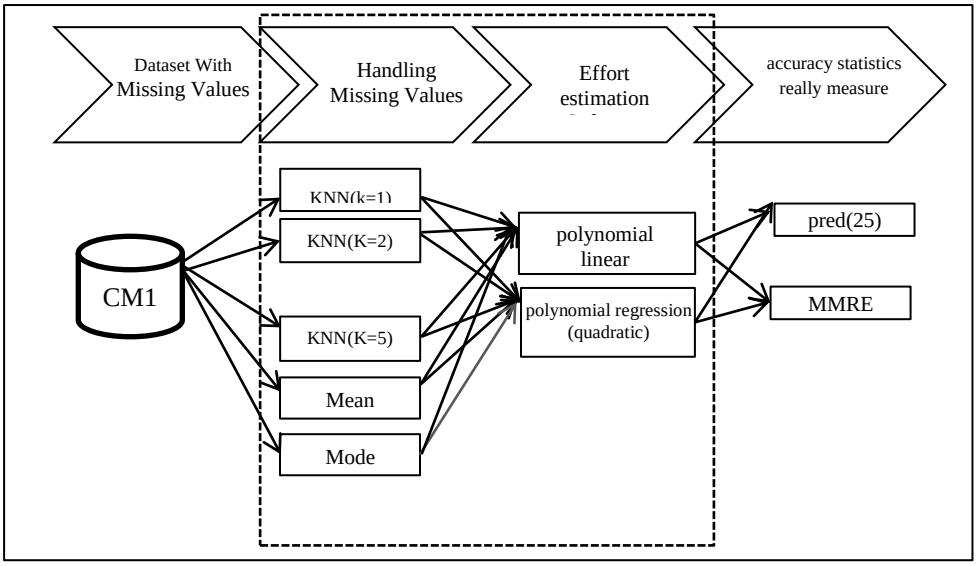


Fig.1. An overview to Parametric Regression With Imputation Techniques

$$E(a,b) = \sqrt{\sum_{i \in D} (x_{ai} - x_{bi})^2} \qquad (2)$$

- $E(a, b)$ is the distance between the two cases a and b,
- x_{ai} and x_{bi} are the values of attribute i in cases a and b, respectively, and
- D is the set of attributes with non-missing values in both cases.

The use of Euclidean distance as similarity measure is recommended by Strike et al and Troyanskaya et al[34][35].

IV .PREDICTION ACCURACY STATISTICS

The mean magnitude relative error (MMRE) prediction accuracy statistic is the most widely used indicator in recent years, particularly when assessing thc performance of software cffort estimation models. The MMRE is defined in [4] as:

$$MMRE = \frac{1}{n}\sum_{i=1}^{i=n}\left(\frac{|x_i - x|}{x_i}\right) \qquad (4)$$

where x, is the actual value and x is the estimated value of a variable of interest.

Another widely used prediction quality indicator is pred(m), which is simply the percentage of estimates that are within *m%* of the actual value. Typically *m* is set to 25 so the indicator reveals what proportion of estimates are within a tolerance of 25%. Clearly, pred(m) is insensitive to the degree of inaccuracy of estimates outside the specified tolerance level[36].

V. PARAMETRIC REGRESSION WITH IMPUTATION TECHNIQUES

this section describes the proposed approach . the overall approach consists of the following three steps as shown fig.1.

step 1. independent missing handling Imputation:MI (Mean Imputation) and KNN(K nearest neighbor) used for handling missing value.

step 2. estimating the effort with parametric regression : the polynomial regression and multiple linear is used for estimating the effort.

step 3. measuring the accuracy of effort estimation . To compare the performances of the two techniques with multiple linear regression and polynomial regression have chosen MMRE, PRED measures

we describe each step in detail next.

A. independent missing handling Imputation

k-nearest neighbor this method the missing values of an instance are imputed considering a given number of instances that are most similar to the instance of interest. The similarity of two instances is determined using a distance Function. The algorithm for k-nearest neighbor is as follows-

Determine the value of K (Nearest neighbors). Here Value of k(1,2,3,4,5)

- Calculate the distance between the missing value instance and other training instance. Here Euclidean distance is used for calculating the distance. Euclidean distance is given by the equation as:-
- After calculating the Euclidean distances choose the data values those having minimum distance. If the value of K is 5 then we have to choose 5 values that having minimum distance. Calculate the mean of these chosen values. The mean is given by the equation as:-
- Calculate the mean of these chosen values. The mean is given by the equation as:-
- Impute M as the output value for missing data[35].

$$M = \frac{1}{n}\sum_{i=1}^{n} m_i \quad (3)$$

another method is MI imputes, This is one of the most frequently used methods. It consists of replacing the missing data for a given feature (attribute) by the mean of all known values of that attribute in the class where the instance with missing attribute belongs. In this we replace all the missing value with its mean[4].

B. estimating the effort with parametric regression

Regression analysis is a statistical method for investigating relationships between a dependent variable and one or more independent variables based upon the analysis of data collected for these variables[5].
the multiple linear regression model the dependent variable is related to two or more independent variables .The general model for n variables is of the form[8].

$$\boldsymbol{y} = B_0 + B_1 x_1 + B_2 x_2 + \cdots B_m x_{in} + e = 1,2,3 \ldots . n \quad (5)$$

Using matrices allows for a more compact framework in terms of vectors representing the observations, levels of regressor variables, regression coefficients, and random errors. The model is in the form[20]:

$$\boldsymbol{Y} = \boldsymbol{X}\beta + \varepsilon \quad (6)$$

and when written in matrix notation we have

$$\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{bmatrix} = \begin{bmatrix} 1 & x_{11} & \cdots & x_{1k} \\ 1 & x_{21} & \cdots & x_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ 1 & x_{n1} & \cdots & x_{nk} \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \\ \vdots \\ \beta_n \end{bmatrix} + \begin{bmatrix} \epsilon_1 \\ \epsilon_2 \\ \vdots \\ \epsilon_n \end{bmatrix} \quad (7)$$

Note that Y is an n_1 dimensional random vector consisting of the observations, X is an n × (k × 1) matrix determined by the predictors, β is a (k+1) ×1 vector of unknown parameters, and ϵ is an n ×1 vector of random errors[23].
The first step in multiple linear regression analysis is to determine the vector of least squares estimators, $\hat{\beta}$, which gives the linear combination $\hat{y}$ that minimizes the length of the error vector. Basically the estimator $\hat{\beta}$ provides the least possible value to sum of the squares difference between ˆy and y. Algebraically $\hat{\beta}$can be expressed by using matrix notation.
An important stipulation in multiple regression analysis is that the variables $x_1, x_2 \ldots x_n$ be linearly independent[8].
This implies that the correlation between each xi is small. Now, since the objective of multiple regression is to minimize the sum of the squared errors, the regression coefficients that meet this condition are determined by solving the least squares normal equation[23]:

$$\hat{b} = (X^T X)^{-1} X^T \quad (8)$$

polynomial regression is a form of linear regression in which the relationship between the independent variable x and the dependent variable y is modelled as an nth degree polynomial. Polynomial regression fits a nonlinear relationship between the value of x and the corresponding conditional mean of y[8].

$$\boldsymbol{y} = B_0 + B_1 x_i^2 + \cdots + B_m x_i^m + e \quad i = 1,2,3 \ldots . n \quad (9)$$

The model is in the form $\boldsymbol{Y} = \boldsymbol{X}\beta + \varepsilon$ and when written in matrix notation we have[8][20]:

$$\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{bmatrix} = \begin{bmatrix} 1 & x_1 & {x_1}^2 & \cdots & {x_1}^m \\ 1 & x_2 & {x_2}^2 & \cdots & {x_{2k}}^m \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 1 & x_n & {x_n}^2 & & {x_{nk}}^m \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \\ \vdots \\ \beta_n \end{bmatrix} + \begin{bmatrix} \epsilon_1 \\ \epsilon_2 \\ \vdots \\ \epsilon_n \end{bmatrix} \quad (10)$$

this paper we focus a quadratic equation produces a parabola.

C. measuring the accuracy of effort estimation

the mean magnitude relative error ,MMRE, and the count of the number of predictions within *m%* of the actuals, pred(m), where ***m*** is usually taken to be 25. These arc particularly important accuracy statistics.

VI.EXPERIMENTAL

this section describes the experimental design for evaluating the performance of and show the intermediate results of our experiments .the overall process consists of the following 5 steps ,as shown in Fig 2.

A. Data preprocessing

The datasets we used are from the CM1 databases.
The CM1 database contains 498 projects from insurance, each project is described with 22 attributes and attribute should include no missing values.
In the first step, pre-processing of datasets, cm1 has been done. At first, normality of the data is evaluated by the use of Kolmogorov-Smirnov test. Due to their lack of normality, the

data is normalized by the standard score method. Furthermore, the t test is confirmed based on the following hypothesis.
The purpose of this step is to normalize the data and to be sure that all dataset features are normal and are associated with the effort. According to the results of the simulation, variables have normalized.

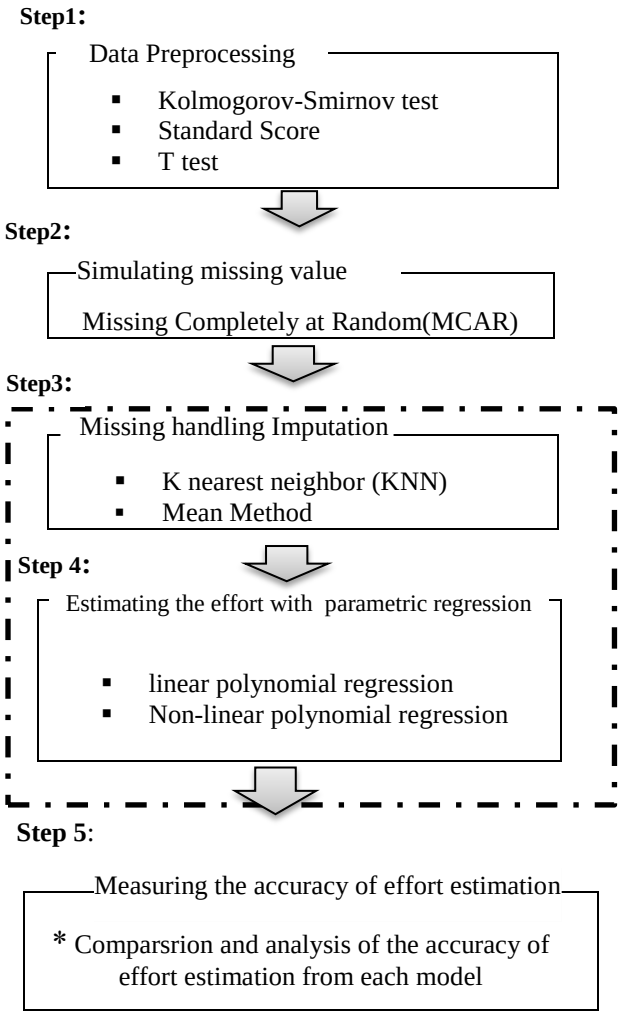


Fig.2.The experimental design

B . Simulation of Missing Values

Cm1 dataset does not have any incomplete dataset. So, incomplete data is simulated in this project and is created based on missing at complete random (MACR). We have considered a parameter as the percentage of incomplete data.

C. Resolving Missing Data

At this stage, the formulas (۱) (۲) are used to handling the incomplete data on the dataset by the mean and the nearest neighbor method.

.

D. Parametric regression methods

For estimating effort in software projects, linear polynomial and non-linear polynomial (squared) regression models are used In this section.

.

E . Measuring the accuracy of effort estimation

In order to evaluate the accuracy of the proposed method and to compare it with the previous method, a set of experiments has been done based on linear polynomial and non-linear polynomial (squared) regression. In addition, 10_fold cross validation method has been used to assess the statistical results.
When the MMRE (*Mean Magnitude of Relative Error*)rate is low, the error in the algorithm is low too. This point, which is calculated in the proposed method, implies a higher precision in the algorithm. Mean magnitude of relative error is displayed on the Fig3, where the horizontal axis shows the parameters of incomplete data and vertical axis represents mean magnitude of relative error(MMRE).

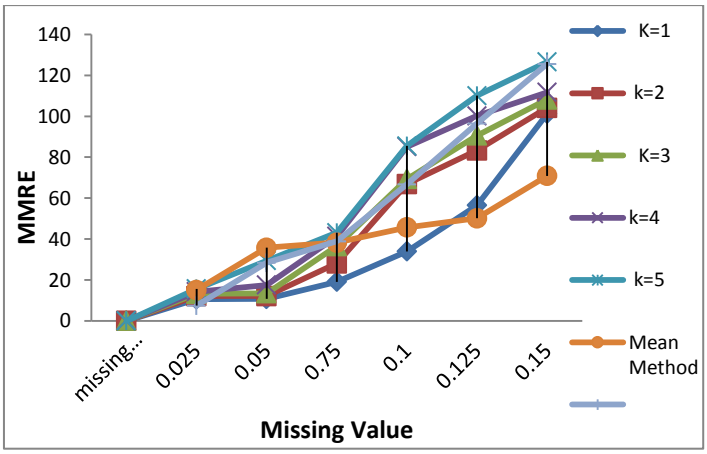


Fig.3. linear polynomial regression (MMRRE)

KNN, with different values of k, and Mean method has been studied on the linear polynomial and non-linear polynomial (squared) regression in this **Fig3**. This study shows when the rate of incomplete data increase, the mean magnitude of relative error increase too. Furthermore, mean method which is used to resolve incomplete data, contain the highest amount of error. On the other hand, the nearest neighbor method has the least amount of error when k=1 **Fig3**. As specified in the **Fig4**, the amount of MMRE is lower in the non-linear polynomial (squared) regression. As a result, the accuracy of which is more than that of the linear polynomial regression method.

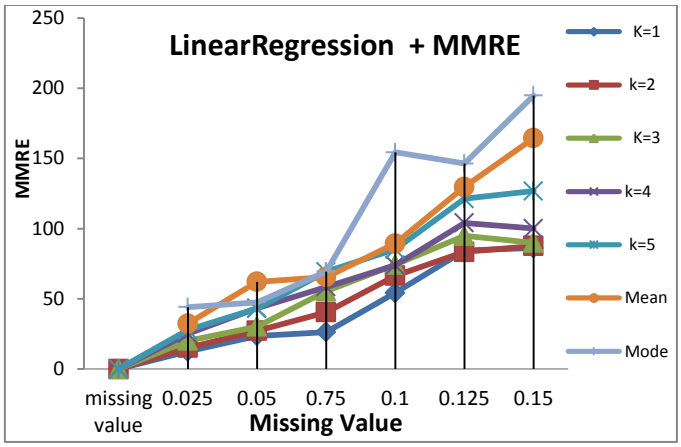


Fig.4. nonlinear polynomial regression (MMRRE)

In this research, a certain amount of error has been calculated for the linear polynomial and non-linear polynomial (squared) regression **Fig5**.

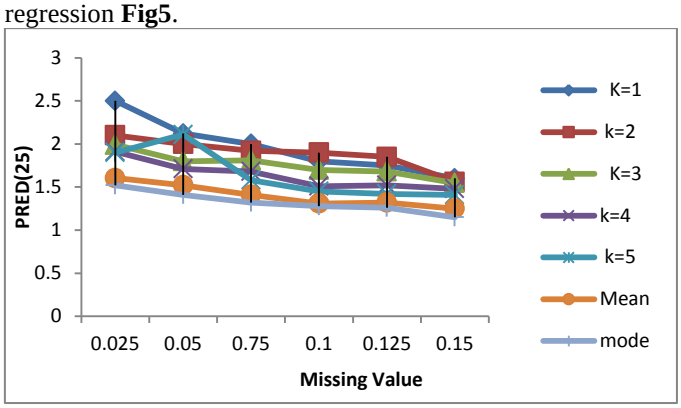


Fig.5. linear polynomial regression (Pred)

It should be noticed that when the amount of PRED (25) increase, the evaluated error rate reduce in the algorithm, and the estimated costs were less or equal to 25 for a larger number of evaluated dataset samples. Therefore, by an increase the rate of incomplete data, the accuracy of studied methods decreases.

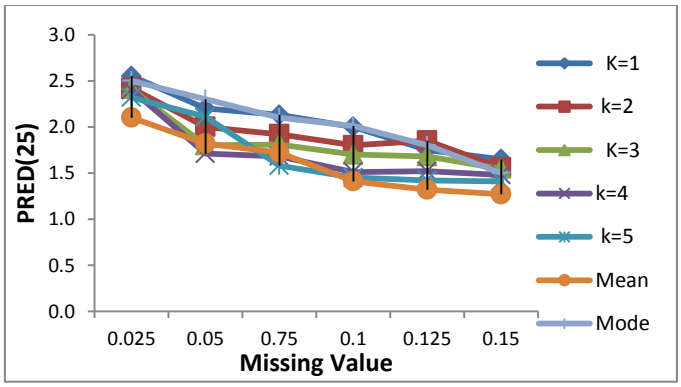


Fig.6. nonlinear polynomial regression (Pred)

We continue our discussion by comparing the proposed method with the results of recent researches. One of the methods which can be applied well in incomplete data, and is focused on recent researches is Bayesian regression, which is a non-parametric method[۱] .In this section of proposed method, we have compared linear polynomial regression with non-linear polynomial (squared) regression by using Bayesian regression method. In order to resolve incomplete data, nearest neighbor method (k=2) has been used. The results of this comparison has been displayed in the table **Fig7** based on PRED(25) evaluation criterion.

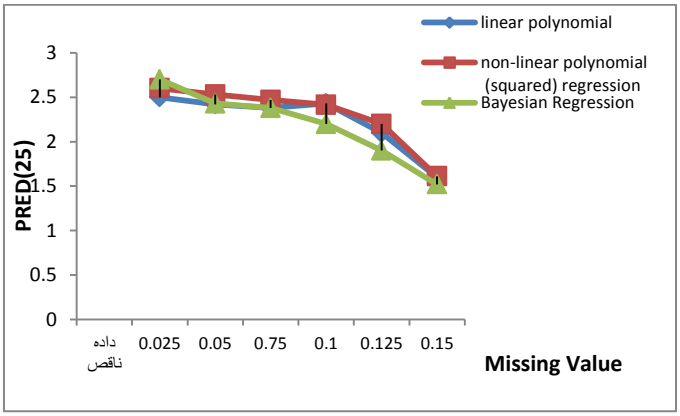


Fig.7.comparing the proposed method (Pred)

In this **Fig7**, it is specified that in most of intervals, the linear polynomial and non-linear polynomial (squared) regression method is better than Bayesian regression method. Because the data is distributed normally (have been normalized), the linear polynomial and non-linear polynomial (squared) regression method works better than Bayesian method in some intervals [۱]. Eventually, we can express this research is complement recent researches. If dataset is normal, we can use the proposed method, which is presented in this research, for estimating software projects with incomplete data. Otherwise, the Bayesian regression method, which has been used in recent researches, is a suitable method for estimating software projects with incomplete data.

VI.CONCLUSION

In this research, we focused on improving the accuracy and reducing the relative error to estimate effort in software projects with incomplete datasets. By using regression methods and resolving incomplete data, we have proposed a combined approach which is important from three perspectives:1) Researches have rarely been done for estimating manpower costs in software projects with incomplete data.

2) Suitable applications are necessary to resolve incomplete data and to maintain optimal efficiency for estimating the parameters.

According to the results, and by comparing this combined approach with recent researches, it can be stated that the

proposed method possess a higher accuracy on the normalized dataset. In addition, it can complement the current research methods.

The proposed method is performed on the CM1 dataset and the results show that the combination of K-Nearest Neighbor and nonlinear regression methods has the best response, signifying accuracy improvement and relative error reduction, in comparing with other approaches.

Our work is limited only to one data set ,which can be expanded further and will use another non-linear regression.

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Merging similarity and trust based social network to enhance the accuracy of trust-aware recommender

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Abstract— Collaborative filtering methods are important and widely accepted technique of user based recommender systems that produce recommendations based on the similarity by the ratings of likeminded users. However, these systems suffer from several inherent shortcomings such as data sparsity and cold start problem. With the development of social network, trust measure introduced as a new approach to overcome the CF problems. On the other hand, trust-aware recommender systems are techniques to make use of trust statements and user personal data in social networks to improve the accuracy of rating prediction for cold start users. In addition, clustering-based recommender systems are other kind of systems that to be efficient and scalable to large-scale data sets but these systems suffer from relatively low accuracy and especially coverage too. Therefore to address these problems, in this paper we proposed a multiview clustering based on Euclidean distance by combination both similarity view and trust relationships that is including explicit and implicit trust. In order to analyze the effectiveness of the proposed method we used the real-world FilmTrust dataset; Experimental results on this data sets show that our approach can effectively improve both the accuracy and especially coverage of recommendations as well as in the cold start problem.

Keywords—cold start, coverage, accuracy, trust-aware recommender system, multiview clustering

I. INTRODUCTION

Recommender systems have been created to provide a list of items suitable for user that rely on the opinions of individuals, to find information of interest to them [1, 2]. Many kinds of methods have been proposed for recommender systems, but collaborative filtering (CF) is one of the most well-known techniques [3, 4]. The essence of CF-based recommender systems is to discover similar users based on their rating profiles therefore Similarity plays an important role in CF techniques. Although CF-based recommender systems gained popularity due to its simplicity, however it suffers from data sparsity and cold start [4, 5]. To better model user preferences for the cold-start users who only rated a few items and sparsity problem, additional user information is often adopted. Comparing with membership and friendship, trust information is of less ambiguity and more relevant to user similarity; therefore formally, trust is strongly and positively correlated with user similarity. Hence trust is able to mitigate the issues of traditional CF such as data sparsity and cold start [4-8].Research has shown that people prefer recommendations from friends to those made by recommender systems. Massa and Avesani [6] analyze the drawbacks of conventional CF-based recommender systems, and elaborate the rationale why incorporating trust can mitigate those problems. They propose Mole Trust algorithm, which performs depth-first search, to propagate and infer trust in the trust networks. Guo et al. [4] proposed a novel method to incorporate trusted neighbors into traditional collaborative filtering techniques. They merge the ratings of trusted neighbors in order to form a new and more complete rating profile for the active users, aiming to resolve the cold start and data sparsity problems from CF suffer. On the other hand Ma et al. [9] propose a social trust ensemble method that linearly combines a social trust and a basic matrix factorization approach. This method is developed by Jamali and Ester [10] their approach focused on where trust propagation is enabled in the social networks. In conclusion, trust-aware recommendations can improve the performance of CF recommender systems; in this regard trust is able to provide an effective view of user preference in addition to similarity.

On the other hand, while confirmed to be efficient and scalable clustering-based approaches to large-scale data sets, but clustering-based recommendation have not been widely exploited in recommender systems.

Most previous researches focused on clustering users from the view of similarity. For example Sarwar et al. [11] base the neighborhood formation on the clustering the members by applying the bisecting k-means algorithm to cluster users in cluster-based recommendation. Finally, they find that in their method the accuracy is decreased around 5% in comparison with the KNN CF method. On the other hand Bellogìn and Parapar [12] show that the accuracy can be improved and even outperform the other Collaborative Filtering approaches by applying more advanced clustering method.

Therefore previous research shows that recommendation based on clustering approaches from similarity view, suffer from comparatively low accuracy; furthermore Coverage remains an unresolved issue too.

In this regard, this paper focuses on the development of a clustering-based approach based on both social trust relationships and similarity based on rating patterns. We adopt the trust as ‘‘one’s belief regarding the ability of other trustee

users in providing valuable ratings''. Whereas, recommender system based on clustering suffer from relatively low accuracy and coverage. Therefore to cope with the above-mentioned issues, we develop a multiview clustering approach by making use of both the view of similarity and the view of social trust based on Euclidean distance. In multiview clustering approach user with different views integrated with each other in this regard more users' recommendation can be selected as an option for other users so directly coverage can be improved.

On the other hand to ameliorate accuracy prediction for cold-start users (users who cannot be clustered due to insufficient data), we proposed a novel trust-based approach by incorporating the explicit and implicit trusted neighbors.

In summary, the main contribution of this article is organized as follows: section 2 gives a brief overview of trust-aware recommender system. In section 3 we proposed a multiview clustering method based on the views of trust and similarity. The proposed method, including aggregating trust neighbors and merging the rating of them, determining the similarity based on confidence, and rating prediction on a target item is present in detail in section 4. In section 5 we behave a series of experiments on film trust real-data set to verify the impressiveness of the proposed method. Finally, some concluding comments are made in section 6.

II. TRUST-AWARE RECOMMENDER SYSTEM

Recent research shows that incorporating trust information in recommender systems improving the quality of recommendation [4, 6, 7and 13]. Using trust can efficiently improve the accuracy prediction of recommender systems in comparison with traditional CF algorithms [6, 14]. Besides similarity, other factors like trust also play important role in providing high quality recommendations. Trust identify as efficient way to improve the recommendation quality and utilize the social network. In this regard various techniques proposed to employ trust information into the CF approaches which especially it called trust-aware recommender system [6, 10, 14, 15].Trust-aware recommender system method are divided into two main approaches containing explicit and implicit [16, 17].The explicit trust of the other users is used to calculate the direct trust value between each pair of users in social network [16]. The Implicit trust is calculated via implicit information obtained from a social network [17].moreover, the implicit approach makes inferences from the trust statements between the users on the base of the item rating [17, 18].An undefined trust value is roughly predict based on the supposition that users nearer in the trust network to the active user have higher trust value [14]. Finally, trust-aware recommender systems present opportunity for recommendations by utilizing users' trust statements especially for systems whose rating data is sparse [4, 19].

III. MULTIVIEW CLUSTERING IN RECOMMENDER SYSTEM

The clusters analysis is an important research field in the data mining, the main goal of these algorithms is to recognize natural groups among thousands of pattern. So clustering algorithm be able to group together the users or items with the same properties [15, 20]. The k-means and k-medoids algorithms are the most well-known partitioned clustering methods due to their effectiveness and simplicity [21-23].Since the k-means produce a cluster center by averaging all the values of each characteristic, it will remove significant personal information for instance trusted neighbors. As a substitute, the k-medoids clustering algorithm chooses a real user as the centroid that minimizes the summation of pairwise distances inside a cluster [22, 24].

The multiview clustering algorithm was introduced for the first time by [25] and this method develop through that rating pattern and social trust by [26]. The basic idea is to search for clustering in different subspaces of a user space. Users have two different kinds of information, namely trust information (social connections) and ratings information issued on items of interest for users. Hence, these types of information describe users from different views specifically, trust links and rating patterns (user behaviors) together. In this section, we intend to cluster users using both ratings and trust information. Mathematically [22], the objective function is given as follows:

$$J = \min \sum_{c \in C} \sum_{u,v \in c} d(u,v) \tag{1}$$

$$d = d_s^2 + d_t^2 \tag{2}$$

Where users u and v are members of cluster, C is a set of clusters, $d(u,v)$shows the distance of users u and v based on Euclidean distance that calculate by equation(2). Then the k-medoids algorithm adopts in order to preserve individuals' ratings and trust information. User similarity is used as the distance metric to measure the closeness of two users; the Pearson correlation coefficient [1] adopted to compute user similarity:

$$S_{u,v} = \frac{\sum_{i \in I} \left(r_{u,i} - \bar{r}_u\right)\left(r_{v,i} - \bar{r}_v\right)}{\sqrt{\sum_{i \in I} \left(r_{u,i} - \bar{r}_u\right)^2} \sqrt{\sum_{i \in I} \left(r_{v,i} - \bar{r}_v\right)^2}} \tag{3}$$

Where $S_{u,v} \in [-1,1]$ denote the similarity between users' u and v; $I = I_u \cap I_v$ denote the set of items commonly that are rated by both users u and v. and finally, the average of ratings given by users u and v are $\bar{r}_u$ and $\bar{r}_v$, respectively. The user distance is thus computed by equation (4).

$$d_s = 1 - S_{u,v} \tag{4}$$

Second, distance trust calculate using the trust information by Mole Trust[6]. The closer two users are located, the higher trustworthiness the users have.

$$t_{u,v} = \frac{1}{d_{u,v}} \tag{5}$$

Where $t_{u,v} \in [0,1]$, is the dependability of user *v* relative to user *u*, and $d_{u,v}$ is the minimum distance between two users according to the trust network. The trust distance d_t, is thus computed by equation (6):

$$d_t = 1 - t_{u,v} \tag{6}$$

And similarity distance d_s, is thus computed by equation (7):

$$d_s = 1 - s_{u,v} \tag{7}$$

The pseudo code of our multiview clustering algorithm is presented in Algorithms 1:

Algorithm1 multiview clustering based on Euclidean distance

Input: *distance matrix D_s, D_t , Sort Trust ; cluster number k*
Output: *user cluster C*

1 $p \leftarrow 0$

2 $disvim \leftarrow \left(d_s^2 + d_t^2\right)$

3 *randomly select k medoids* m_{medids} *from dataset Sort Trust*

4 $C_{disvim} \leftarrow v$, *give* $\min(d_{disvim}(v, m_t))$;

5 *while medoids change and < max iteration do*

6 $p \leftarrow p + 1$

7 *calculate* $sum(u) = \sum_v d_{disvim}(u,v), v \in C^{p-1}$

8 *if* $sum_{disvim}(u) < sum_{disvim}(m_{disvim})$ *then*

9 $m_{disvim} \leftarrow u$

10 $C_{disvim} \leftarrow u$ *for* $\forall v$ *find* m_{disvim} $s.t \min(d(d(v, m_{disvim})))$

11 $swap(m,u), u \in C^{p-1}$

In Algorithm 1, the rating distance and the trust distance are combination together via Euclidean distance then Euclidean distance as inputs to the multiview clustering algorithm which outputs the clusters of users.

IV. PROPOSED METHOD

In this paper, clustering base trust-aware recommender system by using a multiview clustering algorithm is proposed. The proposed method consist of four phases which shown in fig 1. In the first phase, trust matrix is applied to collection the trust user. This phase consists of two steps that include: finding implicit trust also calculates explicit trust by mole trust. Then obtain the trust distance by both of trust neighbors. In the second phase, rating matrix is applied to earn similarity between users, the Pearson correlation coefficient adopted is one of the most well known techniques to compute user similarity, and therefore we used it. The similarity distance is computed. Then in the three phases, a multiview clustering based on Euclidean distance algorithm is applied to group the similar user in several clusters by trust distance and similarity distance. Based on this new distance, the k-medoids algorithm can be applied for clustering users that have higher similarity. Finally, in four phases, for each unseen item, a rate is predicted for recommendation to the active user. Prediction is based on the cluster's member rating and by similarity based on confidence.

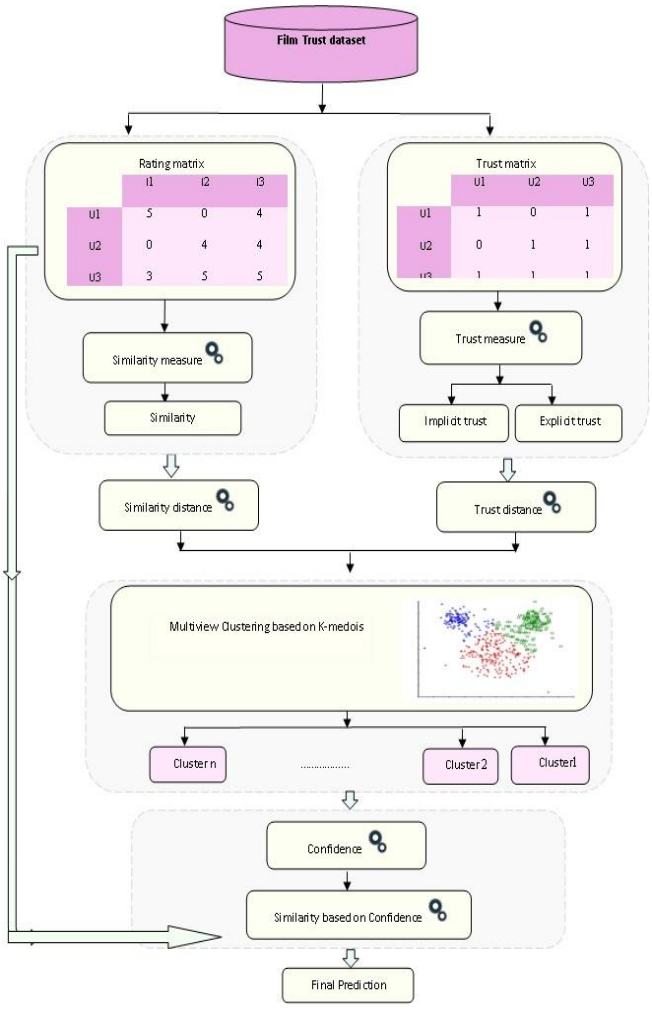


Fig.1. *Overview of proposed method*

4.1. Prediction

After determination the trustworthy neighbors, all the ratings of trusted neighbors merged into a single rating based on the weights of trusted neighbors [4] is defined as follow:

$$\tilde{r}_{u,j} = \frac{\sum_{v \in TN_u} W_{u,v} \cdot r_{v,j}}{\sum_{v \in TN_u} |W_{u,v}|} \tag{8}$$

That is, $\tilde{r}_{u,j}$ is the merged value for user u on item j based on the ratings of all the trusted neighbors, and $W_{u,v}$ represent the importance weight of user *v*'s ratings relation to the user *u* [4]. The weight $W_{u,v}$ is consisting of three parts: trust value $t_{u,v}$,

rating similarity $S_{u,v}$ and social similarity $j_{u,v}$ so, $W_{u,v}$ is computed by equation (9):

$$W_{u,v} = \alpha S_{u,v} + \beta t_{u,v} + (1-\alpha-\beta).j_{u,v} \quad (9)$$

The social similarity is computed by the Jaccard Index and specified as the ratio of common trusted neighbors over all the trusted neighbors, by equation (10):

$$j_{u,v} = \frac{|TN_u \cap TN_v|}{|TN_u \cup TN_v|} \quad (10)$$

Where TN_u and TN_v are the trusted neighbors user *u* and *v* respectively and $j_{u,v} \in (0,1]$.

However, the quality or usefulness of the merged ratings is unknown. Therefore determining the confidence [27] of the merged ratings by equation (11):

$$C_{u,j} = C(p_{u,j}, n_{u,j}) = \frac{1}{2}\int_0^1 \left| \frac{x^{p_{u,j}}(1-x)^{n_{v,j}}}{\int_0^1 x^{p_{u,j}}(1-x)^{n_{u,j}}\,dx} - 1 \right| dx \quad (11)$$

Where, $C_{u,j} \in (0,1]$ is rating confidence $p_{u,i}$ and $n_{u,i}$ referring to the number of positive and negative rating which provided by the trusted users.

In addition to the merged ratings, the confidence is also important to show the quality of the merged ratings of trust neighbor. Therefore introduce a confidence-aware *PCC* [4] to compute user similarity in finally prediction, denoted by $S'_{u,v}$:

$$S'_{u,v} = \frac{\sum_{i \in I_{u,v}} c_{u,i}(\tilde{r}_{u,i} - \bar{r}_u)(r_{v,i} - \bar{r}_v)}{\sqrt{\sum_{i \in I_{u,v}} c_{u,i}^2 (\tilde{r}_{u,i} - \bar{r}_u)^2}\sqrt{\sum_{i \in I_{u,v}} (r_{v,i} - \bar{r}_v)^2}} \quad (12)$$

Where $I_{u,v} = \tilde{I}_u \cap I_v$ refer to the set of items is rated by both users' *u* and *v* after the merging process, and $\tilde{I}_u$ consists of the items that rated by at least one trusted neighbor, $\bar{r}_u$ and $\bar{r}_v$ are the average ratings for users' *u* and *v* respectively, and finally $c_{u,i}$ is the confidence measurement.

Finally, all the rating's users which pertain to the multiview clusters are accumulating to produce a final prediction on a target item *j* that the active user *u* has not rated. So Prediction [4] calculates the average value of all ratings provided by the nearest neighbors *v* weighted via similarity based on confidence $S'_{u,v}$, and formally it computed by:

$$\hat{r}_{u,j} = \frac{\sum_{v \in MV} S'_{u,v} \cdot r_{vj}}{\sum_{v \in MV} |S'_{u,v}|} \quad (13)$$

V. EXPERIMENTS

In order to verify the performance of the proposed method, various experiments were performed with pure multiview clustering, in addition to a number of trust-based method in recommender system. Specifically, the proposed method was compared to the multiview by regarding both of trust and similarity view separately, that the basic model of multiview clustering according to similarity and trust [26], the pure Collaborative Filtering (CF)[3], the basic model of trust-aware recommender system based on Mole Trust [6], and the merge method [4].

5.1. Dataset

In this paper, real-world FilmTrust dataset (trust.mindswap.org/FilmTrust/) is used in experiments. That consists of 1642 users, 2071 movies. This dataset is a trust-based social site that users can rate the interested movies besides this site allows users to share movie ratings and explicitly specify to other users. The users of FilmTrust website will be able to review items and assign them numeric ratings values in the range 0.5 (min) to 4 (max) with step 0.5. Therefore FilmTrust is a dataset that contain both the user-item ratings and data of explicit trust too.

5.2. Evaluation measures

The leave-one-out method mostly is used to compare two recommendation systems [6].In this method, in each step user rating is hidden from the dataset and then its value will be predicted by applying a definite method up to all the testing ratings are covered, finally main value is compared with the predicted rate obtained by the recommendation method. In this paper, the evaluation is former by applying this method on the two data views including cold start and all user. Then the experimental results are analyzed according to the accuracy and coverage measures by Mean Absolute Error (MAE) [12] and Rating Coverage (RC) [12] respectively. The evaluation metrics are described as follows:

$$MAE = \frac{\sum_{i=1}^{n} |r_i - r_p|}{N} \quad (14)$$

Where, r_i is real rating and r_p is predicated rating of the item, *i* for the active user. Also, *N* is the total number of testing ratings.

In addition, the rating coverage defined as number of predictable ratings (*M*) over the all testing ratings (*N*), it given by equation (15):

$$RC = \frac{M}{N} \quad (15)$$

5.3. Result and analysis

In this section, we present a series of experiments on FilmTrust dataset to demonstrate the effectiveness of our approach. Finally results for both view all user and cold user are reported in the table1.

TABLE1. THE MAE AND RC RESULT OVER THE FILMTRUST DATASET

View		Approach measured by MAE,RC			
	Measure	***CF***	***Mole Trust***	***Merge***	***MV based on Euclidean distance***
All Users	MAE	**0.703**	0.771	0.708	0.7795
	RC (%)	%93.84	%30.38	**%95.06**	72.17%
Cold user	MAE	0.744	0.819	0.768	**0.7001**
	RC (%)	%39.64	%23.19	%54.28	**%65.75**

From the table 1 results, it can be conclude that for cold user the proposed method outperformed than the other methods. On the other hand, the result shows that this method obtained the lower values in MAE for all user view; moreover result also show that merge method obtained the higher rate coverage from this view.

5.4 performances for cold users

Whereas the main objective of this research overcomes the accuracy and coverage of cold users, therefore in this section we compare the proposed method with merged method.

The parameter θ is an important parameter that is used as the threshold value and this parameter shows of the proposed reliability measure. Therefore In this paper we used varies the threshold θ from 0.0 to 0.9 with step 0.1 to test the performance of the proposed method based on 3, 5 and 10 cluster in compare merge method for the FilmTrust dataset. Fig. 2 and Fig. 3 reports the results of different θ values on the proposed method over MAE and RC measure respectively.

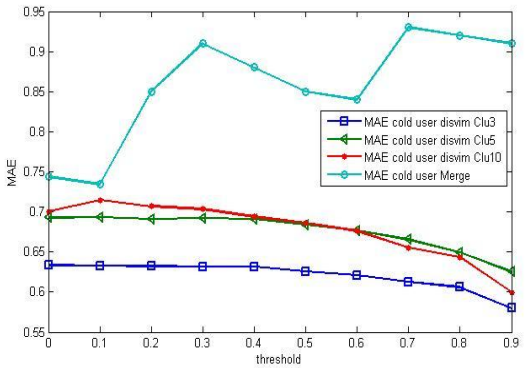


Fig.2. *the MAE in the view of Cold Users*

The result according to fig.2 shows that MAE measure depend on the threshold value and based on the proposed method according to 3, 5 and 10 clustering, performance to be better than merge method. So multiview clustering can be improved the accuracy of cold user in cluster-based recommendation.

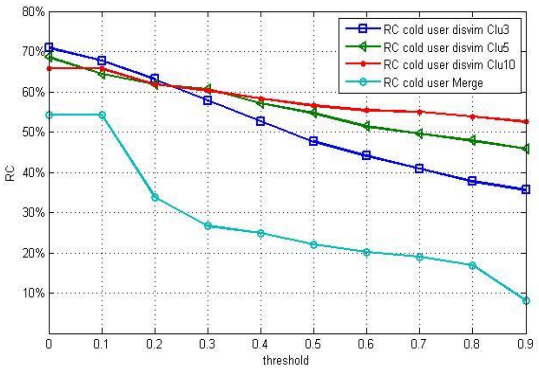


Fig.3. *the RC in the view of Cold Users*

The results coming from fig.3 show that when the value of θ increases, the value of the rating coverage will be reduced. So it can be concluded that the lower value of θ improving the coverage measure. On the other hand, the higher value of threshold results reducing the rating coverage (RC). Furthermore, in comparison with merge method we obtain that proposed method achieve best result; it confirms that multiview clustering to improve the coverage cold start user.

VI. CONCLUSION

Traditional user-based recommender systems like CF-based recommender systems are proposed the likeminded user for providing the recommendation based on similarity. Cold start is one of the main problems of these systems. Trust is a concept that has recently takes much attention to improve the cold start problem. This paper proposed a novel method for trust-aware recommender system by multiview clustering based on Euclidean distance to alleviate the cluster-based recommender system problems including: the low accuracy and coverage. In the proposed method, According to Euclidean distance, similarity-based distances and trust-based distances combined together. Then User Clustered by applying a k-medoids clustering method based on this new distance. In addition to accommodate the accuracy prediction's cold start users (the users who have rated less than five items) in this clustering method we employed both of the implicit trust and explicit trust for trust statement.

The experimental results on FilmTrust dataset showed that (1) the combination of similarity pattern and trust information were the useful in determining a real prediction for active user; (2) the multiview clustering method outperformed the accuracy and coverage and it can effectively handle especially for cold start problem.(3) our proposed method worked better than other user-based recommender system approaches. To sum up, the proposed method effectively increase clustering-based methods by asset of the combination view of trust information and similarity.

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A Novel Method for Malware Detection Using Audio Signal Processing Techniques

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***Abstract*—Malware is any kind of program that is designed to perform malicious activity in computers and networks. To evade traditional signature-based malware detection techniques, malware developers employ obfuscation techniques. Two main type of obfuscation techniques are polymorphism and metamorphism. New approaches for detecting obfuscated malwares are commonly based on machine learning techniques to extract features from binary bytes, opcode sequence or function calls of programs. In this paper, we propose a novel method based on audio signal processing techniques. We represent binary bytes as audio signals and then apply Music information retrieval (MIR) techniques to find musical patterns using MFCC and chromagram features in them. Then, we create machine learning model based on extracted features in order to classify new samples. Our technique is light weight and consumes low memory. To evaluate effectiveness of our method, we have done several experiments. The results of these experiments show that our technique has good accuracy while it is low memory and time consumption.**

Keywords—malware; malware detection; audio signal processing; MFCC; classification

I. INTRODUCTION

Malware or Malicious Software is a software that is designed to perform malicious activity such as gaining unwanted access to private computers of network, sensitive data manipulation or stealing confidential data [1]. Malwares are categorized in viruses, worms, Trojans, spywares and rootkits.

With the popularization of computer and web, the number of malwares increases dramatically. So defense against malwares is an important topic in computer and network security. Most free and commercial antivirus products are based on traditional signature-based techniques for detecting malware. Signature is a sequence of bits or bytes in a malware that is unique in this program and finding an instance of this sequence in a executable file indicates that this file is a malware or a benign. This approach is accurate and fast but cannot find new instances. In order to evade this technique, malware writers employ new method called code obfuscation [2].

Code obfuscation changes the structure of program while function remains unchanged. Obfuscating makes new different instances of a program, so signature based detectors cannot detect these new programs and they have to update with new signature database that is difficult and time consuming.

Two main type of code obfuscating are polymorphism and metamorphism [3]. A polymorphic virus encrypts its code and has a decryptor that decode encrypted code when program is running in the memory. With the help of dynamic analysis, we can find this type of malwares easily. On other hand a metamorphic virus are more robust against detecting and change itself in each infection. Register swapping, subroutine permutation, Garbage instruction insertion, Instruction substitution and Transposition are a few simple of morphing techniques.

Many techniques have been proposed to detect obfuscated codes. Static analysis or behavioral pattern analysis of programs can be employed as a method to coping with obfuscating. Static analysis relies on feature extracted from files, while dynamic-based analysis are based on features that are extracted from executed program (program in memory) for example system resource usage pattern [4]. Static analysis can provide us more usable information because many malwares don't fully act in emulation environments. But in case of polymorphic viruses because of malicious code encrypted in file, in many cases static analysis cannot bring us usefull information for detecting them and in this case dynamic analysis is more usable.

Static approaches are categorized in low-level and high-level methods. In Low-level approach, features are obtained directly from binary of files. For example, byte sequence, the string in content of file or PE header are used as input data for these techniques.

Second one, uses higher level information from file, for example create call graph of API or function calls for finding similar graphs, or disassemble file and extract opcodes in order to constructing similarity matrixes of opcodes to measure similarity between files [5]. This approach is more fallible than the low-level approach because extracting features are not always done correctly. for example opcode sequence of a program cannot be taken from polymorphic malwares directly or many virus programmers use some techniques to conceal API calls and causes to find them hard and error-prone. Also, low level approach is faster than high

level in feature extraction phase and even in classification phase.

In this research we propose a novel approach for distinguish malwares from benign using audio signal processing techniques. In Music information retrieval (MIR) field, some feature are obtained from the music for classify based on content or genre, and retrieving other useful information about songs [6]. in MIR we are trying to find musical patterns from a song and measure similarity between them for classify them by genre, rhythm or speaker. A music in fact is consists of sequential music notes that generate by musical instruments like piano. On the other hand, a program is also a sequence of bytes that generate by a compiler. because of the similarity between a music and a executable file at this aspect, we have proposed a method to represent binary file as a music and then we have applied MIR techniques in order to find musical patterns in intended music and finally, we have used the resulted features for classifying them.

We shows that our technique has acceptable accuracy for detecting malicious programs. Our detection method has two points of strength: it does not need to extract high level features from executable and needs only some bytes of files to classify them, and also it is fast and is low memory and time consumer that makes it to use as real time virus detector.

This paper is organized as follows. In Sect. 2 we discuss related work in static malware detection both in byte level and opcode level. Section 3 provides background information about digital music classification and generation. Sect. 4 covers our novel method to detecting malwares with MIR techniques. In section 5, we provide experimental results of this technique and compare it to other methods. Section 6 contains our conclusion and a consideration of possible future work.

II. Related Work

In this section, we discuss a few representative sample byte level techniques which have been done on malware classification.

Y.Zou and M.Inge [7] proposed a novel byte-level method that used Prediction by Partial Matching (PPM) [8] which is a compression based algorithm for creating Benign and Malware models. Then, employing these models for classification of the new files. Each file is compressed by malware and benign models independently. After that, the model with higher compression rate determines appropriate class for the file. The idea behind the compression based classifiers is that compressing a sequence of bytes is only possible when some statistical patterns occur in bytes. So, if the higher number of similar patterns appear in two sequences of bytes, there is a chance that these two are in the same class. The most disadvantage of compression based classifier methods is that the high memory usage of maintaining compression models. So, instead of using the entire content of the file, their method ignored PE header and used the first block of executable after omitting null bytes to improve the memory complexity. We should consider that, if memory constraint doesn't exist, creating models and predicting new instances are time consuming.

Z. Khorsand and A. Hamzeh improved PPM compression based method with smarter selecting program bytes for creating PPM models [9]. They proposed two new method which the first uses PE header bytes for creating models and the second uses ASCII Strings that have length of four bytes or higher as input of training PPM models. They showed that this approach has higher performance than the models constructed from the subset bytes of the program content, and even needs smaller memory. Memory requirement problem is still exist in this approach that makes it difficult to use in real time virus detection. They indicated that with increasing the order of PPM the accuracy of method increases but memory constraints don't allow to use high PPM order and even to use high number of samples for training models.

In the method proposed in [10], J.Z. Kolter and M.A. Maloof, all n-grams of each executable file in the dataset are generated and then, the most important n-grams that gain highest information about file are selected as features of file. They give these features to machine learning classifiers such as SVM, Naïve Bayes and decision trees for detect unknown malware instances. This work uses binary of programs as input data and is analogous to our method in this aspect.

For an example in machine learning methods that worked with opcode sequence of files for feature extracting and classifying new instances, we introduce Santos et al. [11] provided method, that is a data mining approach which is based on frequency of opcode sequences that appeared in programs. They found relevance of opcodes with data mining techniques and obtained the weighted term frequency (WTF) for each fixed length opcode sequence in the file. Then features was constructed by these frequencies and then, they used for compute the similarity between malware and benign samples and also, to train machine learning classifiers in order to detect new instances. This approach uses high level features and need to disassemble files that is error-prone and time consuming and is not very robust against packed files.

III. Background

In this section we briefly discuss following topics: Generating programmatically music audio signals with MIDI standard in computer, Music classification techniques based on music content and music genre also the most used audio features in MIR field that represent musical patterns of a sound for classification tasks.

A. Midi Files

MIDI or Musical Instrument Digital Interface is a language for generating digital music from information in real time [12]. MIDI does not define the sound itself, but contains only a sequence of instructions or MIDI messages to create the sound by a synthesizer. Synthesizer is a software or hardware that generates digital or analog sound signals from MIDI messages and sends it to an output channel like speakers or a wav file [13]. The main messages in MIDI are the "Note On" and "Note Off" message. The "Note On" message is sent

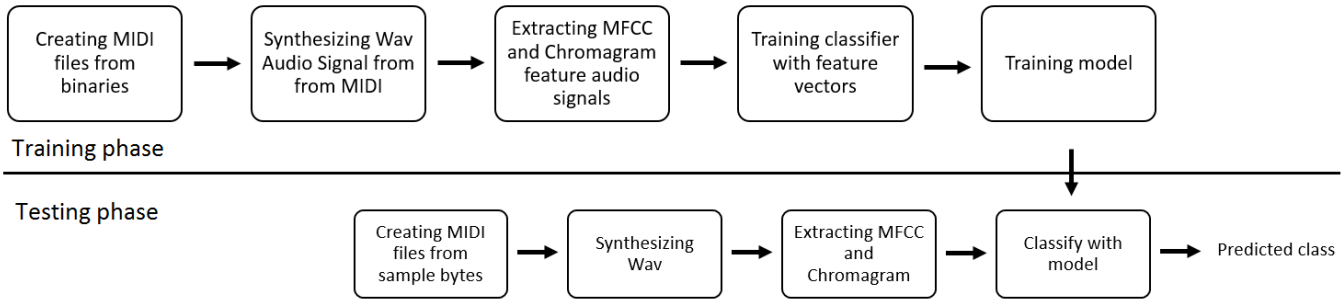


Figure 1 Proposed Method

when we want to play a musical note such as C# 3 on a piano. When a synthesizer receives this message it starts playing expected note with correct pitch and volume level. The "Note Off" message causes the synthesizer to stops playing corresponding note. If a "Note Off" message doesn't receive, the synthesizer continues playing the note. The pitch value in "Note On" message determines the frequency of the note to be played that is from 0 to 127 and the middle C note being represented by the value of 60. The velocity value in "Note On" message specifies the sound volume of the note to be played. It affects note sound loudness and also the quality of the sound (the timber).

To tell the synthesizer what sound (musical instrument) must be used to play notes, we need to use "program change" message. With the use of this message, we can determine instruments for playing notes. For example, piano or guitar. General MIDI (GM) standard defines a list of 128 instruments that simplifies compatibility in platforms, for example the piano is 1 and the acoustic guitar is 25 [14]. Each instrument only can play distinct pitches (some frequencies). For example, an acoustic piano has 88 keys, or 88 distinct pitches/notes.

For playing multiple notes from several instruments in the same time, MIDI provides us up to 16 channels. Each channel can contain notes for a distinct instrument. Channels are independent in velocity, note messages and instruments. For example, we can use a channel for playing piano notes and another for guitar and third channel for violin. Using MIDI files for creating artificial sound signals in computer is a fast and accurate way.

B. Music Classification

Automatic music classification based on their genre is a challenging task in digital audio signal processing [15]. Audio signal processing tasks are done in both time and frequency domain. Typically signal divides into frames based on their times and then a frequency domain process such as MFCC or chromagram is done on entire frame for extracting features from each frame. Then the bag of feature set can be used to training a classifier like SVM.

C. Chromagram features

The Chromagram or Harmonic Pitch Class Profile are features represent melodic and harmonic information of the song by using a projection of the spectrum onto 12 bins where each bin represents one of the 12 tone of the musical octave. These tones are C, C#, D, D#, E, F, F#, G, G#, A, A# and B. We can use these features for music chord recognition. Chroma based features could be used for MIR tasks like pattern discovery and audio thumbnailing [16].

Chromagram features are in time domain and for a specific time each bin value indicates the amplitude of its bin at this time.

D. MFCC

The Mel-frequency cepstrum (MFC) is a representation of the short-term power spectrum of a sound, based on a linear cosine transform of a log power spectrum on a nonlinear Mel scale of frequency and commonly used in signal processing tasks as audio features for music classification, speaker recognition and speech recognition [17]. Mel-frequency cepstral coefficients (MFCCs) are short-term spectral-based features of a sound. They are derived from a type of cepstral representation of the audio clip. The name Mel comes from the word "melody" to indicate that the scale is based on pitch comparisons. The difference between the cepstrum and the Mel frequency cepstrum is that in the MFC, the frequency bands are equally spaced on the Mel scale, which approximates the human auditory system's response more closely than the linearly-spaced frequency bands used in the normal cepstrum. This frequency warping can allow for better representation of sound. For each tone with an actual frequency, f, measured in Hz, a subjective pitch is measured on a scale called the 'Mel' scale. The Mel-frequency scale is linear frequency spacing below 1000 Hz and a logarithmic spacing above 1000 Hz. As a referencing point, the pitch of a 1 kHz tone, 40 dB above the perceptual hearing threshold, is defined as 1000 Mels [18].

IV. Proposed Method

In this paper, we employ techniques from Music Information Retrieval (MIR) field as a means for computing similarity between files to detect unknown malwares. Music is a sequence of notes that are played in a time sequence. Each musical note has a specific frequency in Hz and shape. Shape of a note determines by instrument that plays it. For example, shape of note C in octave 1 by piano is different from the same note with equal octave on the guitar. One of the most interesting studies in Music Information Retrieval field is to

find musical patterns in a sound and classify sounds by their genres like Pop, Rock or Jazz. On the other hand, binary files like Windows Executable (EXE) and DLL are a sequence of bytes with some byte patterns. Due to this analogy between a binary file and a music, we use Music classification techniques for detecting malwares by representing binaries as music signals and then apply MIR feature extraction techniques on these signals to find patterns and give it to a classifier for detecting class of new unknown file.

Our technique is static and use low-level bytes from programs for creating music and then classifying them, so It doesn't need to disassemble and extract opcodes or finding called APIs or functions. Also, because of our approach is in byte level, there is no different for the method to treat with packed and unpacked files. This technique is light-weight and fast while it doesn't need large memory space and works with only 48 MB of RAM for 2000 training samples, so it can be used as a real time virus detector in online environments.

This method consists of four main steps: Generating MIID from binary files, generating audio signal from MIDI, applying music classification techniques for extracting audio features and training classifier and detecting the class of new instances. An overview to our method is depicted in Figure 1. In the following, we will explain each step of proposed method.

A. Generating MIDI from binaries

In the first step, we construct MIDI files from each executable file. For this purpose, we select 2nd 512 bytes of each file because most of the first bytes of PE files are similar. Musical note in MIDI instruments are in range 0 to 127 and moreover in real, they support musical notes less than 128, for example Piano supports up to 88 notes that is not sufficient for mapping every byte to a MIDI note because a byte values is the range of 0 t0 255, so we need at least two notes for mapping a byte to MIDI. For this reason, every byte divides into two halves. The upper half consists of 2 most significant bits (bit 7 to 8) and the lower covering other 6 bits (bit 1 to 6). The MIDI file is created in two channels that each channel is programmed by a different musical instrument. Then, each half value is used as an index for selecting a MIDI note for relevant channel, the upper half is used to map bits 7 and 8 to a note in first channel and the lower is used to map bits 0 ta 6 to a note in second channel.

For example, suppose that a byte with value 0D8 in hex that is 11011000 in binary. Then the upper half is 3 (11b) and lower half is 24 (011000b). So, the midi notes (pitch) number in channel 0 will be 3 + n, and the note number in channel 1 will be 24 + m, that n and m are constant values. These two notes play in the same time and also have same duration to play.

In music theory, tempo is time between successive notes and is indicated in beats per minute (BPM). for example, tempo 480 means time between successive notes are 0.125 second. We should determine tempo for each channel in MIDI files. We have chosen tempo 480 for all channels in MIDI files that results in generating lower size audio files in the next step. Notes in real have attenuation. When a note is played in a specific tempo, the sound of note continues playing for some time after its duration and loses its energy gradually. So, in content of the generated signal of a note we have some track from previous notes and this situation is good to demonstrate dependency of bytes in a pattern in fact, each musical note signal (represented program byte) has some information from previous notes (bytes).

B. Synthesize MIDIs to generate Wav files

MIDI files are only a sequence of messages that needed for creating real audio signals so we need to render them for producing music signals. In this step, we generate .wav audio file from MIDI files by a MIDI synthesizer. A MIDI synthesizer is a tool that parse midi events and synthesize sound signals by a sound font. A sound font is a library that contains instrument note signal data and information about synthesizing them [20]. We are used General MIDI Sound Font 3 (GM3) as sound font for generating our Wav files. Sampling rate of generated audios are important for quality of features for classification. The more sampling rate the more accurate audio features but this cause to generate bigger wav files that require more memory space and increase computing time complexity in feature extraction step. Then we chose 22050 Hz as a tradeoff for sampling frequency of Wav audio files.

C. Feature extraction and classification

In this step, most common audio features that are used for computing similarity measure between audio files are extracted from wav files that are generated in previous step. MFCCs and chromagram are desirable features because they are most important representations of speech/music for audio/music classification task. In addition to these features, Zero Crossing Rate, Energy, Entropy of energy, Spectral centroid, Spectral spread, Spectral entropy, Spectral Flux and Spectral Rolloff are extracted. For get more information about these features go to [19]. MFCCs and chromagram overhand are 26 elements so every feature vector has 34 feature.

We use pyAudioAnalysis library that is a python tool for a wide range of audio analysis tasks, including feature extraction, classification, segmentation and visualization [19]. Extraction process is done in short-term that means audio signal divide into 500 msec frames with 250 msec steps that make overlapping between side by side frames. Then, features are computed for each frame independently. With selecting 480 as tempo, each note plays for 125mse so, the reason for choosing 500 msec as the frame size is to covering each frame more than one note (in fact more than one byte of executable file. Furthermore, overlapping in frames causes to consider one byte in more than one frame, so, indeed extracted features represented continuous byte sets that appear in executables. Thus these features can be used for measure similarity between music signals that here are represents of the executables in fact.

In the final step, mean of feature vectors for a file are computed and are considered as feature of file. Then, we train a machine learning classifier (for example KNN or Random

Forest) with these features to create classifier model. We use this model to predict class of unknown files.

V. Experiments and Results

This section provides information on our experimental results. First, we summarize the hardware and software used in the experiments. Then we present and discuss our main results and compare proposed approach to other relevant methods.

A. Dataset

A dataset with 3400 samples contain both malware and benign samples are selected. It is a mixture of PE and non-PE files. These files can be packed or unpacked, because our approach relies on bytes and doesn't sensitive to this problem.

B. Benign Dataset

The benign dataset files are selected from original Windows XP files and other utility software. For insure that these files are not contain of malicious contents, we were scanned them with ESET NOD32 and Kaspersky antiviruses. Benign dataset consists of 1600 EXE and DLL. They are divided randomly into two subset of training set with 1100 samples and testing set with 500 samples. The size of benign files is in the range of 1KB to 15MB.

C. Malware Dataset

Malware files were collected from 'VX Heavens' virus collection. Dataset of 'VX Heavens' can be download from http://vxheaven.org. Analogous to benign dataset, malware dataset is also consisting of 1600 samples that were grouped into 1100 training and 500 testing samples. The dataset includes different kinds of malware such as Virus, Trojan, Backdoor, Hacking tools and Rootkits. Size of malware files are in the range of 1KB to 11MB.

D. The Experimental Environment

All experiments have done under the environment with following specification:

Ubuntu 15.10 as operating system, Intel(R) Core(TM) i7-930@2.80GHz processor and 6.0GB of RAM. We have used sklearn package [21] and WEKA [22] as a library for classification tasks and pyAudioAnalysis library [19] for audio feature extraction tasks.

E. Discussion of the results

In the first experiment, we show the performance of our method. First, training dataset were trained with KNN (with N= 9 as the best N), AdaBoostM1 and RandomForest (with 100 trees) classifiers. To evaluate the competency of our proposed method, we used some common performance evaluation metrics such as True Positive Ratio (TPR), False Positive Ratio (FPR), Precision, Recall, Accuracy and F-measure.

To train the classifiers, we have generated MIDI files with tempo 480 from 2nd 512 bytes of files that each byte was mapped to two musical piano notes in two different channel in the same time. Then, we synthesize them to produce real audio wav signals with 22050 sample bitrate. In the next step, we have used pyAudioAnalysis library to divide signals to equal 500msec frames with 250msec as frame step size. Due to considering tempo 480 in generating MIDI files, the time between successive notes are 125msec. So, we have chosen 500msec for frame size to in fact considering 5 sequence bytes of executable file in each frame as measuring byte pattern length and because our steps are 250msec, so successive frames are common in representing of 2.5 bytes of file. Then, audio features are extracted (MFCC and Chromagram) from each frame. Mean of all frames for a sound are computed to get a feature vector per file. We have given these feature vectors to classifiers for creating appropriate model. Finally, we have used these models to predict proper class for each training sample. Results of classifiers are shown in Table 1. They are achieved by selecting best parameters for each classifier. A ROC curve (Receiver Operating Characteristics curve) for the classifier are obtained in Figure 2,3,4.

TABLE I. Results of Proposed Method

Classifier	TPR	FPR	Precision	Recall	Accuracy	F-Measure
KNN	0.90	0.10	0.90	0.89	90.0	90.0
AdaBoost	**0.92**	**0.07**	**92.2**	**92.2**	**92.2**	**92.2**
Random Forest	**0.92**	0.08	92.0	92.0	92.0	92.0

F. Comparison with another byte level methods

In these experiments, we evaluate our method with another analogous methods.

To comparison our method with other byte level methods we have been selected PPM compression based method in [7] and Kolter's [10] approach as a machine learning technique. As we mentioned before, compression based methods are heavy memory consumers for maintaining compression models, for example to maintaining PPM models with 2200 samples (1100 sample per class) with block size of 512 bytes (null bytes are omitted), we have reached to 2GB memory heap size. Even with selecting headers in [9] as input data from each sample memory problem is also exists, while our method is light weight and consumes only 48MB of RAM for classification same dataset with better performance accuracy which indicates that our approach can be used in online malware detection scenarios.

Compression based method in [7] used PPM for modeling benign and malware. In this approach, the first block of file after PE header was selected as input data training for training PPM models. In this experiment, we selected 3072 as block size and PPM order of 4 for PPM based method that is the best parameters value for it.

Kolter's proposed method [10] is also relay on bytes of executable files for classification that is similar to our method in this case. This method is based on the byte n-grams. With select n-grams to 4 and choose 30,000 first bytes of each file, we need 2 GB for classifier heap. Next, 500 n-grams with highest information gain from binary are selected and are given to decision tree, SVM and AdaBoostM1 classifiers. Memory consumption is also the main problem of this method. So in this case, our method is also much more light weighted and resource-thrifty. Table 2. shows the results of our method versus other methods using acheive best results of each method with 2GB memory constraint.

TABLE II. COMPARISION BETWEEN OUR METHOD AND THE OTHER METHODS

Classifier	TPR	FPR	Precision	Recall	Accuracy	F-Measure
Kolter's [10]	0.92	0.11	88.8	92.0	90.2	90.4
Y.Zou's [7]	**0.93**	0.09	89.9	**93.5**	91.6	91.7
Proposed method	0.92	**0.07**	**92.2**	92.2	**92.2**	**92.2**

These experiments shows that our method has good accuracy even with using 512 bytes of each file while uses much lower memory than compression based methods and Kolter's n-gram machine learning-based approach.

Although opcode-level machine learning/data mining methods can gain more transparent features and indeed can gain more accuracy to detect unpack samples but they are weak to predict packed instances because all of opcodes are not available in static analysis. Also, opcode extraction is a time-consuming and fallible phase in these methods. So, our method can be used in online malware detection application because of its simplicity and time and memory friendly.

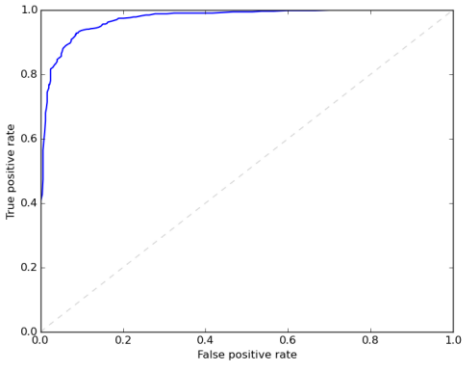


Figure 2 ROC of Random Forest with AUC = 97.3

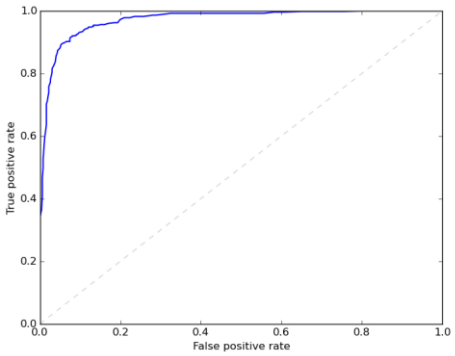


Figure 3 ROC of AdaBoostM1 with AUC = 97.23

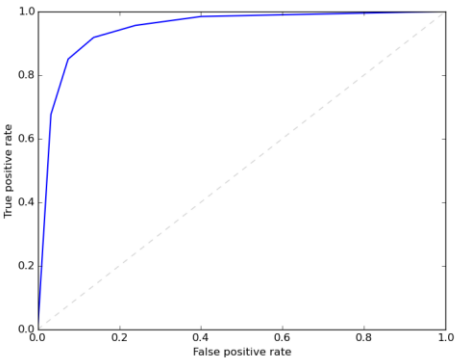


Figure 4 ROC of KNN with AUC = 95.2

VI. CONCLUSION AND FUTURE WORKS

In this research, we employed audio signal processing techniques (Music information retrieval method-MIR-in specific) for detection of malwares in byte-level. One of the most interesting challenges in MIR field is to classify music and sounds base on their content, genre or their speaker. MIR methods try to find some patterns in audio signal as features for representing the signal and then gives these features to machine learning classifiers for creating models and classify the new instances. Most common features that used for music genre detection, speech recognition and speaker recognition, are MFCC and chromagram features. The idea for this research is that we can represent binary as signal and then apply MIR methods to find some pattern in signal that can be used for distinguishing between binary classes.

We try to find an approach for representing binary files as signals in order to apply audio signal processing techniques. For this purpose, we construct MIDI files from binaries. Then, Wav files are generated from MIDI files. These files are real digital audio signals which is our approach to represent the binaries in the form of an audio. In the next step, because of

MFCC and chromagram are in frequency domain we apply framing on signals with size of 500msec that indeed are represent of 5 bytes of binary, and compute MFCC and chromagram feature vector for each frame independently. Also, frames have overlapping with each other, then we can find similar patterns of bytes more accurate. Feature vector of all frames are averaged to get a single feature vector for each file. Finally, we construct machine learning models based on these features and use the model for predicting unknown samples.

We evaluate our method with multiple machine learning classifier with 2200 training samples and 1000 testing samples. Then we have compared our method with compression based method and also a n-gram based machine learning approach. These techniques are both byte-level and are similar to our method in this case. Experiments show that our proposed method has good accuracy while consumes much lower memory and get lower time for extracting features, creating model and classify new instances than other methods.

There are many possible improvements to the proposed method here. Finding better representing of binaries as signals for gaining more transparent audio features can be done, for example finding better way to map bytes to musical notes and generating musical rhythm from binaries. Also, audio thumbnailing that is a good way to compute similar pieces of audio which can be used for getting better features and accuracy. Audio segmentation and prediction of audio segments label based on observed segments with HMM models can also improve performance of our method.

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Time series forecasting using improved ARIMA

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***Abstract*— in recent years, there has been an explosion of interest in forecasting time series databases in different applied areas. Forecasting is one of the main goal's mining of time series databases. Time series forecasting has been shown effective in suitable decision making in various domains. So far, a variety of techniques have been proposed to obtain goal of prediction and analysis of literature this area is in different directions. In this regard, in this paper, there are two goals. First, provide a review. For this goal, this paper classifies previous major works that investigated the forecasting of time series data in different application areas. Second, propose a novel approach to improve ARIMA model by applying a mean of estimation error for time series forecasting. Experimental results indicate that the proposed approach can improve performance in the process of time series data forecasting.**

Keywords—time series; forecasting; ARIMA; mean of estimation error

I. INTRODUCTION

The goal of data mining is to find the hidden patterns from data [1]. Temporal data mining is one of the important branches of data mining. Mining large temporal data sets is an active area of research [2]. Usually, we have two famous types of temporal data, first and the famous one is time series data, and the second is data with time points [3, 4]. Time series data is an important class of temporal data objects, a collection of observations, which are in chronological order made [5]. A time series is a sequence of observed data, usually ordered in time.

Mining is the final goal to discover hidden information or knowledge from either the original or the transformed time series data. Time series mining is a knowledge discovery from data sets with a dimension of time [6]. It is connected with the data mining of a large collection of sequential data with index time. The purpose of time series mining is classified into four groups: forecasting, description, explanation and control. Forecasting is one of the main goals of time series mining in various application domains. It is used in different application areas such as: weather [7-10], financial [11-15], medical [16, 17, 18] etc.

There are various techniques in the field of time series forecasting in different application areas [19-22]. This paper tries to provide a review on major works done in this field. For achieve this intent, we introduce a classification for previous techniques in the field of time series forecasting according to duration of prediction. Also, in this paper, an approach is proposed based on the mean of estimation error in order to improve performance of a prediction process.

The rest of this paper is organized as follows: In section II, proposed classification for time series forecasting was presented. An approach is proposed to improve performance of prediction with aspect accuracy in section III. Section IV is represented experimental results. Conclusion is presented in section V.

II. CLASSIFICATION OF TIME SERIES FORECASTING TECHNIQUES

So far, different techniques have been proposed for time series mining to achieve in goal of forecasting in variety of areas of application [10, 15, 20, 22]. Review of researches is demonstrator plurality and variety of theirs. In this paper, forecasting techniques are classified based on forecasting duration of techniques into groups: estimator of short-lived and estimator of long-range. Below, each group is described briefly.

A. Estimator of Short-lived

In different application areas, we collect observations about some phenomenon or quantity at regular intervals to form what is called a time series. Predicting future observations [23] of a collected sequence of historical observations are called time series forecasting. Forecasts are vital since they guide decisions in many areas of application and depending on the specific application can be required in estimator of short-lived or estimator of long-range. Estimator of short-lived is an estimator of one-ahead-step or short-term and forecast several minutes, hours, days or months ahead. There are different works in topic of an estimator of short-lived. For example, in [22], short-term load forecasting has been done using random forest. As another example, in [24], short-term electricity price has been predicted using wavelets and multivariate time series. Also, short-term passengers demand forecasting, which has been done using univariate time series theory in [21].

B. Estimator of long-range

Estimator of long-range is typically useful for strategic planning where decisions must be taken for a long-term

duration. In the last two decades, there have been few studies involving algorithms and methodologies from machine learning. However, the lack of communication between these different fields made it difficult to have a broad overview of the different developments in this area [25]. Estimator of long-range can be a multi-step-ahead forecaster. When facing a multi-step-ahead forecasting problem, we typically have a choice between the recursive and the direct forecasting strategy. There are different works in topic of an estimator of long-range. For example, multi-step-ahead forecasting of wind power has been done by different class of neural networks [26]. Furthermore, authors in [27] have been done one-step and multi-step ahead stock prediction using back propagation neural networks. Another example, authors in [20] have been done multiple-step-ahead time series forecasting by using Gaussian process.

III. PROPOSED APPROACH FOR TIME SERIES FORECASTING

A time series can be defined as a chronological sequence of observed data from any periodical task or behavior, or activity in fields like engineering, biology, economy, or social sciences, among many others [28]. There are several different approaches to time series forecasting, which are generally categorized as follows [29]. Traditional statistical approaches, including moving average, exponential smoothing, and auto regressive integrated moving average (ARIMA) are linear in that predictions of the future values are constrained to be linear functions of past observations. Second category is nonlinear techniques. In problem of time series forecasting, the technique of auto regressive integrated moving average or ARIMA model widely has been used for predicting future value [2]. It has been called Box Jenkins model and Future value of a variable is calculated by a linear combination of past values and errors in ARIMA by Equation 1:

$$y_t = \theta_0 + \varphi_1 y_{t-1} + \ldots + \varphi_p y_{t-p} + \varepsilon_t - \theta_1 \varepsilon_{t-1} - \ldots - \theta_q \varepsilon_{t-q} \quad (1)$$

Where y_t is real value at time of t, θ and φ is model coefficients, P and q are integer numbers called order of the autoregressive and moving average, respectively, and ε_t is error.

In this section, an approach is suggested to improve performance of ARIMA model. To overview the prediction approach to the problem of time series forecasting, an illustrative diagram is given in Fig. 1. In proposed approach, at first, collected observations of unknown system is divided into two data set training and test. The training data set, T_D is given as follows:

$$T_D = \{x(i), i = 1, 2, \ldots\} \quad (2)$$

Then, training data set is modeled by using ARIMA to forecast future values. Estimation error is calculated by Equation 3:

$$E(t) = X_T(t) - X_F(t) \quad (3)$$

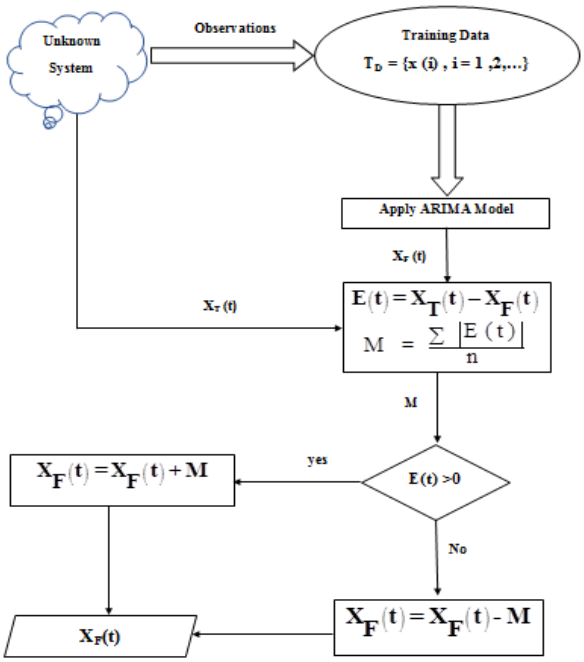


Fig.1. *Proposed approach for time series forecasting*

Where $X_T(t)$ is target output, $X_F(t)$ is predicted output. Our proposed approach is based on applying mean of estimation error in forecasting process. Mean of estimation error is calculated by Equation 4:

$$M = \frac{\sum |E(t)|}{n} \quad (4)$$

Where n is the number of target output data. According to values of $E(t)$, mean of estimation error is considered in calculation of predicted values. Value of $E(t)$ can be positive or negative.

IV. EXPERIMENTAL RESULTS

Three time series data set are used in this study to assess performance of proposed approach to basic ARIMA. Results of evaluation indicate appropriateness and effectiveness of the proposed approach in univariate time series forecasting.

A. Example 1. Monthly births time series

The data used is the monthly New York City births (NYB) time series data [30] for the period from January-1946 to December- 1959. NYB data comprises 168 data points. Time series data of NYB is shown in Fig.2.

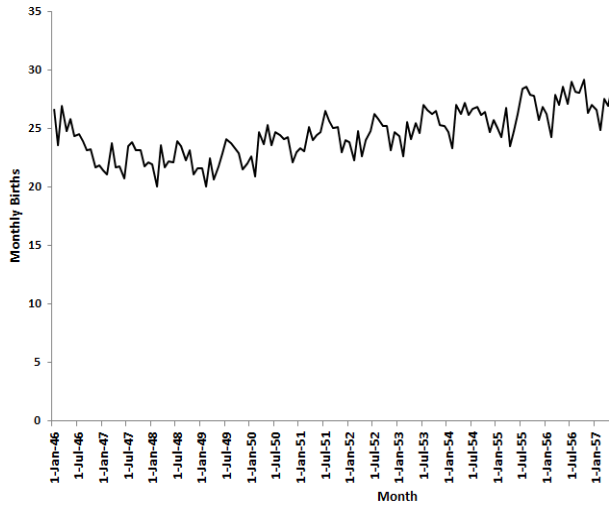


Fig.2. *Monthly New York city births: Jan 1946- Dec 1959*

For data analysis, the first 120 data points are used for training data set and the remaining 48 data points are used for testing. Three performance measures are used for determining forecasting efficiency, namely mean square error (MSE), root mean square error (RMSE) and mean absolute error (MAE). The first performance measure is MSE, which is used to compare predicted a value with actual value or target. The MSE is calculated by Equation 5:

$$MSE = \frac{\sum_{t=1}^{m} (X_T(t) - X_F(t))^2}{m} \quad (5)$$

Where $X_T(t)$ is the actual value or target value, $X_F(t)$ is predicted value and m is number of target output data.

The second performance measure is a root mean square error (RMSE), which is used to compare predicted value with actual value or target data. The RMSE is calculated by Equation 6:

$$RMSE = \sqrt{\frac{\sum_{t=1}^{m} (X_T(t) - X_F(t))^2}{m}} \quad (6)$$

The third performance measure is mean absolute error (MAE). The MAE is defined by Equation 7:

$$MAE = \frac{\sum_{t=1}^{m} \left| (X_T(t) - X_F(t)) \right|}{m} \quad (7)$$

In this part, at the first, the basic ARIMA model is used to forecast NYB time series data. It with different parameter *(p, d, q)* values are computed and is selected the optimal model. The result of performance measures with ARIMA model is shown in TABLE I. Optimal model is ARIMA (0, 1, 1). From TABLE I, it is seen that the minimum MSE and minimum MAE values are obtained for the ARIMA (0, 1, 1).

TABLE I. PERFORMANCE MEASURES USING BACIS ARIMA FOR NYB DATA

Models	Performance Measures	
	MSE	MAE
ARIMA(2,1,0)	0.003	0.04
ARIMA(1,0,1)	0.015	0.11
ARIMA(0,1,1)	**0.002**	**0.04**
ARIMA(1,2,1)	0.043	0.16

Achieved improvement by proposed approach for prediction of NYB time series data is shown in TABLE II.

TABLE II. COMPARISON PERFORMANCE MEASURES OF TECHNIQUES

Techniques	Performance Measures		
	MSE	RMSE	MAE
Basic ARIMA [28]	0.002	0.044	0.04
Proposed approach	**0.0007**	**0.028**	**0.023**

According to obtained results from above table, the proposed approach is able to achieve significant performance over basic ARIMA model for used NYB time series data set in this paper. The percentage improvement achieved by the proposed approach with respect to MSE, RMSE and MAE values over basic ARIMA model are presented in Fig. 3.

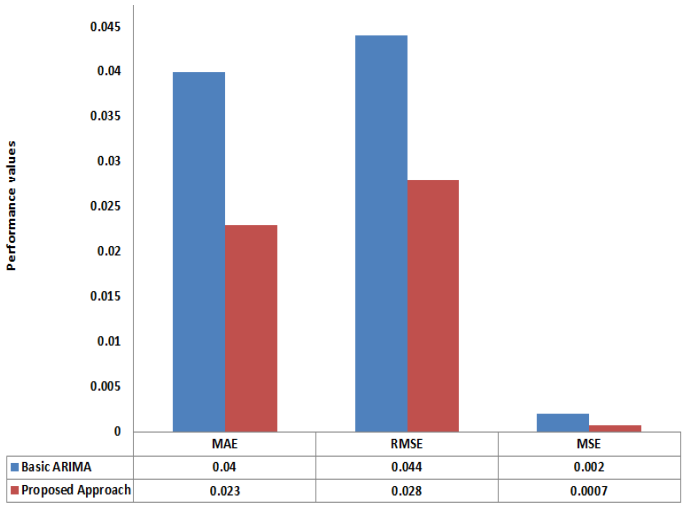


Fig.3. *Percentage achieved improvement using proposed approach*

It is clearly that the result derived from Fig. 3 indicates that in terms of performance, a proposed approached gives the better results compared against basic ARIMA model. The prediction responses by the proposed approach are shown in Fig. 4.

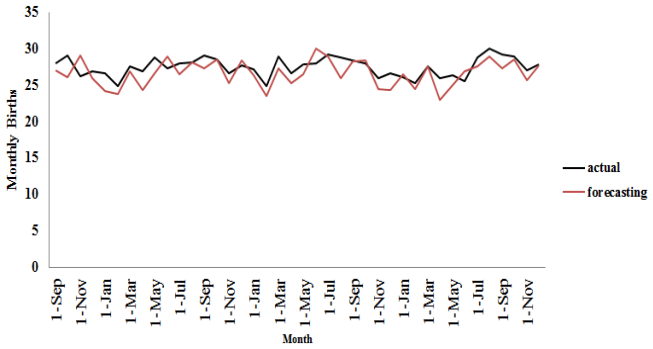


Fig.4. *Prediction responses using the proposed approach*

B. Example 2. Annual immigration time series

The data used is the annual immigration time series data into United States (AIU) [30] for the period from 1820 to 1962. AIU data comprises 143 data points. Time series data of AIU is shown in Fig.5.

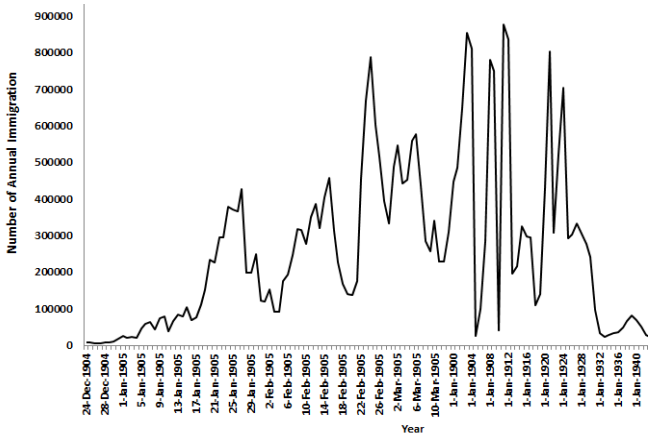


Fig.5. *Annual immigration in to the United States: 1820-1962*

For data analysis, the first 100 data points are used for training data set and the remaining 43 data points are used for testing. Performance is measured to Basic ARIMA for AIU data in TABLE III.

TABLE III. PERFORMANCE MEASURES USING BACIS ARIMA FOR AIU DATA

Models	Performance Measures	
	MSE	MAE
ARIMA(1,1,1)	0.260	0.137
ARIMA(1,0,1)	**0.139**	**0.117**
ARIMA(0,1,1)	0.194	0.118
ARIMA(2,1,1)	0.226	0.127

From TABLE III, it is seen that the minimum MSE and minimum MAE values are obtained for the ARIMA (1, 0, 1). According to obtained results from above table, the proposed approach is able to achieve significant performance over basic ARIMA model for used AIU time series data set in this paper. The percentage achieved an improvement by the proposed approach with respect to MSE; RMSE and MAE value over basic ARIMA model are presented in Fig. 6.

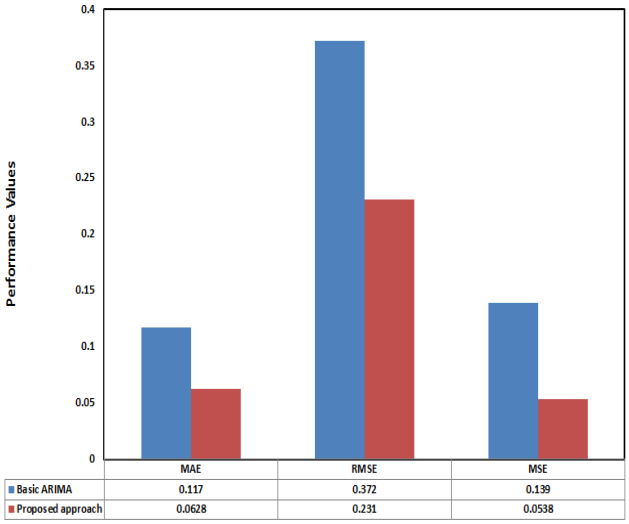


Fig.6. *Percentage achieved improvement using proposed approach*

It is clearly that the result derived from Fig. 6 indicates that in terms of performance, a proposed approached gives the better results compared against basic ARIMA model.

C. Example 3. Monthly number of cases of measles time series

The data used is the monthly reported number of case's measles time series data in to the Baltimore [30] for the period from 1939 to 1972. Time series data comprises 349 data points. Time series data of a number of cases of measles is shown in Fig.7.

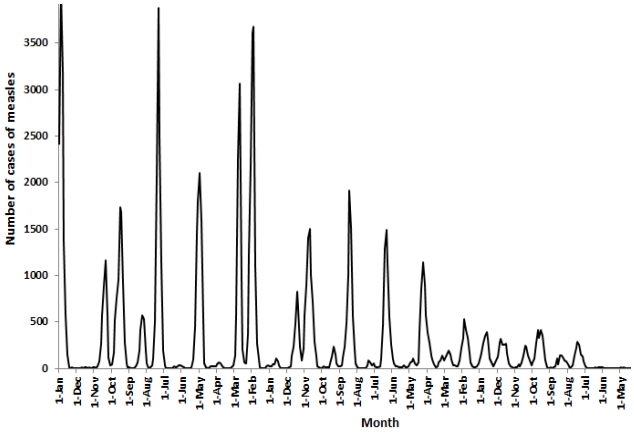


Fig.7. *the monthly reported number of cases measles: 1939-1972*

Performance is measured to basic ARIMA for a number of cases of measles time series data in TABLE IV.

TABLE IV. PERFORMANCE MEASURES USING BACIS ARIMA FOR MEASLES DATA

Models	**Performance Measures**	
	MSE	**MAE**
ARIMA(1,1,1)	**0.11**	**0.23**
ARIMA(1,0,1)	0.74	0.249
ARIMA(0,1,1)	0.39	0.55
ARIMA(2,1,1)	0.13	0.99

Achieved improvement by a proposed approach for prediction of a number of cases of measles time series data is shown in TABLE V.

TABLE V. COMPARISON PERFORMANCE MEASURES OF TECHNIQUES

Techniques	Performance Measures		
	MSE	RMSE	MAE
Basic ARIMA [28]	0.11	0.33	0.33
Proposed approach	**0.09**	**0.30**	**0.26**

According to obtained results from above table, the proposed approach is able to achieve significant performance over basic ARIMA model for the used number of cases of measles time series data set in this paper.

V. CONCLUSION AND FUTURE WORK

Forecasting of time series data sets is one of the important topics in many of the application areas such as weather, financial, medical and etc. There are different techniques in this field. In this paper, time series forecasting techniques have classified and placed into two groups based on forecasting duration. Groups have called an estimator of short-lived and estimator of long-range. Furthermore, an approach is proposed based on applying a mean of estimation error for time series forecasting in basic ARIMA model. As a result can say the improved ARIMA model is better than basic ARIMA model and accuracy is acceptable in proposed approach. As the future work, we will investigate an application of proposed approach in multivariate time series data sets.

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Self-localization of humanoid robots using Particle Swarm Optimization algorithm

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***Abstract*—A key problem of decision makingfor autonomous robot is self-localization of robots toward coordinate origin. The aim of localization is finding the Cartesian coordinates and robot's body direction in a global coordinate system. In this paper, we present image processing-based method for soccer humanoid robot's self-localization. This method uses an inverse perspective map to convert the obtained image into taken image from top view.Also.it employs line Hough transform to modify the changing of image rotation and it defines robot's location coordinates relative to the origin using particle swarm optimization algorithm. In this paper, an efficient objective function is presented to use in PSO algorithm. The most important feature of this method is to use IPM transform for deletion of perspective effects. This method relative to changing of size and form of different shapes inside of ground is resistant. Self-localization of soccer robots is one of the testing fields of this method.**

Keywords—Self-localization, inverse perspective transform, particle swarm optimization, Hough Transform

I. INTRODUCTION

Definition ofrobots position relative to the origin coordinates is one of the most important problems in decision making field of smart robots. In soccer robot, definition of robot's exact position is a key issue to get next decisions. Amongwhole of the available sensors in robot, vision give most information with very high accuracy in the biggest range. In this paper, self-localization of robot is performed using the taken image by camera situated at soccer humanoid robot's head according to adaption the observed lines in image by map of this lines in robot's memory. Some existing challenges are shape and size changing of rectangles, circle and ground lines angle changes according to their distance from robot. The main reason for these changes is angle between robot's camera and horizon line that cause to create perspective in image. Perspective complicatesdifferent patterns recognition. Another point isvery wide-spreading state space for different positions that the real time search is impossible in this space. For example, in a ground with dimensions 9×6m, if accuracy has been about 5cm, robot can be placed in 21600 different places. Due to imagining the different angles for robot, robotcan observe 7776000 different image modes in game conditions. It is possible that angle between robot's head and horizon line is considered constant. In this method, first all points of ground lines are extracted then position matrix of these pixels is rotated using Homography matrix in space and became to an image from top view[1].Then image angle is modified and after than it, the best location is found using particle swarm optimization algorithm that maximize the objective function[2]. The presented method can been used in various fields such as pattern-matching [3], positioning using taken images by bird defensive equipment and also special pattern recognition in satellite images.

Probabilistic methods are among common methods in the field of Global Positioning Systems(GPS)[4] problem solving such as Bayes filter.Bayes method uses conditional probability distribution for finding coordinate [5].We can find the several models of Bayes method for solving of this problem, such as Kalman filter [6,7], Markov[6,8] and particle filters [9,10,11].

Rusdinar et al. [12] are presented a self- localization method based on scanner laser information for mobile robots. Their method [12] mainly focus on positioning in 2D environments using particle filter. Another approach is fuzzy approach [13,14] that it is used in field of robots self-localization finding. In fuzzy approach, robot has a knowledge about own position place at any moment time that this knowledge is shown as one fuzzy set on state space of the possible positions. Each position has a membership degree that shows its proximity measure into real position [8]. One of the popular methods in positioning is Mont Carlo Method (MCL)[10]. MCL has ability for problem solving of global and local positioning. It uses particle filter for positioning [15,16].In particle filter is estimated knowledge by limited number of particles. Each particle is a hypothesis about being in a special position from space of all positions. Algorithm's accuracy and its computational load depends on the number of particles [2]. Usually, if number of particles increase then accuracy

increases and computing performance reduces. In this model, each particle has a weight that shows the importance measure of that particle and sum of all these weights is equal to 1.

II. METHOD

The aim of positioning is finding the Cartesian coordinates and robot's body direction in a global coordinate system. Inthis paper, we present image processing-based method for soccer humanoid robot's self-localization. First this method definethe pixels relevant lines of ground in image. These pixels are replaced with the numerical value of 1 and other pixels withthe numerical value of 0, the obtained image from these points are converted to taken images from the top view using an inverse perspective map. Then, the angle longest sequence of available values 0 in the image are obtained using the line Hough transform. This angle will be used to modify the changing of image rotation. In next step, the obtained information are processed using particle swarm optimization algorithm in form a matrix with values of 0 and 1and are defined robot's location coordinates relative to the origin.
GPS algorithm includes four main steps. These are as follows, respectively:

A. Take input image and extract points related to ground lines,
B. Apply IPM(Inverse Perspective Map) transform,
C. Obtain robot rotation angle,
D. Use PSO algorithm.

A. Take input image and extract points related to ground lines

In first stage, we consider white points in green background as points related to ground line in order to reduce noise and processing load in applying of IPM transform, then we save coordinate of these points. The saved points are only points that affect IPM mapping in next stage. Fig.2 shows image after processing.

B. Apply IPM transform

Taken raw image bysituated camera in robot's head isn't suitable for self-localization because of existence of perspective phenomenon. Therefore, it is highly desirable that the taken image is became to image of top view. Lines dimensions and shapes size which there are in this image are fixed and this is main feature of this image. For this reason, we use homography matrix [17]. This matrix show the relationship between two points in space with$m' = HM$,

$$m' = (x', y', 1), m = (x, y, 1) \quad (1)$$

H is a matrix with dimensions 3×3 so-called "homography matrix "[17].
We can move and rotate each point toward another point in space by this matrix. If all pixels coordinate of an image are moved by this matrix, we can create an image from another view. This transformation is famous to bird eye transformation

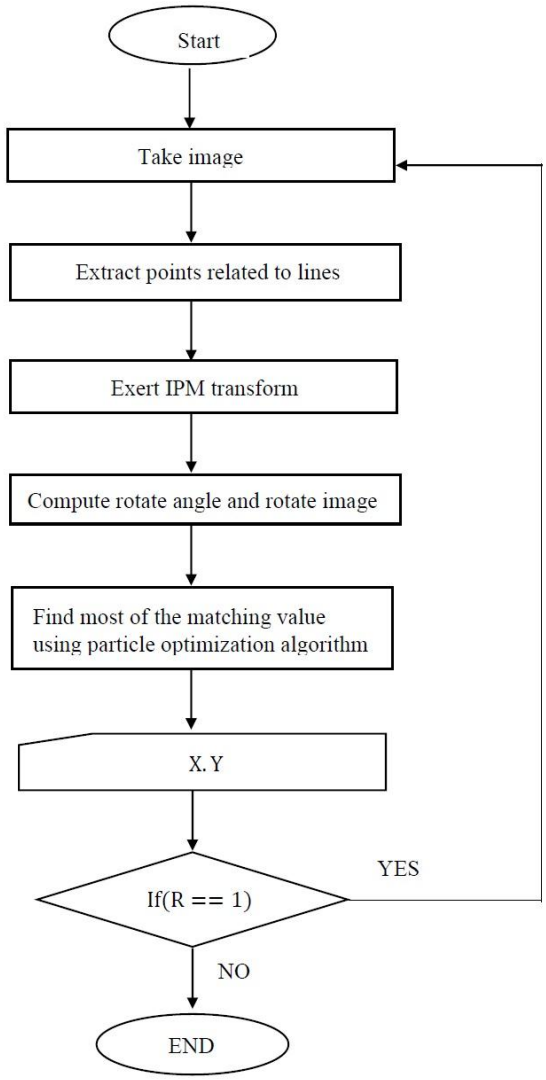


Fig1. The flowchart of algorithm stages

or conversion from top view. In fig3, real camera place and virtual camera is seen after than transformation.
New position of pixels has been obtained using equation (2),(3) and (4)[17].

$$H_{x^*} = H\frac{x\sin\theta + f\cos\theta}{-y\cos\theta + f\sin\theta} + d \quad (2)$$

$$H_{y^*} = H\frac{y\sin\theta + f\cos\theta}{-y\cos\theta + f\sin\theta} + d \quad (3)$$

$$Hd = \left|\frac{H(\sin\theta + f\cos\theta)}{f\sin\theta - \cos\theta}\right| + 1 \quad (4)$$

H isheight of main camera from ground, (x,y) is position of a pixel in taken image. (x*,y*) is position of same pixel after than transfer. θis angle between camera and horizon line and f is focal length of the camera. In fig.4 shows result of transformation exerting on points of line.

C. Obtaining of robot rotation angle

Robot can stay on different angles at any moment, therefore obtained image rotates depending on robot rotation measure.This image rotation causes high span of state space.

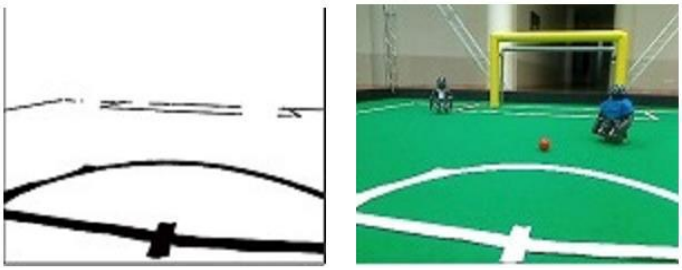


Fig2. (a)Taken image by camera situated in robot's head,(b)obtained image after than extra points deletion.

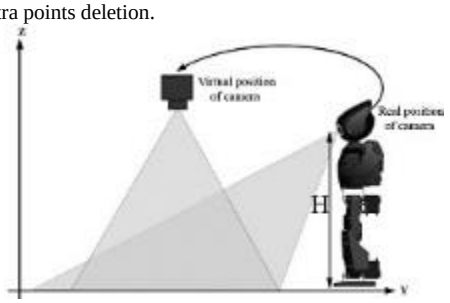


Fig.3:Camera angle change using homography matrix

In order to remove this rotation from image, we should rotate obtained image against robot rotation direction.In this case, we need to robot's head rotation angle. The easiest way is using compass sensors in robot. These sensors defines that robot's head angle according to earth's magnetic property. Basic problem of these sensors is their high sensitivity into noise. This problem causes that accuracy reduces about -15 to+15 degree. Another way uses observed lines angle in image. Line Hough algorithm is used obtaining this angle. This algorithm can determine all available lines in image and sort these lines from largest to smallest. Of course, this algorithm only uses the angle of longest line withleast 30 pixels length. The angle of these lines is very exactly since IPM stage but there is a main problem which robot can't denote that line angle is defined regarding to ground horizontal or vertical line or none of those.So to solve this problem, we employ the taken angle from compass sensor and the obtained angle from image together. Then we compute the difference between obtained angle from compass and extracted angle from image. Because there are only horizontal or vertical straight lines in image, it define that obtained line angle relates to horizontal or vertical line of image. Then it rotates proportional image with its. We directly can use the obtained angle from sensor while it employ military sensors with suitable accuracy. If it isn't allowable to use compass sensor, this algorithm is able to determine position without head angle. Of course, two points is identified according to symmetry of ground as a possible place.

D. USING PSO

Due to the angle changing of 360 □ and also minimum requirements accuracy of this problem,robot can estimate own place with 5cm accuracy, sum of the number of different images are equal to 7776000 in a ground with 6×9m even since IPM transformation and noise deletion because of robot



Fig.4: (a) Obtained image after than deletion of pixels which aren't relate to ground lines.(b)image after than exerting of IPM transformation on image

visibility is 120□ and robot can stay on each point from ground with difference angles. If each image has resolution with 100×100 pixels, it needs to about 80 milliard comparisons for positioning at any moment. In fig.5,we see several images that robot can observe in a place.*R* robot can see different images in a fixed point, as shown in fig.5.This field of view causes robotself-localization solving complexity. For this reason, existence of a fully smart way is necessary for passing this challenge in the solving of this problem. PSO algorithm is used solving of this problem. In PSO algorithm employ 50 particles which are distributed randomly in whole space. New position of particles obtain with (5) and (6) equations[2].

$$v[t+1] = \omega * v[t] + c_1 * r_1 * (pb[t] - x[t]) + c_2 * r_2 * (gb[t] - x[t]) \quad (5)$$

$$x[t+1] = x[t] + v[t+1] \quad (6)$$

In above equations, ω is inertia coefficient, r_1,$r_2$are random numbers with monotonous distribution and range of [0,1]. c_1,c_2 are learning coefficients too. r_1,r_2 create variety answer and in this way, full search is done in space. c_1 is learning coefficients regardingpersonal experiences and also c_2 is learning coefficients regardingcollective experiences. pb is the best experienced success by each particle and gb is the best experienced success by whole particles too.Thereupon,each particle consider 3 parameters when it move. These parameters are according to these relations, as follows:

1- Previous direction of own movement,

2-The best position where it is placed on,

3-The best position are experienced by collective.

We need to have an objective function for using PSO algorithm that can define utility measure of answer at any moment[2]. One two-dimensional (2D) array computes the objective function. The array includes values between -1 and 1. The dimensions of the array is proportionate to the tournaments (playgrounds).This 2D array includes slightly accuracy(5cm) and the real ground dimensions and 70cm

border around of the ground .Therefore, it involves 148×208 points. The corresponding element value to places where line stay on, is equal to 1 and other elements are between -1 and 1 according to distance of those points from the nearest point regarding one line in ground. These obtain (7) equation.

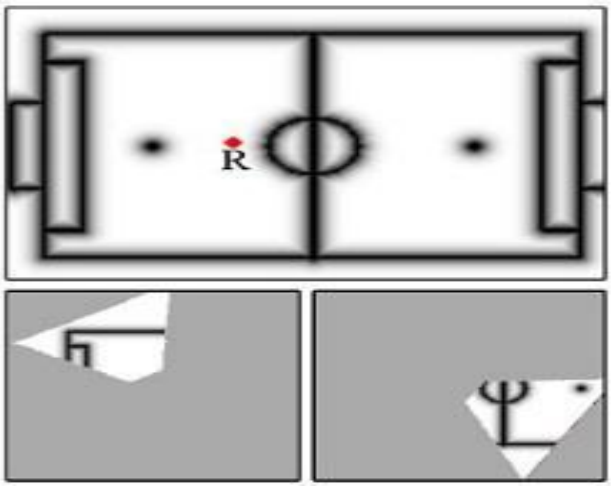


Fig.5: Robot can see tow sample images only by changing of angle

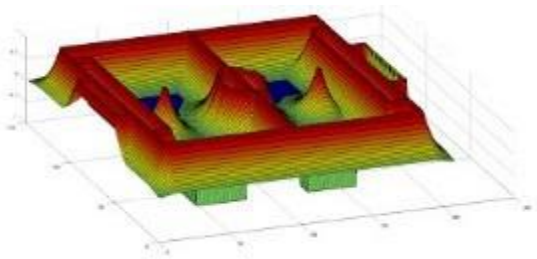


Fig.6:wmatrix since weight.

$$p = \begin{cases} \left(\frac{\max(d)-d}{\max(d)}\right)^4 & d \le 10 \\ -1 & d > 10 \end{cases} \quad (7)$$

d is distance between a point in array with nearest point to line and max(d) is equal to most tolerable distance that it is considered to 10 in here. Fig.6 show w matrix since weight. Robot can see 4.5m distance to own with acceptable accuracy at any moment.

Visible range of robot is a circle with 4.5m radius without considering of robot angle at any moment. This circle is considered in 2D array with 180×180 dimensions (4.5 m view radius create a circle with 9m diameter, as we can consider this circle in a square with 180 member side and computing to compute 5cm accuracy).While points are defined as a line in image, they have 1 value and other points are considered 0 in this array. This matrix is called search matrix and is shown with p. Formation stages of the search matrix show in fig.7.p Search matrix has a scale as w matrix. Fitness function value or f function computes in (x,y) point from w matrix using (8),(9) and (10) equations.

$$n(x,y) = \sum_{i=-90}^{90} \sum_{j=-90}^{90} p(i,j)\omega(x+i,y+j) \quad (8)$$

$$ns = \sum_{i=-90}^{90} \sum_{j=-90}^{90} p(i,j) \quad (9)$$

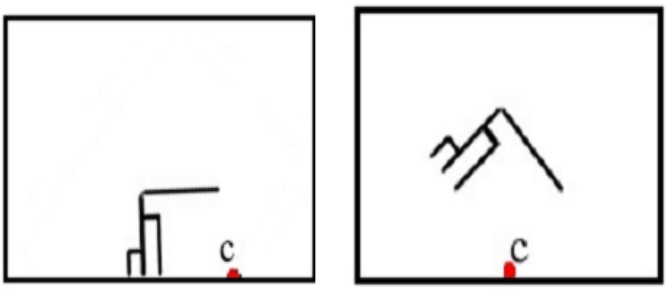
$$f(x,y) = \frac{n(x,y)}{ns} \quad (10)$$

Equation(10) has value between -1 and 1 and it shows conformity among p matrix and ω matrix. If points near to the lines are rated proportional to their distance in w matrix and even p matrix have been small displacement or changing of angleabout 6□,then f function amount is maximum in point on map which robot stay on it.Fig.8 shows various values of (10) equation for an image from robot staying on whole possible points. In fact, (10) equation compute correlation measure of input image with ground map in different places. Also due to negative values in w matrix, If 1 values in p matrix stand in negative values in w matrix, then output value reduces in (8) equation. Whereas output values in (8) equation reduce in mistake regions and they increase in regions of near to answer and this is main reason of existing of the changes domain from -1 to 1 in w matrix.

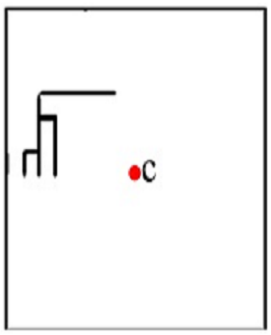
III. OBTAINED EXPERIMENTAL RESULTS

The steps of algorithm implementation and 4 iterations from particle swarm optimization algorithm are shown in fig.9, respectively. This method usually find one of the optimumpoints in less than 40 times. It considers c_1 and $c_2$values equal to 2 and w=0.8, as it succeed to find the global optimization in this problem at 90 percent of the times.

Soccer robots is used to test this algorithms. They are one of the application fields from this method. Robot works 94 minutes with 12.5 image frame per second in the simulation



(b) (a)



(c)

Fig.7: Search matrix formation stages

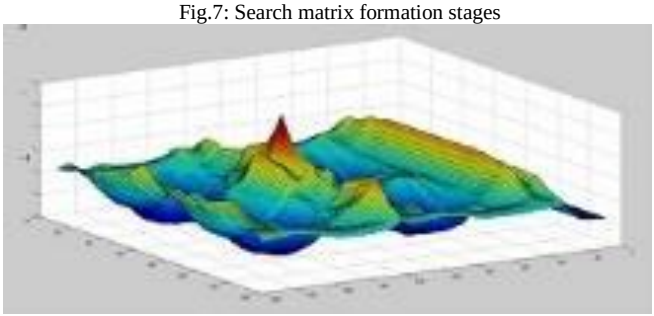


Fig.8: function values of whole possible points that robot staying on them

Table 1: Comparison of the fitness function calculating

method	Number of the f computing function
Without using PSO	21600
Using POS	Max 2000

Environment. In total, 56558 image frames were evaluated. Real place and robot's head angle are received through simulator for frame and these values simultaneous are saved with extracted values by proposed method. Robot could do the correct self-localization in 52827 times (94 percent) and didn't success in 3731 times (6 percent).In this state, inability in self-localization considered the distance error more than 30cm and angel more than 15□. Table 2 shows the results of algorithm evaluation in 56558 frame.

IV. CONCLUSION

In this paper is presented a method for recognition of position based on taken images. The inverse perspective mapIs used to speed increasing and decreasing of input informationdimension. w Matrix dimension is defined depending on the environment where positioning runs on it. This matrix is became weight according to the information of the edge detection in another applications. The aim of this application is finding of the best position with 5cm accuracy. If accuracy reduce to 1m, then algorithm can process the very large matrixes in real time. Also, (10) equation is used to finding of the robot position. It computes each of the places that robot may be stay on it in non-smart methods. Number of this function computing are reduced using particle swarm optimization algorithm for every time self-localization.Comparison between two methods is shown in table 1. This method has high accuracy because of it uses points related to ground lines for self-localization. Also, this method can recognize own position with some of these points. For this reason, it is very resistant into the noise.

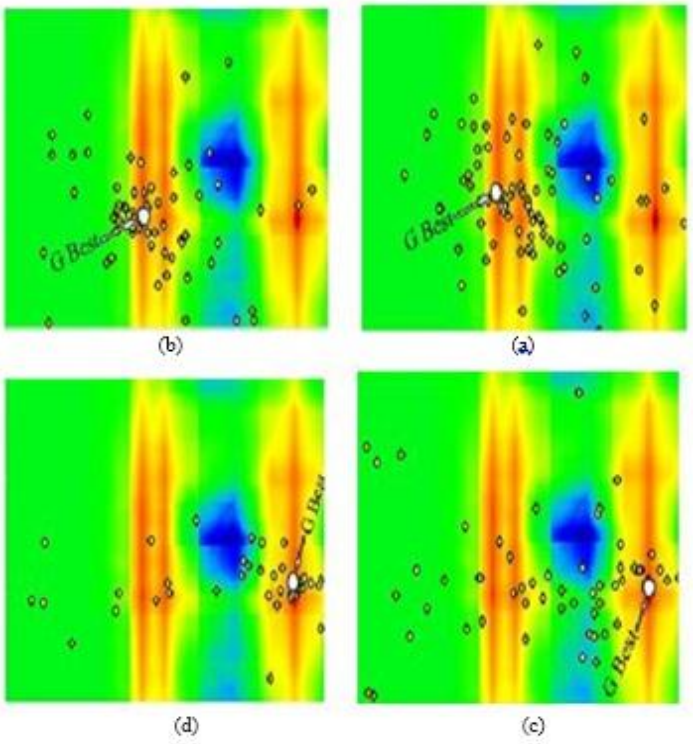


Fig.9: (a) PSO in first iteration,(b) tenth iteration, (c) twentieth iteration and (d) fortieth iteration.

Table2: The error measure of obtained positions

error	average	maximum
Position error(cm)	11.23	29.35
Angle error(degree)	6.25	14.78

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Design of a New, Light and Portable Mechanism for Knee CPM Machine with a User-Friendly Interface

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***Abstract*— After a knee joint surgery, due to severe pain and immobility of the patient, the tissue around the knee become harder and knee stiffness will occur, which may causes many problems such as scar tissue swelling, bleeding, and fibrosis. A CPM (Continuous Passive Motion) machine is an apparatus that is being used to patient recovery, retrieving moving abilities of the knee, and reducing tissue swelling, after the knee joint surgery. This device prevents frozen joint syndrome (adhesive capsulitis), joint stiffness, and articular cartilage destruction by stimulating joint tissues, and flowing synovial fluid and blood around the knee joint. In this study, a new, light, and portable CPM machine with an appropriate interface, is designed and manufactured. The knee joint can be rotated from the range of -15° to 120° with a pace of 0.1 degree/sec to 1 degree/sec by this machine. One of the most important advantages of this new machine is its own user-friendly interface. This apparatus is controlled via an Android-based application; therefore, the users can use this machine easily via their own smartphones without the necessity to an extra controlling device. Besides, because of its apt size, this machine is a portable device. Smooth movement without any vibration and adjusting capability for different anatomies are other merits of this new CPM machine.**

Keywords*— *CPM Machine; Continuous Passive Motion; Rehabilitation; Dynamic Analysis; Lead screw

I. INTRODUCTION

Nowadays, in the modern era human being is threatened with musculoskeletal trauma. Musculoskeletal injuries are among the most common ailments, which are caused by different reasons such as muscular atrophy due to ageing, congenital anomaly, exercise-induced damage, obesity, and ignoring ergonomic principles during the work [1].

Motion ability of people can be limited by musculoskeletal injuries, and then this situation may reduce their own quality of life. In some cases, this situation may cause muscular atrophy, and then patient ought to do knee replacement surgery –total knee arthroplasty– or even patients have to use a prosthesis in their own knees [2, 3]. Generally, the healing process of a muscle and retrieving motion ability, need patience and time. This process is constituted of multiple sessions of physiotherapy, which physiotherapist implements periodically some regular exercises on the damaged joint [4].

The CPM machine is a smart apparatus that accomplishes physiotherapist tasks such as intermittent and periodic exercises of the joints, etc. [5] In 1926, Von Riemke stated that regular and slight movement of the joint after joint surgery, can reduce recovery time and improve the treatment process [5, 6].

The continuous passive motion idea was presented by Salter et al. [7] for the first time. By studying on the knee joint of rabbits, they have found that the slow and continuous movement of the joint under pressure can accelerate the recovery and rehabilitation processes of the knee joint and its components like covering the knee joint, ligaments, and tendons [7, 8]. This idea was verified by experimenting on patients at 1978 [9]. A CPM machine can retrieve the Range of Motion (ROM), and by healing ACL (Anterior Cruciate Ligament) injury declines swellings of the joint, which is caused by knee surgery [5, 10, 11].

Furthermore, A CPM machine has other applications, for instance, pain relief, prevent muscle breakdown, speeding up the healing process, improving ROM in the shorter period of time, and decreasing the risk of blood clotting [5, 9-13].

Common CPM machines have some limitations and disadvantages [5]. These devices are bulky and heavy; hence, the machines have not the ability of slight motions [5]. Also, due to this problem, there are some structural drawbacks in these apparatuses to adapt to the human`s ergonomic. Moreover, common CPM machines, have not user-friendly and appropriate user interface [5].

According to the afore-mentioned issues, the main aim of this study is design and fabrication of a portable and adjustable CPM machine with a user-friendly interface for users. As an exemplification, one of the most important merits of this new portable device is, adjusting ability to different foot sizes for a wide variety of the patients. In addition, the new and user-friendly interface of this apparatus, contribute to the patients to store information of their own illness, and to record their own recovery processes, on their mobile phones.

II. METHODOLOGY

Detailed design of the developed CPM machine will be described in this section. The CPM apparatus is consisted of different components, which their relationships are

demonstrated in Fig. 1. The illustrated components are explained in the following subsections.

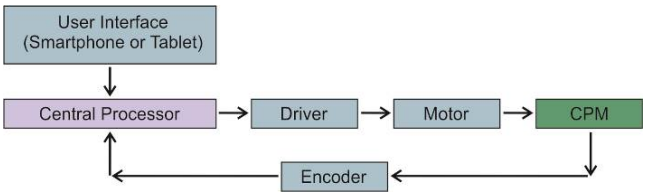


Fig. 1 – The main parts with its own connection ways in the new CPM machine

A. User Interface

Nowadays, smartphones have become an integrated utility of every person`s life, and also are using widely in the industry. The user interface of this device is based on Java and Android operating systems, which throughout Bluetooth connect to the CPM machine. This user interface (Fig. 2) not only can adjust the pace and ROM of the patient`s knee, but also can store general information and health progress of the patient.



Fig. 2 – User interface to control the CPM machine

B. Main Processor and Connection to Smart Device

The HC–05 module was used in this study, in order to communicate a smartphone with the CPM machine. Communication, sending, and receiving of the information by this module is through serial data. The ATmega2560 is used as the main processor of this device on the ArduinoMega2560 platform, Fig. 3.



Fig. 3 – (a) Main and central controller (ArduinoMega2560) (b) Bluetooth communication system (HC–05)

In order to control the CPM, the desired commands defined by the user, should firstly be transmitted to the main processor via the Bluetooth. These commands along with encoder output signals, are carried to the microcontroller. Then, controlling commands will transmit from the microcontroller to the motor as PWM signal. To observe and record data of the patients, all information like instantaneous speed, time, etc. will send to the smartphone; afterwards, this information will be recorded there.

C. Motor Drive

A drive motor (M542, Leadshine Co., China) is used in this apparatus. This drive motor is a suitable one system for two and hybrid-four phase stepper motors. In comparison with common and old L/R drivers, this drive can generate more torque and higher speed, precisely.

D. Motor

Based on power and torque analysis, which will be held in the future parts of this study, a stepper motor (HS2257, Leadshine Co., China) is implemented in the CPM machine. This two-phase motor can generate a smooth and uniform motion with 1.8 $\frac{degree}{step}$ resolution, and 22 $\frac{N}{m}$ torque. In addition, based on section III (analysis), this motor (Fig. 4) can guarantee all requirements of the system.

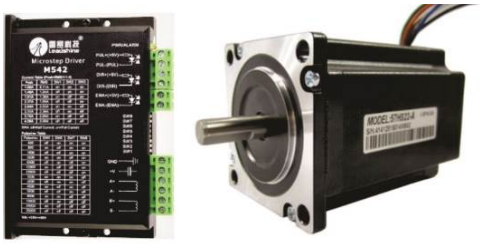


Fig. 4 – The stepper motor with its driver

E. Encoder

To acquire the precise location, pace, and wrapping angle of the leg, an encoder (E6B2-CWZ6C, OMRON Co., Japan) is implemented on one of the legs of the CPM machine (Fig. 5). By moving two links, the output signal of the encoder will change; these signals will be processed in the microcontroller, and then will send to the smart device for demonstrating to the user.

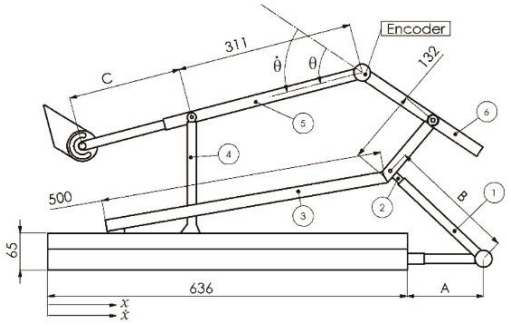


Fig. 5 – Front view of the CPM machine mechanism

F. Mechanical Structure

In order to design and fabricate a useful and applicable CPM machine, all constraints and requirements of the user should be considered. For instance, the motion of the knee should be smooth, uniform, and slow. Thus, a ball screw is used to convert a rotational movement to a linear motion; also, this ball screw reduces the clearance in this mechanism. According to Plagenhoef et al. research [14], on 135 persons consisted of 35 men and 100 women, the average length of the thigh (femur) bone in leg of the human is 24.05 % of one`s height. In addition, based on this study, the length of the tibia bone in the leg of human, is 25.2 % of the human`s height. Hence, in this study, all designing steps have done by considering these conditions. Fig. 5 and Fig. 6 show front and isometric views of the CPM apparatus. The lengths of the links A, B, and C, are variable, according to the patient`s anatomy.

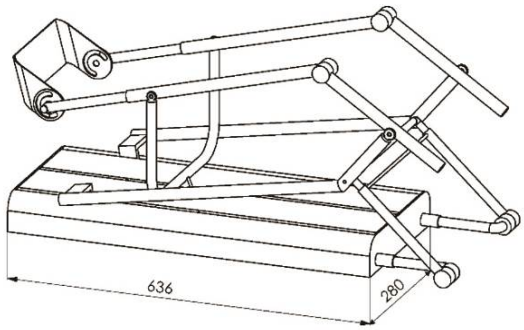


Fig. 6 – Isometric view of the CPM machine, with its total dimensions

III. Results and Discussion

A. Dynamic Analysis

After modeling of the designed CPM machine in the SolidWorks software, to verify the designing steps, this machine has been studied dynamically. Hence, this mechanism has been investigated by ADMAS software to study its paces and forces. This step is a necessary step during design procedure since, some processes like motor and lead screw selection, and other mechanical details are completely dependent on the applied forces on the apparatus. Furthermore, through this software, maximum and minimum linear velocity of the lead screw and rotational speed of the knee, can be obtained. Assumed values, which have been used in designing and calculation steps, are presented in table 1. Moreover, the controller is designed based on these values.

Table 1 – The main components and their specifications

No.	Material	Density ($\frac{kg}{m^3}$)	Young's modulus ($\frac{N}{m^2}$)	Poisson`s Ratio	Weight (kg)	No. of Pieces
Base	Cast Iron	7080	10^{11}	0.210	4.67	1
1	Stainless Steel	7750	1.9×10^{11}	0.305	0.25	2
2					0.21	1
3					0.70	2
4					0.54	1
5					0.55	2
6					0.40	2
Leg 1	N/A	5000	N/A	N/A	9.64	1
Leg 2	N/A	2700	N/A	N/A	16.67	1
Total Device					9.26	

In the ADAMS software, after defining constraints and weight of the components, four sensors have been used to find connections between velocity and location of the lead screw with angular velocity and angle of the knee joint. Two sensors (angle and angular velocity sensors) have been implemented on the knee joint, and the other two sensors (location and velocity sensors) have been put on the lead screw, Fig. 7. The sensor is a state variable that can measure changes, such as distance, velocity, and so on. Besides, to find the force exerted to the lead screw, a bi-directional linear force actuator is used on the screw to measure the force on this screw, as it is shown in Fig. 7.

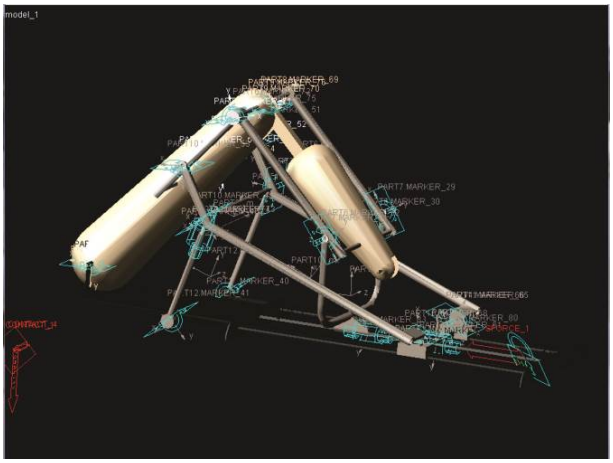


Fig. 7 – Schematic view of the apparatus in the ADAMS software

In order to design appropriate controller, and analysis its effect on the CPM behavior, the modeled sample in the ADAMS software is connected to a pre-designed controller in the MATLAB-SIMULINK, Fig. 8. In this manner, the designer is able to study the linear and angular velocities, and the behavior of the CPM machine according to the applied force on the ball screw.

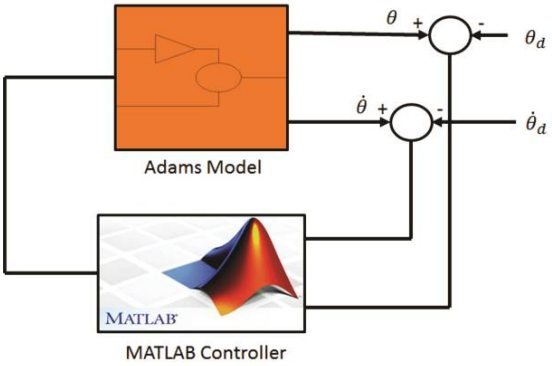


Fig. 8 – The connection between MATLAB and ADMAS sofware

A PID controller ($P = 50, I = 5, D = 50$) is used to control this system; this controller is added in order to obtain the force range in the simulation. Equation (1) is considered as desire data signal, after connecting these two software (MATLAB and ADAMS).

$$\theta = 53.5 + 62\sin(0.2t) \quad (1)$$

Where, θ is the angle of the knee joint, and t is the time. The frequency (0.2 Hz) in this equation, is obtained from the equation (2), by supposing a complete round-trip motion of the leg in 1 minute.

$$\begin{cases} \omega = \frac{2\pi}{T} \\ T = 30 \end{cases} \Rightarrow \omega = \frac{2\pi}{30} \cong 0.2 \quad (2)$$

Where, T is the period of each complete motion, and ω is the angular velocity. This frequency is one of the most common frequencies in physiotherapy equipment.

The simulation results are presented in Fig. 9. As Fig. 9(a) shows, the controller appropriately working and pursue the desired value. Fig. 9(b) indicates that the maximum force applied to the lead screw is 613 N. This amount is quite a convenient value, according to common motors and lead screws. As it is shown in the Fig. 9(c), the optimal length of the ball screw must be 0.3 m.

Fig. 9(d) demonstrates that the maximum linear velocity of the lead screw is 0.15 $\frac{m}{s}$, which this amount can determine the pitch of the screw according to the chosen motor. According to Fig. 9(e), the maximum angular velocity of the patient`s knee is 0.3 degree/s. This amount is an appropriate value to heal the patient`s knee in that, higher velocities may damage patient`s knee [15]. A summary of the derived results of this simulation is prepared in the table 2.

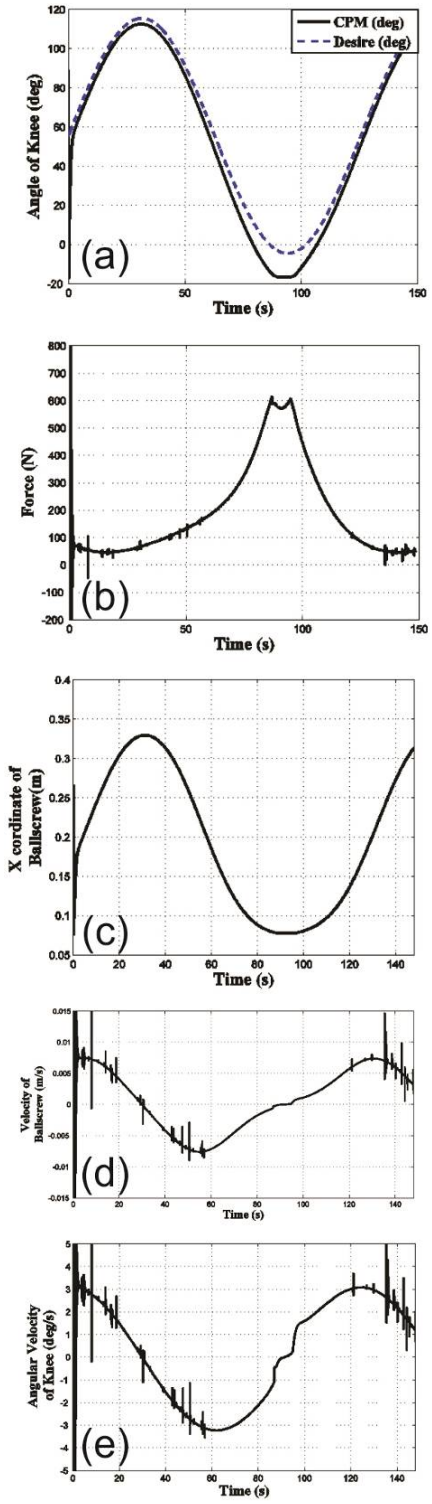


Fig. 9 – The results of the simulation and analysis with MATLAB and ADAMS software. (a) Angle of the knee. (b) Applied force to the ball screw. (c) The distance of ball screw from the end of the CPM machine. (d) Linear velocity of the ball screw. (e) Angular velocity of the knee joint

Table 2 – Assumptions used in modeling process, which is derived from simulation and analysis

Criterion	Amount	Application
Velocity of screw	$Max = 0.015\ \frac{m}{s}$	To determine the pitch of the screw
Location of the ball screw	$Max = 0.3\ m$	To determine the length of the screw
Angle of the knee	$Max = 120°$ $Min = -15°$	To determine ROM and the controller performance
Angular velocity of the knee	$15\ \frac{degree}{s}$	
Horizontal applied force to the ball screw	$Max = 613\ N$	To determine the motor

B. Motor and Lead Screw Selection

As claimed by Plagenhoef et al. [14], the maximum weight and length of a 130 kg person`s leg are, about 26 kg and 100 cm, respectively. The horizontal exerted force to the ball screw, in the simulation, is 613 N (Fig. 9(b)), and the vertical applied force will be neutralized with the reaction forces of linear guides; thus, does not influence on the horizontal movement of the screw.

The free body diagram and the exerted forces to the screw are represented in Fig. 10. The maximum and the minimum forces required to move the screw can respectively obtain from equations (3), and (4) [16].

$$P_R = \frac{F(\frac{l}{\pi d_m}+f)}{1-(\frac{l}{\pi d_m})} \quad (3)$$

$$P_L = \frac{F(f-\frac{l}{\pi d_m})}{1+(\frac{l}{\pi d_m})} \quad (4)$$

As it is indicated in Fig. 10, P_R is the force applied to the screw, when it is returning from the end of the ROM (-15°) to the beginning of the ROM (120°). Also, P_L is applied force to the screw, when it is moving from the beginning to the end of the ROM.

As it is shown in equation (5), the amounts of P_R, and P_L will be obtained by substituting values of F, l, f, and d_m in equations 3, and 4.

$$\begin{cases} F = 613\ N \\ d_m = 0.012\ m \\ f = 0.3 \\ l = 0.4 \end{cases} \Rightarrow \begin{cases} P_R = 275.22\ N \\ P_L = 115.20\ N \end{cases} \quad (5)$$

By considering P_R as the maximum required force to move the screw, the maximum torque can be calculated as written in equation (6).

$$T_{max} = P_{max} \times \frac{d_m}{2} \Rightarrow T_{max} = 1.651\ N.m \quad (6)$$

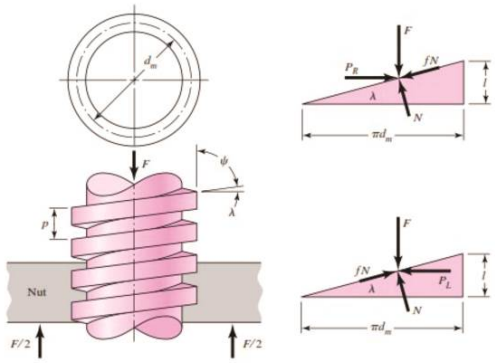


Fig. 10 – Free diagram of the lead screw with the exerted forces[16]

Based on the simulations that have done by ADAMS software, maximum required pace to generate a linear movement of the screw is 0.01 $\frac{m}{s}$. Hence, angular velocity of the screw, can be obtained from equation (7).

$$\omega_{screw} = 0.01\ \frac{m}{s} \times \frac{1\ rev}{0.004\ m} \times \frac{2\pi\ rad}{1\ rev} = 15\ \frac{rad}{s} \quad (7)$$

Finally, as it demonstrated in equation (8), the required power of the motor can be calculated. In addition, the final model of this CPM machine is indicated in the Fig. 11.

$$P_{motor} = T.\omega = 24.76\ watt \quad (8)$$



Fig. 11 – Final CPM machine with the new design

IV. Conclusion

After knee joint surgery, due to the severe pain and immobility of the patient, the tissue around the knee become harder and knee stiffness will occur. In addition, many problems such as scar tissue swelling, bleeding, and fibrosis will also be generated. A CPM machine is a device, which is being used for patient recovery, retrieving moving abilities of the knee, and reducing tissue swelling, after this surgery. Common CPM machines

Common CPM machines are bulky and heavy; thus, the patient, who is working with these devices, needs someone to help. Due to these problems, the patient has to go to health

centers sometimes. In this study, a new, lighter, and portable CPM machine with an appropriate interface, is designed and manufactured. The patient can work with this new apparatus merely by adjusting his/her own leg, and without any external helps. According to the carried out simulations and analysis this advantage not only declines the energy consumption but also increases the efficiency of this machine.

Besides, the developed CPM has been made portable (by putting in a backpack) and inexpensive by its simple and light design. Moreover, the user interface of this system is an Android-based application, which makes it a user-friendly device, and contributes to patients having their own treatment information on the smart devices like smartphones and tablets, and spend their healing process at their own houses.

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Particle Swarm Optimization based Feature Selection with Novel Fitness Function for Image Steganalysis

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Abstract—**One of the most effective issues on the performance of steganalysis is feature selection that aims to select the most significant and influential feature elements. In this paper, a new method of feature selection is proposed based on optimization process of Particle Swarm Optimization (PSO) with novel Area Under Area the receiver operating characteristics Curve (AUC) measure as the fitness function to improve the performance of detecting stego images from the cover images in steganalysis problem. Due to the high convergence rate and specific search strategy of PSO, it is able to find the best feature subset and so, the performance of steganalysis will be improved. The proposed method is evaluated on Breaking Out Steganography System (BOSS) benchmark and the obtained results proves the ability of the proposed method in feature selection for steganalysis problem.**

Keywords— steganalysis; PSO; feature selection; AUCt.

I. INTRODUCTION

Steganography is the skill of embedding messages in audio and video as multimedia file where nobody can identify the presence of the secret message except the sender and receiver of data. Steganography can be considered as a secure approach to transfer hidden information through the mentioned data if there is not any detectable signs in stego-image because of the embedded message. It is important that the message should be embedded in a way that there is not any noticeable difference between the stego-image and original image named in literature as the cover image. If more than 50% of secret message hidden in an image can be estimated by a method, the steganographic organization would be considered as broken.

Steganalysis is the skill of discovering the secret message in a multimedia file without any information corresponding to the steganography algorithm or the hidden message such as the length of message or its location in an image. Steganalysis approach can be divided into two categories: static and dynamic. In static steganalysis, the goals are discovering the existence or non-existence of a hidden message and also identifying the stego embedded algorithm. Dynamic steganalysis aims to identify the embedded message length, its position(s), the secret key utilized in the process of embedding the message, some parameters of the stego implanting algorithm and discovering the concealed message.

Since image is one of the best solutions to provide perfect cover of object for steganography [1], the hidden message can be discovered from the image by the processing of the extracted feature vector of image. This affection can be harmful in terms of long computation cost and large storage space

Due to the presence of irrelevant and/or redundant elements in the extracted feature vector of image, the performance of steganalysis methods would be degraded significantly in terms of long computation cost and large storage space. In this regard, one of the best solutions to improve the performance of steganalysis method is elimination of irrelevant and/or redundant feature elements in order to design a compact learning method with reduced computational cost for steganalysis task. Swarm intelligence-based feature selection is one of the most interested solutions to select a subset of full-informative features from the original set of features. In swarm intelligence-based methods, a population of agents is defined to search the problem space to find the global best region. In the category of swarm intelligence, several methods are introduced such as Ant Colony Optimization (ACO) [2], Artificial Bee Colony (ABC) [3], Artificial Fish Swarm Algorithm (AFSA) [4], Particle Swarm Optimization (PSO) [5] and so on. Among all of the mentioned methods, PSO takes the advantages of high convergence rate and low computational cost.

One of the recently proposed steganalysis methods is IFAB [1] which is a new steganalysis method for detecting stego images from the cover images using ABC-based feature selection method with SVM classifier. In comparison to the PSO approach, ABC has lower convergence rate. Because of the higher optimality of PSO, this paper proposes a new steganalysis technique for the classification of images into two classes of stego-image and cover-image using PSO-based feature selection and SVM classifier. Also, the proposed method benefits from Area Under Area the receiver operating characteristics Curve (AUC) measure as the fitness function of PSO process. According to the results obtained by the proposed method, the results of previously proposed IFAB is improved in this paper in terms of accuracy.

The rest of the paper is organized as follows: Section 2 gives a brief review of previous works. Section 3 presents the PSO method. The innovations of this paper are introduced in Section 4. Section 5 reports the experimental results on well-

known datasets using different classi ers and the work is concluded in Section 6.

II. RELATED WORKS

Recently, several studies in the field of digital image steganalysis are focused on dimensionality reduction which is categorized to two groups of feature extraction and feature selection. In the next two subsections, related works to the mentioned groups of dimensionality reduction will be described.

A. feature extraction

Since the main goal of steganalysis task is classification of test image into one of the classes of stego and cover, the steganalysis task is a process similar to the pattern recognition procedure. Also, the common point between steganalysis task and pattern recognition procedure is feature extraction which the method maps the input data into a new space with lower dimension and so, the original dataset will be represented in the new space with lower dimension [6]. Since there is difference between the feature vector of stego-image and the feature vector of cover-image, processing the feature vectors of these two kinds of images provides a way to classify test images and so, more difference shows more influential feature elements. There are several feature extractor techniques proposed in steganalysis problem that are listed as follows:

- CHEN (486): Markov features using intra- and inter-block dependencies [7],
- CC-CHEN (972): CHEN features enhanced by Cartesian calibration [8],
- LIU (216): the union of diff-abs NJ-ratio and ref-diff-abs NJ features published in [9],
- CC-PEV (548): Cartesian-calibrated PEV feature set [10],
- CC-C300 (48,600): the high-dimensional feature space proposed in [11],
- CFn (7850): compact rich model for DCT domain proposed in [12],
- SPAM (686): subtractive pixel adjacency model [13].
- Note that the above values which are mentioned in (.) are the length of corresponding feature vector.

B. Feature selection

In the group of feature selection methods, the goal is to select a subset of full-informative features from the original set of features. In other words, the removed features should be irrelevant, redundant and useless in the set of original features. Feature selection methods are categorized into four sub-categories such as filer, wrapper, embedded and hybrid. In the class of filter-based techniques, each feature is evaluated distinctly based on its discriminative ability between different classes. The main property of filter-based methods is their ability to effectively identify and remove irrelevant features without consideration of any learning method. The main drawbacks of these kinds of methods are inability to remove redundant features and ignoring the dependency between the features. In the wrapper-based techniques, a leaning method is utilized to iteratively assess the quality of feature subsets. Due to the consideration of dependency between the features, these methods can effectively identify and remove both of the irrelevant and redundant features [14]. The main drawback of these methods is high computational cost and time-consuming for high-dimensional datasets due to the training phase of learning method. In the embedded category, feature selection is an embedded part of learning process of a model and so, the learning part and the feature selection part can not be separated [15]. Similar to the wrapper-based methods, the embedded methods are able to efficiently eliminate the irrelevant and redundant features, but they suffer from time complexity due to the training of used machine learning method. The last group of feature selection techniques is hybrid-based methods which aim to benefit from computational efficiency of filter-based methods and appropriate performance of wrapper-based methods. Due to the employing of filter models and wrapper models as two separate steps, the hybrid-based methods shows poor performance in terms of accuracy. Fisher score [16] and Laplacian score [17] are the best known graph-based feature selection methods. Graph-based Semi-supervised Feature Selection (GSFS) is another graph-based feature selection method which combines the spectral graph theory and conditional mutual information to select relevant features and also remove redundant features. Zhang and Hancock [18] proposed a hypergraph-based feature selection technique that consists of two steps: all attributes of dataset is encoded in an undirected weighted hypergraph where nodes denote features and edge weight means multidimensional interaction information between the features connected by the edge; after that, the nodes of hypergraph are clustered into different groups to determine the most informative feature subset. In [19], a fast clustering-based feature selection algorithm (FAST) is developed to solve the problem of clustering for high dimensional data. This method includes four steps: 1) elimination of irrelevant features, (2) building a minimum spanning tree from relative features, (3) partitioning the spanning tree, and (4) selecting representative features. In [20], an unsupervised graph-based method is introduced to remove redundant features. For this purpose, at first, the feature elements of dataset was represented in the structure of undirected weighted complete graph where nodes are feature elements and the weight of edges shows dissimilarities between the features. After that, part of graph with the maximum average weight was determined as the densest subgraph and finally its corresponding nodes were selected as the nal feature subset. Due to lack of consideration of relevancy of each feature, nal subset might not be the best representative of features. To overcome the problem of this paper, Bandyopadhyay et al. [21] hybrids the concept of finding the densest subgraph with feature clustering in two main steps: finding the densest subgraph which contains the maximum number of non-redundant features and then a feature clustering approach is applied on the non-redundant features in order to achieve a reduced feature subset.

III. PARTICLE SWARM OPTIMIZATION (PSO)

PSO [5] is one of the best swarm intelligence-based optimization techniques that was born from social behavior of animals such as bird folk and sh swarm. PSO consists of a population of particles in which each particle is a feasible solution in problem space and search the space in order to move toward nal best solution by adjusting its path and moving toward the best personal experience and also the best swarm experience. There are two information vectors for each particle such as position and velocity which are updated over the search process. In PSO, population includes N particles in D-dimensional space where the current position and velocity of ith particle are presented by $x_i = \{x_{i,1}, x_{i,2}, \dots, x_{i,D}\}$ and $v_i = \{v_{i,1}, v_{i,2}, \dots, v_{i,D}\}$, respectively that are updated as follows [5]:

$$v_{i,j}(t+1) = wv_{i,j}(t) + C_1 R_{i,j}^1 \left(Pbest_{i,j}(t) - x_{i,j}(t)\right) + C_2 R_{i,j}^2 \left(Gbest_j(t) - x_{i,j}(t)\right) \quad (1)$$

$$x_i(t+1) = v_i(t) + v_{i,j}(t+1) \quad (2)$$

where C_1 and C_2 are acceleration coe cients and w is inertia weight that can be a constant number or a positive function, R is a random number in range [0 1], $Pbest_i(t)$ is the best position experienced by particle i until time t, and $Gbest(t)$ is the best position discovered by the whole particles until time t. To update the value of $Pbest_i$, following equation is employed [5]:

$$Pbest_i(t+1) = \begin{cases} Pbest_i(t), & if\ f(x_i(t+1)) \geq f(Pbest_i(t)) \\ x_i(t+1), & ot\ \ erwise \end{cases} \quad (3)$$

where $f(x_i)$ is the fitness value of particle i. The best swarm experience is updated as follow:

$$Gbest(t+1) = argmin_{p_i} f(Pbest_i(t+1)) \ , \quad 1 \leq i \leq N \quad (4)$$

IV. PROPOSED METHOD

In this paper, a new method of feature selection based on the optimization process of PSO for steganalysis task is proposed. The proposed method consists of two main steps: feature selection and learning that will be described as follows.

A. Feature selection step

The main contribution of this paper is proposed in feature selection step. As the mentioned before, there are several feature extraction methods which are applied for steganalysis problem. In this paper, at first, two feature extraction methods, CC-PEV and SPAM, are applied on input image dataset to produce feature vectors with 548 and 686 elements, respectively. Since length of the feature vectors are too long, the storage and computational cost of a steganalysis system will be high, and so, it is necessary to eliminate irrelevant and ineffective feature elements or select full-informative and influential feature elements. The proposed scheme of this paper for feature selection is utilization of PSO which searches the feature space to select the best feature elements. To this end, a population of particles in D-dimensional space is randomly created within range [0 1] where D equals to the length of original feature vector. To make a relationship between the value of decision variable and status of corresponding feature element in terms of selection/elimination, if the value is higher than a predefined threshold value, then the corresponding feature element will be selected; otherwise it will be removed from the original feature set. After the generation of initial population, the fitness value of each particle should be computed that will be described in the next subsection. Then, the entire set of particles explores the search space to find the best subset of features. In each iteration, the position and velocity of each particle, the best experience of each particle and the best experience of swarm are updated using (1)-(4). After a number of iterations, the best particle with the best fitness value is selected as the best selected feature element. The next subsection will introduce the proposed fitness function for PSO optimization process.

B. Fitness function

The second innovation of this paper is utilization of AUC measure as the fitness function of PSO. AUC function measure measures the discriminative power of binary classi ers. The input of this function is a particle and its output is a scalar value in range [0 1] in which high AUC value shows the remarkable performance for binary classi cation. AUC measure is based on Receiver Operating Characteristic (ROC) which is a two dimensional curve to compute the classi cation accuracy of a binary classifier [22]. The ROC curve is constructed using four variables: True Positive (TP), False Positive (FP), True Negative (TN) and False Positive (FP) where TP is the number of predicted positive cases that are actually positive, TN is the number of predicted negative cases that are actually negative, FP is the number of predicted positive cases that are actually negative and FN is the number of predicted negative cases that are actually positive. In ROC curve, the horizontal and vertical and vertical axes which are named Sensitivity and (1 - Speci city) are measured as follows:

$$Sensitivity = \frac{TP}{TP + FN} \quad (5)$$

$$Specificity = \frac{TN}{TN + FP} \quad (6)$$

The AUC value is calculated by taking the integral on the area under the ROC curve [23]. So in this paper, the AUC function is measured according to the selected feature subset proposed by particle i. Note that the particle with the highest fitness (AUC) value can be considered as the best particle and so, its selected feature elements will be determined as the best feature subset.

C. Learning step

The last step of the proposed method is training and testing of a specific machine learning approach for the task of steganalysis. The machine learning technique used in this

paper is Support Vector Machine (SVM) [28] which is a supervised learning method for the tasks of classification and regression. SVM aims to construct a hyperplane with maximum margin in high-dimensional space to classify data samples. The best results of SVM are obtained when the hyperplane has the largest distance to the nearest data points from any class. If the data points are not linearly separable, the data pints are transformed to the higher-dimensional space using kernel function. In this paper, linear SVM (SVM with linear kernel) is employed for steganalysis problem. To train the SVM model, the best feature subset that is found by PSO algorithm is applied on the whole dataset to maintain the most significant features or remove the least significant features. In the feature selection scheme, the features with values higher than a predefined threshold will be remained while the features with values lower than the threshold will be removed. After the feature selection step, the new dataset with reduced number of dimensions is employed for training of SVM model. Finally, the trained model is evaluated on testing set for classification of stego-image and cover-image.

V. EXPERIMENTAL RESULTS

In this section, the performance of the proposed method is evaluated and compared with other well-known feature selection approaches and also with a novel Markov blanket embedded Gentic Algorithm (MBEGA) approach [24] and IFAB [1] in terms of accuracy, number selected feature elements, and so on. MBEGA uses Markov blanket to ne-tune the search according to the feature elements selected by GA solutions. This search strategy takes advantage of both Markov blanket and GA wrapper feature selection with the aim to improve the classi cation accuracy and accelerate the search to keep relevant features.

The image dataset used in this paper is breaking out steganography system (BOSS) [25] version 1.01 which contains 10,000 cover images and 10,000 stego images. Note that the rate of hidden text embedding in BOSS system is 0.4 per pixel. As the mentioned before, two methods of SPAM [13] and CC-PEV [8-9] are applied on the BOSS system to extract the features for steganalysis. The length of the extracted feature vectors using SPAM and CC-PEV methods are 686 and 548 respectively. In parameter setting of the proposed methods, the population size is set to twice the number of features in dataset, maximum iteration is 20, inertia weight is 1, and both of C_1 and C_2 are 2.

In the first comparison, the classification accuracy of the proposed method that is named as PSO-SVM on SPAM dataset is compared to ABC-j48, ABC-NB and ABC-SVM. The ABC-j48 method is the combination of j48 classification algorithm and ABC method as the feature selection. Similar to ABC-j48, ABC-NB uses Naïve Bayes (NB) classifier to evaluate the feature subset extracted by ABC method. The ABC-SVM method which is named IFAB in literature utilized SVM classifier with ABC algorithm for feature selection in steganalysis problem. According to Table 1, the best classification accuracy is obtained by the proposed method where the proposed method significantly increases the accuracy compared to the other methods. Since the feature selection method used in all of the other methods is ABC algorithm, number of the selected features for all of them is the same as 80 out of 686 feature element while number of the selected features using PSO algorithm is 140 that shows 79.59% reduction in feature space. However the PSO method shows lower percentage of feature reduction than the ABC algorithm, but higher classification accuracy of the proposed method than the other methods proves the superiority of PSO to the ABC method in terms of selection of the most significant and influential feature elements. It is likely that ABC removes the features which are important and should be kept.

The classification accuracy of the proposed method on the CC-PEV dataset is reported in Table 2. In CC-PEV, the proposed method shows the best classification accuracy, in comparison to the other methods. Similar to SPAM dataset, PSO achieves lower percentage of feature reduction compared to ABC method, but the classification accuracy of the proposed method is significantly higher than the other methods. This table is the second claim to show the priority of PSO to ABC in terms of feature selection.

Table 3 compares the classification results of the proposed method with several classic classifiers on both of SPAM and CC-PEV datasets such as ABC-NB, ABC-J48, different combination of MBEGA, Releif-J48, SMO [24] *k*-Nearest Neighbor (*k*-NN) [26] and Spegasos [27]. By employing of PSO, the proposed method takes the advantage of best classification accuracy on both of SPAM and CC-PEV dataset. Also the classification results on SPAM and CC-PEV with total features is reported where comparing the results of SPAM and CC-PEV with the proposed PSO-SVM proves the effect of PSO-based feature selection with novel AUC fitness function on the performance of SVM.

Table 4 compares the different feature selection methods on SPAM and CC-PEV datasets in terms of number of selected features where the proposed PSO-AUC method selects the largest number of features compared to the other feature selection methods. As a result, the proposed PSO-based feature selection method with the novel AUC fitness function can be considered as the best solution to improve the performance of a steganalysis system by choosing the most significant feature elements.

VI. CONCLUSION

In this paper, a new method of feature selection for the task of image steganalysis is proposed based on PSO optimization technique. The proposed PSO method benefits from novel AUC measure as the fitness function. The proposed method is evaluated on feature vectors extracted by SPAM and CC-PEV methods. By utilization of SVM model as the classifier, the proposed method outperforms the rest of feature selection methods and classic classifiers. However the proposed PSO-based feature selection method selects the largest number of features compared to the other feature selection method, but the superiority of the proposed method in terms of classification accuracy proves the effect of selected feature.

TABLE I. CLASSIFICATION ACCURACY OF DIFFERENT SYSTEMS ON SPAM DATASET.

Measure	Approach			
	ABC-J48	***ABC-SVM***	***ABC-NB***	***PSO-SVM***
Number of selected features	80	80	80	140
Selected feature accuracy	58.3%	60.98%	57.4%	82.62%
Number of primary features	686			
% Reduction in feature	88.33%	88.33%	88.33%	79.59%
% Increase in accuracy	0.3% increase	2.98% increase	0.6% decrease	24.62% increase

TABLE II. CLASSIFICATION ACCURACY OF DIFFERENT SYSTEMS ON CC-PEV DATASET.

Measure	Approach			
	ABC-J48	***ABC-SVM***	***ABC-NB***	***PSO-SVM***
Number of selected features	250	250	250	363
Selected feature accuracy	65.3%	68.22	64.6%	87.7%
Number of primary features	548			
% Reduction in feature	54.37%	54.37%	54.37%	33.76%
% Increase in accuracy	0.3% increase	3.22% increase	0.4% decrease	22.7% increase

TABLE III. CLASSIFICATION ACCURACY (%) OF DIFFERENT METHODS ON SPAM AND CC-PEV DATASET

Dataset	Classification method									
	SPAM	***CC-PEV***	***ABC-NB***	***MBEGA-Releif-J48***	***ABC-J48***	***MBEGA-Releif-SMO***	***Spegasos***	***k-NN***	***ABC-SVM***	***PSO-SVM***
SPAM	58	-	57.4	58.2	58.3	59.08	59.2	60.8	60.98	82.62
CC-PEV	-	65	64.6 %	65.15	65.3	66.02	66.9	67.1	68.22	87.7

TABLE IV. COMPARISON OF DIFFERENT FEATURE SELECTION METHODS WITH CORRESPONDING FITNESS FUNCTION ON BOTH OF SPAM AND CC-PEV IN TERMS OF NUMBER SELECTED FEATURES.

Dataset	Feature selection method					
	ABC-SVM	***ABC-NB***	***ABC-J48***	***MBEGA-Releif-SMO***	***MBEGA-Releif-J48***	***PSO-AUC***
SPAM (686)	80	80	80	18	64	140
CC-PEV (584)	250	250	250	180	200	363

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Text summarization using concept graph and BabelNet knowledge base

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Abstract— **With rapid increasing text information, the need for a computer system to processing and analyzing this information are felt. One of the systems that exist in analyzing and processing of text is a text summarization in which large volume of text is summarized based on different algorithms. In this paper, by using BabelNet knowledge base and its concept graph, a system for summarizing text is offered. In proposed approach, concepts of words by using BabelNet knowledge base are extracted and concept graphs are produced and sentences, according to concepts and resulting graph are rated. Therefore, these rating concepts are utilized in final summarization. Also, a replication control approach is proposed in a way that selected concepts in each state are punished and this causes to produce summaries with less redundancy. To compare and evaluate the performance of the proposed method, DUC2004 is used and ROUGE used as evaluation metric. The proposed method by compared to other methods produces summaries with more quality and fewer redundancies.**

***Keywords*—Information Retrieval, BabelNet, Text Summarization, Graph Concepts, Community Detection**

I. INTRODUCTION

A summary is compact display of a document. Automatic text summarization refers to the process of reducing the quantity of the text preserving the actual content of the document. System that summarizes a document to a single document called single document summarization. On the other hand, system that summarizes a set of documents into a single summary is called multiple-document summarization. In general, the output of summarization system is included two types [19]: extractive and abstractive. In extractive summary, the important sentences of the original document are identified and are use in final summary. In abstractive summary there are sentences that do not exist in the original document but express main concept of document. According to these definitions, it can be understood that abstractive summary need to understand document completely and needs tools for natural language processing. So, it causes providing a good abstractive summary to be difficult [11].

In this paper, a method for summarizing multiple documents is proposed and by using abstractive way, key sentences are identified. The proposed system is based on identifying concepts of BableNet knowledge base. By Using the concepts and relationships which are identified from documents, a graph is produced and then similar concepts are extracted from this graph so they are placed in related community. Sentences with respect to these concepts and their communities are rated and final summary is produced. In following, at first a brief history of the pervious methods for a document and multi-document summarization are describe and then proposed system is describe completely. One important feature of purposed system is that redundancy of information is prevented and also concepts of sentences are considered.

II. Related Work

Interest in automatic text summarization, arose as early as the fifties. After investigation on text automatic translation, automatic text summarization was discussed immediately [6]. In 1958, Luhn suggested to weight the sentences of a document as a function of high frequency words [13]. Initial summarization systems were based on heuristic properties such as location of sentences in text, frequency of repeated words, existing of words token and overlap between sentences and headlines. These features were combined by using a linear weighting function and each sentence is given a special rate and the sentences with higher rate are used in final summary.

More advanced techniques use graph-based methods. In the graph-based methods documents are usually displayed as graphs which in these graphs, nodes indicate text fragments such as, words, sentence. Edges are relations and similarity between them [7]. When the graph is produced, important nodes are detected and they are used for producing summary [14]. LexRank is an example of graph-based methods for multi-document summarization [3]. In this approach, an undirected graph which is fully connected is considered for a set of documents that are going to be summarized. In this graph one node is allocated for each sentence that is indicated by tf-idf and edges are labeled based on intra-sentence cosine similarity. Nodes which are most connected are selected for using in a summary. Graphsum is another graph-based approach that is used for multi-document summarization [1]. In this approach, the relation between different words are identified using association rules then by using these relation the graph is created. In this graph, nodes which are words or combinations of words are ranking based on PageRank and these ranking are used for extracting the sentences. Graph-based approach provided an acceptable result in the identification of important and valuable sentences but most of them consider sentences as a bag of words and concepts of documents are ignored.

Some algorithms which are provided for summarization, use clustering. Clustering is the process of grouping similar objects in the same class. When clustering is used in the summarization, objects are sentences and classes are clusters that sentences belong to them. Some researches in the field of summarization have used clustering approach to identify the main titles and by using these titles produced final summarization. Also some algorithms have been proposed in which, instead of clustering sentences they cluster words. In [2], an algorithm is used for hierarchical clustering of graph of words and according to a level that words belong, important words are identified and they are considered as the key words in sentences.

In [18], a summary is provided using the Wikipedia knowledge base. In this method, first, sentences are mapped to concepts of Wikipedia. The resulting mapped is displayed in a bipartite graph in which a set of nodes are sentences of document and other set of nodes identify the concepts of Wikipedia. Then a matrix is considered to show the relationship in a bipartite graph. In this matrix, each row indicates a sentence and each column indicates a concept. For producing summary, this matrix is used. One of the drawbacks of this method is redundancy, because all sentences which are related to a concept are considered and it is possible sentences be similar. Another drawback of this method is that it does not consider the relationship between concepts and it is possible that a concept be general form of other concepts. WordNet is a semantic network which is consisted of Synset and they are linked through semantic relationship [8] WordNet can be used as knowledge base to identifying the concepts in the original text in order to produce summaries [17]. First, a text is mapped to the WordNet knowledge base then a semantic graph is created for each sentences of the document and according to number of parent's node, edges are rated and nodes with high rates are selected as summary sentences.

III. Our Approach

The proposed approach in this paper is abstractive multi-document summarization and is based on the knowledge base for the English language. In this proposed approach instead of words and compounds, concepts related to them are used and graph of concepts are built using the BabelNet knowledge base. In this graph, the nodes represent concepts and name entities and edges represent the semantic relation between them then the graph is divided into a set of related concepts and by using purposed approach, sentences are rated and according to these rates they are selected for summarization. The proposed method consists of five main steps: preprocessing, Identifying and weighing concepts, producing graph, community detection and selecting sentences. These steps are illustrated in figure 1.

A. Preprocessing

In this step, some pre-processing is performed for a document. This pre-processing includes the removal of frequent and words that carry little information such as prepositions and pronouns.

B. Identifying and weighting concepts

The purpose of this stage is the extraction and weighting of document's concepts. To do this, BabelNet knowledge base is used. BabelNet is a very large semantic network and multilingual network. Concepts and relations are harvested from the largest available semantic lexicon of English, i.e., WordNet [3] and collaboratively-edited encyclopedia, i.e., Wikipedia. So, it causes coverage of concepts in BabelNet be larger than other knowledge bases.

In the proposed process, first words are mapped to BabelNet concepts and then by applying existing disambiguation system in BabelNet, the best concepts for each word are selected. After extracting the concepts, tf-idf is used for weighting concepts in document. After this step, set of documents are changed to a weighted non-repetitive set of concepts which they will be used in the next step of proposed approach.

C. Creating graph

After identifying and weighting concepts of the document, relation of between pair of concept is calculated by using of

BabelNet. These semantic relations consist of: derive, is-a, part-of, related, gloss-related [14]. By identifying concepts and edges between them, an undirected graph is constructed which in it nodes are weighted concepts and edges are relation between the concepts.

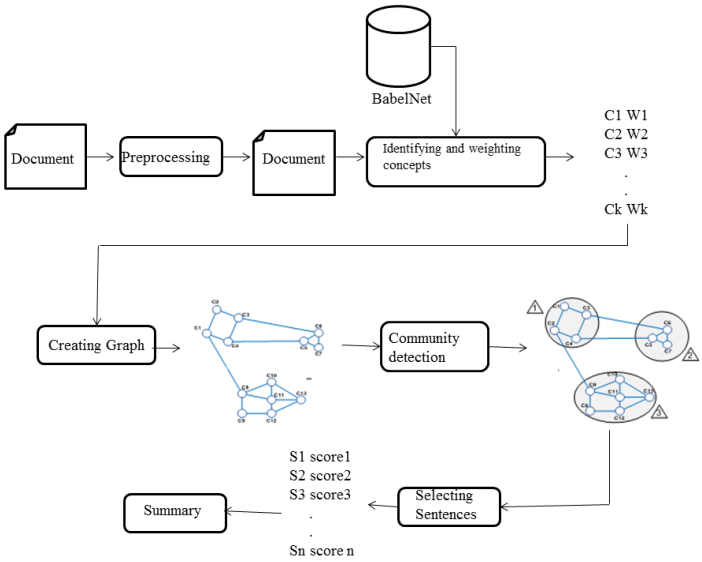


Fig. 1. Process of proposed method

D. Community detection

In the previous step, graph's concept using BabelNet was created. In this step, similar communities in the graph are identified. Since the resulted semantic graph of concepts is a very large graph and the number of communities is not specified, Girvan Newman algorithm is used to identify similar communities. This algorithm is based on the elimination of edges between communities and is one of the most widely used methods for detection communities in complex networks and large graph [4]. Girvan Newman algorithm involve iterative removal of edges from the network to split it into communities, the edges removed being identified using one of a number of possible "betweenness" measures [5]. At the end of this stage, a group of communities are created which includes a variable number of unique, similar and weighted concepts. Also, some of these communities contain the very small number of concepts which are usually insignificant and unrelated to the original title of documents.

E. Selecting Sentences

For rating sentences, each community is weighted according to weights of its concepts in that community. The weight of each community is sum of the total weight of the concepts in the community and is calculated according to formula 1:

$$W(C_i) = \sum_{k=1}^{n} W(concept_k), concept_k \in C_i \qquad (1)$$

In this formula, C_i indicates ith community, $W(C_i)$ is weight of community C_i, n is concepts of C_i and $concept_k$ is kth concept in community. Weight of each concept is indicated by $W(concept_k)$. Then a linear function is used to rate sentences. Weight of each concept in a sentence is considered when calculating its rate. For calculating rate of sentence formula 2 is used.

$$Score(S_j) = \frac{1}{n} \sum_{k=1}^{n} (W(C_i) + W(concept_k) + Degree(concept_k)) \qquad (2)$$

In this formula, S_j is jth sentence, n is number of concepts in S_j, $concept_k$ indicate kth concept in sentence S_j, $W(concept_k)$ is weight of kth concept, $Degree(concept_k)$ is degree of this node in graph, C_i is community that concept i is in and $W(C_i)$ is weight of community C_i. After summing up the weight of cluster, concepts and degrees, result is divided by number of concepts in the sentence in order to avoid including just long sentences in summary.

Because the proposed method for extracting sentences uses weighting concepts and community, in produced summary, there is the possibility to repeat sentences with similar concepts. In calculating the rating of two sentences which have similar concepts, sentences will have same rate, because concepts in same community have same weight and degree. Actually, using one of them in the final summary is enough. To solve this problem, after selecting concepts of a sentence, in calculating rate, other sentences are not included and it causes sentences with similar concepts of previous sentences are punished and their rate become less and the possibility of being in summary becomes low.

IV. Evaluation

In this section, we first introduce data set and evaluation metrics. Then we present experiment results and compare suggested method with other methods.

A. Data Sets

DUC conferences have published data to summarizing text in the English language since 2001. DUC 2004 is one of the versions of DUC data set which is used for single-document and multi-document summarization and includes a set of documents along with a summary of the human. This data set includes 500 documents from various sources [12]. These 500 documents contain 50 different categories which each of these 50 categories contain 10 documents. And for each ten documents, four summaries presented by different people.

B. Evaluation measures

In English, the most popular evaluation measure is ROUGE which is Recall-Oriented and is used to assess automatic single document and multi-document summaries [10]. The measures count the number of overlapping units such as n-gram, word sequences, and word pairs between the computer-

generated summary to be evaluated and the ideal summaries created by humans [9].

$$ROUGE-N = \frac{\sum_{S \in \{ReferenceSummaries\}} \sum_{N-gram \in S} Count_{match}(N-gram)}{\sum_{S \in \{ReferenceSummaries\}} \sum_{N-gram \in S} Count(N-gram)} \quad (3)$$

In formula 3, ROUGE-N is an n-gram recall between a candidate summary and a set of reference summaries. In this formula *n* stands for the length of the n-gram, *gramn*, and *Countmatch*(*gramn*) is the maximum number of n-grams co-occurring in a candidate summary and a set of reference summaries. Skip-bigram is any pair of words in their sentence order, allowing for arbitrary gaps. Skip-bigram co-occurrence statistics measure the overlap of skip-bigrams between a candidate translation and a set of reference translations. Skip-bigram is any pair of words in their sentence order, allowing for arbitrary gaps. Skip-bigram co-occurrence statistics, ROUGE-S, measure the overlap ratio of skip-bigrams between a candidate summary and a set of reference summaries [9].

C. Comparison

In the proposed method, there are a set of concepts that have been in their respective communities and each of these communities, according to the concepts that contain, have weight. Communities that have important concepts gain higher weight while communities that include unimportant concepts and unlike main title of text, will have less weight. Thus, sentences that have concepts from higher communities should be encouraged and get higher rate, although some of these concepts are in higher communities, its weight is low or have little contact with other concepts. So, in addition to community weight, weight and degree of the concept is also considered. Also to avoiding duplicate concepts, approach of ignoring selected concepts is introduced. In this approach, after extracting each summary sentence, previous selected concepts are ignored and sentence weigh is recalculated.

The proposed method is compared with four multi-document summarization methods. These methods include, SUMMA, Graphsum, LexRank, Microsoft. SUMMA is a single and multi-document summarization. It uses features such as position of a sentence in document, similarity with first sentence, word frequency and existence of words of title in sentences. To control Sentence repetition, similarity between sentences is calculated in order to prevent repeated sentences are not consider in document. But this approach does not have any control over duplicate concepts and their placement in the final summary. LexRank is famous approach for text summarization and is based on graph. This approach considers a fully connected undirected graph for a set of documents which are to be summarized. Nodes which have most connections are selected for summarization. Microsoft summary is a feature of Microsoft Word software and is based on frequency of words. Graphsum is graph-based approach which considers combination of repeated words in documents and uses association rules for identifying the links between them. This algorithm uses greedy approach to selecting sentences and control just repeated sentences.

In Table 1, value of ROUGE-1 ،ROUGE-2 and ROUGE-SU4 for proposed approach is compared with Graphsum, LexRank and Microsoft approach. In figure 2, also values are presented by a chart.

TABLE 1. Comparison between proposed method and others

Approach	ROUGE-SU4	ROUGE-2	ROUGE-1
Proposed approach	0.40893	0.08425	0.11830
Graphsum [1]	-	0.093	0.13
LexRank [3]	0.37580	0.07226	-
SUMMA [20]	0.36682	0.07335	-
Microsoft [20]	0.35691	0.03939	0.069563

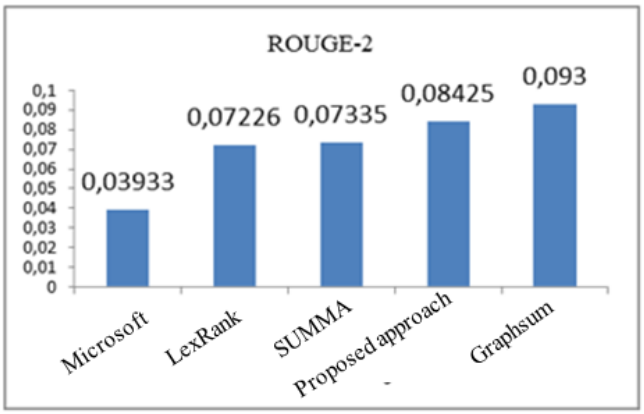


Fig. 2. Comparing proposed method with other methods

V. CONCLUSION

In this paper, a method for presenting multi-document summarization is proposed. Proposed method of text summarization uses BabelNet knowledge base and concepts graph. It extracts meanings of words using knowledge base and makes a concept graph from extracted concepts. After making graph, communities are detected with Girvan Newman algorithm then we introduce a linear function to calculate the score of sentences according to communities. The use of concepts instead of words caused better understanding and produced summary is closer to human summaries

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Identify human personality parameters based on handwriting using neural network

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***Abstract*—The survey of person's handwriting and its parameters anatomy will lead the psychologists to investigate the psychological principles of behavior, temperament, character, personality and the nervous and social aspects of a person's brain. The human's handwritings in different psychological states including: anger, calm, happiness, excitement and different emotional states will show one's reaction or behavior at the same situations or same states. Analyzing one's handwriting is one of the scientific methods for evaluating and understanding one's personality. When a person's personality is analyzed, the effect of his personality or character on his/her handwriting is obvious and remarkable. The purpose of this method is to identify a person's personality through his/her handwriting. The literature shows that the identification and verification of human's identity from handwriting is common and relatively useful. Moreover, identification of one's identity from signature is more common. In this paper, in order to identify the character parameters in training stage, The Minnesota Multiphasic Personality Inventory was applied, and for identification of one's personality from his/her handwriting, a hidden Markov model and neural network (MLP) to perform classification was used so that MLP was used to identify those properties which are not related to the writer and a hidden Markov model was used to classify those properties which are related to the target writer. In this stage, in order to select the most similar image to the image of the input context, the image of input context after eliciting its property will be compared with all existing patterns in database. Finally the test output regarding the personality of the image of the target text which is recommended by the system will be introduced as the parameters of the output character.**

Keywords—handwriting recognition,Persian handwriting, neural network, MMPI personality test.

I. INTRODUCTION

Handwriting analysis is an act that has been performed for many years. However, when we analyze the behavior and personality of an individual, its effects are still discussable. Each of these neural brain patterns lead to a unique neural and muscular movement for an individual; therefore, this small subconscious movement occurs for each person, who has a certain personality feature while writing. the problem of recognizing the writer`s personality from his handwritten texts aims to specify the personality of the writer given a handwritten text, which of course this personality elicitation is performed based on samples of different individuals` handwritings. Professional handwriting researchers investigate and analyze the sample handwriting.

Writing can indicate personality features like feelings, fear, honesty, etc. identifying the personality of a human being by his handwriting is an old technique. Before, the nature of an individual was predicted manually, which took a long time. Recognizing a writer`s personality from his handwriting has recently become a considerable and interesting subject in psychology.

II. PREVIUS WORKS

This section discusses a number of feature extraction methods from Persian and Arabic alphabets, words, and handwritten texts.

Reference [1] reviews identity recognition methods from handwriting and graphology. Moreover, a review of handwriting analysis computer systems in the market is presented and compared for better understanding.

Reference [2] points out and uses salient and important features of using handwriting in graphology analysis, including curves and figures in paper margins, line spaces, line tilts, word tilts, sharpness of edges, character sizes, text density, writing speed, and order point. This paper proposed some methods for the first time. Moreover, for automatic feature extraction from Persian handwritten texts, 24 training samples and 118 test samples are used for the experiments.

Reference [3] considers 6 different feature types for computerizing handwritten graphology: 1- character sizes, 2- word tilts, 3- baseline, 4- pen pressure, 5- space between characters, and 6- space between words in the document that is used to recognize the writer`s personality.

Reference [4] claims that potential behavioral and personal deviations of an individual are possible by analyzing his handwriting. In this paper, two methods are proposed for handwriting analysis:

1- Graphology that is a psychological analysis method.
2- Graphology that is used to identify the writer.

Reference [5] discusses the effect of brain neural patterns on micro-movements of the muscles, such that because of these micro-movements, personal parameters are emerged in human daily behaviors like writing a text. All hits, patterns, and the pressure that is applied when writing a word can express personal behaviors of an individual. In this reference, features like the tilt of the baseline, pen pressure, tilt and size of characters are used to extract the personal parameters of an individual. This reference used the linear regression method at the classification stage.

Reference [6] extracts personal parameters like extrinsic emotions, fear, trustworthiness, etc. from the graphology of handwriting. Professional handwriting tests, which are called graphology, are mostly recognized by part of the handwritten text. The handwriting analysis accuracy depends on the skills of the expert. In this paper, a method was proposed to investigate the personality based on features like baseline, pen pressure, and character t in a separate handwritten text. These parameters and features are defined as the input of a neural network, whose output is the personal behavior of the writer. The performance of this system is measured by different experiments.

Reference [12] uses computers to accelerate the image processing of Persian handwritten texts. More specifically, important features are extracted from the handwritten text to understand the psychological state of the writer. In order to do so, features like boldness, compression, and two word space measures are achieved. The tilt angle of the text is then obtained and after removing it, the main points corresponding to the right, left, and up margins, as well as the shape of the margins are achieved. Finally, the line vibration is obtained. Extracted features are divided into four groups, which are sent to three fuzzy systems and a non-fuzzy system to recognize the personality of the writer.

III. The Minnesota Multiphasic Personality Inventory

The Minnesota Multiphasic Personality Inventory[1] is the most widely used and researched standardized psychometric test of adult personality and psychopathology.[1] Psychologists and other mental health professionals use various versions of the MMPI to help develop treatment plans; assist with differential diagnosis; help answer legal questions (forensic psychology); screen job candidates during the personnel selection process; or as part of a therapeutic assessment procedure.[2] The original MMPI, first published by the University of Minnesota Press in 1943,[3] was replaced by an updated version, the MMPI-2, in 1989. A version for adolescents, the MMPI-A, was published in 1992. An alternative version of the test, the MMPI-2 Restructured Form (MMPI-2-RF), published in 2008,[4] retains some aspects of the traditional MMPI assessment strategy, but adopts a different theoretical approach to personality test development.

A new and psychometrically improved version of the MMPI-2 has been developed employing rigorous statistical methods that were used to develop the RC Scales in 2003 and used in 2008. The new MMPI-2 Restructured Form (MMPI-2-RF) has been released by Pearson Assessments. The MMPI-2-RF produces scores on a theoretically grounded, hierarchically structured set of scales, including the RC Scales. The modern methods used to develop the MMPI-2-RF were not available at the time the MMPI was originally developed.The MMPI-2-RF builds on the foundation of the RC Scales, which are theoretically more stable and homogenous than the older clinical scales on which they are roughly based.

A. Validity Scales

The validity scales in all versions of the MMPI-2 (MMPI-2 and RF) contain three basic types of validity measures: those that were designed to detect non-responding or inconsistent responding (CNS, VRIN, TRIN), those designed to detect when clients are over reporting or exaggerating the prevalence or severity of psychological symptoms (F, Fb, Fp, FBS), and those designed to detect when test-takers are under-reporting or downplaying psychological symptoms (L, K, S). A new addition to the validity scales for the MMPI-2-RF includes an over reporting scale of somatic symptoms (Fs) as well as revised versions of the validity scales of the MMPI-2 (VRIN-r, TRIN-r, F-r, Fp-r, FBS-r, L-r, and K-r). The MMPI-2-RF does not include the S or Fb scales, and the F-r scale now covers the entirety of the test.

Table1.Validity Scales

Abbreviation	***Description***	***Assesses***
CNS	"Cannot Say"	Questions not answered
L	Lie	Client "faking good"
F	Infrequency	Client "faking bad" (in first half of test)
K	Defensiveness	Denial/Evasiveness
Fb	F Back	Client "faking bad" (in last half of test)
VRIN	Variable Response Inconsistency	Answering similar/opposite question pairs inconsistently
TRIN	True Response Inconsistency	Answering questions all true/all false
F-K	F minus K	Honesty of test responses/not faking good or bad
S	Superlative Self-Presentation	Improving upon K scale, "appearing excessively good"
Fp	F-Psychopathology	Frequency of presentation in clinical setting
Fs	Infrequent Somatic Response	Overreporting of somatic symptoms

B. Clinical Scales

The original clinical scales were designed to measure common diagnoses of the era.

Table2.Clinical Scales

Abbreviation	***Description***	***What is measured***
Hs	Hypochondriasis	Concern with bodily symptoms
D	Depression	Depressive Symptoms
Hy	Hysteria	Awareness of problems and vulnerabilities
Pd	Psychopathic Deviate	Conflict, struggle, anger, respect for society's rules
MF	Masculinity/Femininity	Stereotypical masculine or feminine

[1] MMPI

		interests/behaviors
Pa	Paranoia	Level of trust, suspiciousness, sensitivity
Pt	Psych asthenia	Worry, Anxiety, tension, doubts, obsessiveness
Sc	Schizophrenia	Odd thinking and social alienation
Ma	Hypomania	Level of excitability
Si	Social Introversion	People orientation

IV. General Principles of Personality Recognition System from Persian Handwritten Texts

Figure (1) presents the block diagram of a personality recognition system from the handwritten texts. The innovative methods in personality recognition from handwritten texts are ensued by changes in running one or several blocks of the following diagram. The general name of the system is in fact changed to the block performance. For instance, recognizing personality from handwritten texts based on neural networks is in the classification section.

A. *Pre-Proccessing*

All operations performed on texts, which facilitate the process of following phases, e.g. removing noise, smoothing, thinning, language recognition, word fonts, etc. the set of these processes have the following goals [13]:

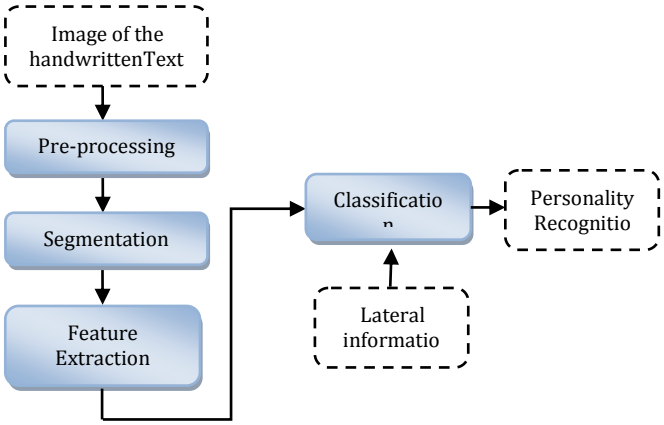


Figure 1. The block diagram of a personality recognition system

1- Reducing noise
2- Contour smoothing
3- Storing information that should be protected (thinning)

Activate binarizing for facilitating working with edit, ruler, and paragraph markers. By activating “Ruler” in the “View" section, you can see the settings of specific distances, columns, and margins. In order to find the undesired parts of paragraphs, like spaces between alphabets, pages, and lines, specific spaces, and chapter headers, activate paragraph markers (¶) in the “Paragraph” toolset.

B. *Segmentation(Sepration)*

The segmentation stage is very important for feature extraction, and calculating the sizes of characters and words in personality recognition systems from handwritten texts [14].

C. *Feture Extraction*

Feature extraction aim is to reduce data to a set of features, such that they are constant in the handwritten texts of a certain individual and independent of the other person's handwriting.

1) Text Independent Features

Independent text features include the margin value from the beginning of the page, word expansion, characters sizes, line spaces, word spaces, word tilts, horizontal to vertical ratio of characters, and lie tilts.

2) High-Order Local Autocorrelation as a Text Dependent Feature

Autocorrelation is one of the most well0-known functions insensitive to shift [7]. In what follows, a special type of autocorrelation is introduced:

Autocorrelation function is known as a shift insensitive function. The N-th order autocorrelation function is defined by N location changes$(a_1, a_2, a_3, \dots, a_N)$, from reference point r as equation (1).

(1)

$$x^N(a_1, a_2, a_3, \dots, a_N) = \int I(r)I(r + a_1) \dots I(r + a_N)dr$$

Where, I(r) is the text image and $r = z = (\log(p), \boldsymbol{P})$. There are many autocorrelation functions, which are resulted from different combinations of location changes on the text image. In this research, the number of location changes is reduced by removing location changes that are equal due to the same shift. In other words, the value of N is limited to 3 (N= 0, 1, 2, 3). Moreover, the ratio of location changes and displacements are limited in a 3×3 position window [7]. In order to obtain the values of HLAC, the text image is first scanned by 70 local 3×3 masks. The sum of the multiplication of corresponding pixels` values by one (pixels of black mask) is then computed for each mask [8]. This method is known as HLAC feature (figure 2).

3) Feature Vector and Generalized Discriminant Analysis (GDA)

In the proposed personality recognition system, when the number of training patters is greatly increased, the resolution of HLAC is reduced, which causes class interference. In this research, generalized discriminant analysis is used to increase the space and resolution of different classes [10]. GDA is resulted from the non-linear extension of the linear discriminant analysis and it is successfully used for many applications. This method can be used to overcome classification problems. GDA helps us to combine features and increase the resolution of the classes.

4) Classification and Recognition (With One or Several Classifiers)

This stage includes methods to map each pattern extracted from the feature extraction stage with one of the classes of the corresponding pattern space. This is performed through minimizing the feature vector of each input pattern in proportion to one of the reference vectors. Reference vectors are vectors that are derived from the training samples a priori. The proposed techniques for this stage can be searched in one of the general pattern recognition discussion groups [10]:

- Pattern matching
- Statistical techniques
- Neural networks

The three groups above are not necessary performed separately and they may be found among the techniques of other groups.

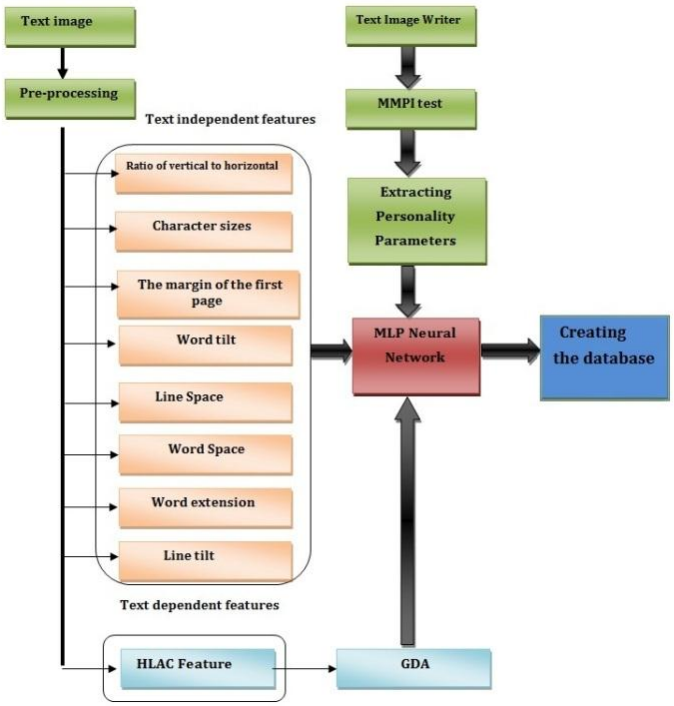


Figure 3. the block diagram of the personality recognition system

V. The Structure of the Handwriting Personality Recognition System

The proposed personality recognition system consists of two main training and test sections (figure 3). In the training section, after extracting features from all patterns of the input text image, the corresponding output is created using a MMPI personality test [11]. These input-outputs are then trained as a pattern in a neural network and finally, a comprehensive database is created as a result of training.

In the test section, this database is used as the main comparison reference. At this stage, after feature extraction, the input text image is compared with all patterns in the database to find the closest image. Finally, the output of the MMPI personality test corresponding to the selected text image is introduced as output personality parameters.

VI. Experimental Conditions and Database Type

In order to evaluate the proposed method, 70 individuals with different educations, ages, and genders were asked to fill the designed forms with their ordinary handwriting. These individuals were selected from ordinary people (college students, employees, etc.). Table (3) presents the characteristics of these individuals, including gender, education, and age.

Table 3. The characteristics of the individuals who filled the database's forms

Gender		Education			Age	
Female	Male	Elementary school to diploma	Diploma to undergraduate	Undergraduate to doctorate	7 to 40	Higher than 40
32	38	18	36	16	37	33

In order to perform the experiments and evaluations, these individuals were asked to write a constant text in one paragraph, which contained various words.

Subsequently, each writer took the MMPI personality test, which was designed in 1940s by two researchers of the University of Minnesota, United States. This personality test consists of 71 fundamental questions and the writer should select from true or false options. Finally, a score is given to the test that is in fact the character profile based on eleven clinical scales. These results are stored together with the ID that is assigned to each writer before writing the corresponding paragraphs.

The following points are considered when filling the forms:

- There is no limitation regarding the handwriting type. The collected samples include various handwritings. Of course, in some cases of writings filled by female individuals, the handwritings are very similar.
- The individuals were asked to fill the forms in a specific time duration and write using their ordinary handwriting without trying to alter or improve it.
- The forms do not have lines and only the paragraph area is specified.

Since the handwriting of each individual is changed by his/her mental and environmental conditions, the subjects were asked to fill the forms with patience and tranquility. After collecting the forms, they were all scanned as gray-scale images in 300dpi resolution.

VII. The Environment of the Simulated Software

In this dissertation, all simulation are performed using MATLAB 2013a and in some cases, Matlab instructions are used to transform gray-scale images into binary ones and label groups. Moreover, DRTools[2] toolbox is used to apply the GDA algorithm, whose reception and route should be separately defined in the Matlab toolbox.

VIII. Results of the Proposed Algorithm

In this section, the output of the proposed personality recognition system is compared with those of MMPI test (i.e. the 11 scales of the MMPI test).

Figure 4 presents the HLAC feature before and after using the GDA algorithm:

In figure 4, the horizontal axis represents the number of handwritings and the vertical axis shows the value of the extracted feature. As we can see in the figure, after applying GDA, the resolution is considerably increased. In these experiments, from the total 70 samples, 50 were selected for training and the rest was used for tests. This comparison is performed for different training conditions, including the main parameter of the MLP neural network, e.g. the number of neurons in the middle and input layers, training duration, etc. table 4 presents the results of this comparison.

As we can see, the highest recognition rate is resulted when the number of neurons in the input layer is 18 and the number of neurons in the hidden layer is 10. Results of the neural network are presented in figure5.

Table 4. Comparison of the results for different neural network training conditions

The averagepersonalityrecognition rate in comparison to MMPI test		Training duration (seconds)	Number of trainings	Number of neurons in the hidden layer	Number of neurons in the input layer
Test	Trainig				
46 %	69%	500	70	5	10
59 %	72%	500	70	7	15
61 %	76%	700	70	10	18
52 %	74%	1100	70	15	20
57 %	71%	2000	70	19	25

As we can see, the highest recognition rate is resulted when the number of neurons in the input layer is 18 and the number of neurons in the hidden layer is 10. Results of the neural network are presented in figure 5.

[2] Dimensionality Reduction

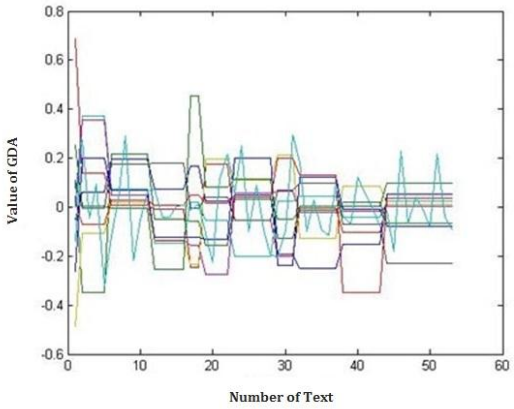


Figure 4. The extracted features for 53 handwritings without using GDA

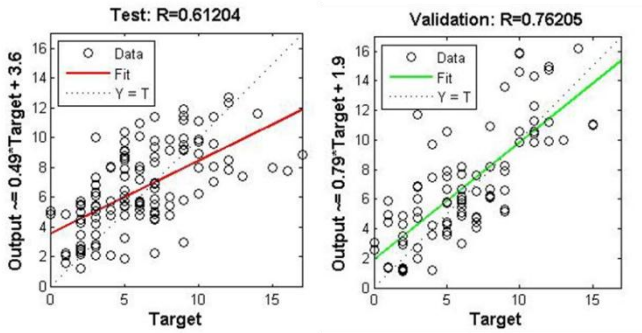


Figure 5. (a) Regression of the validation data (b) regression of test data

Figure (5a) presents the regression of validation data and figure (5b) presents the regression of the test data. Moreover, table 3 is presented to show the role of each feature extraction stage in improving the final output of the personality recognition system.

In this table, the input feature vector of the personality recognition system only consists of one feature extraction method mentioned in each row. The same feature vector is used to estimate the clinical and validity scales of the neural network. Therefore, according to the recognition rate of the personality recognition system in each row, we can find the effect of the feature extraction method on estimating the clinical and validity scales parameters.

According to table 5, we can find some important points. The sum of the values in each row of table 5 and normalizing it, shows the effect of each feature extraction stage on the final output of the personality recognition system.

As we can see, the HLAC feature has the highest effect (29.08%) and the ratio of vertical to horizontal words has the lowest effect (8.56%) on the accuracy of the propose system`s output. Moreover, the sum of the values of each column in table 5, whose results are presented in figure 6, shows the average estimated scales for each test of the proposed personality recognition system.

Table 5: The role of each feature extraction stage in improving the final

Feature / Scale	*Ratio of vertical to horizontal*	*Character sizes*	*Word tilt*	*Line spaces*	*Word spaces*	*Margin value from top of page*	*Word extension*	*Line tilt*	*HLAC feature*
L	5%	6.5%	6.8%	8.5%	4.5 %	3.1 %	6.4 %	6.5 %	17.3 %
K	4.5%	5.8%	6.2%	7.6%	5.1 %	3.8 %	5.6 %	6.7 %	16.8 %
F	4.8%	6.1%	5.6%	6.4%	3.1 %	4.2 %	6.1 %	5.9 %	16.2 %
Ma	5.1%	5.4%	5.9%	6.8%	4.7 %	4.5 %	4.9 %	6.1 %	17.5 %
Sc	5.7%	4.6%	6.1%	5.2%	3.4 %	4.1 %	5.7 %	5.3 %	16.5 %
Pt	6.1%	6.8%	6.4%	7.5%	4.6 %	3.2 %	4.9 %	5.6 %	16.4 %
Pa	4.7%	5%	5.2%	6.9%	4.5 %	4.5 %	5.2 %	6%	16.4 %
Pd	4.2%	5.3%	5.5%	7.2%	5.1 %	4.3 %	5.8 %	6.5 %	17.1 %
Hy	5.8%	4.9%	6.4%	6.9%	5.7 %	3.5 %	4.5 %	5.9 %	17.6 %
D	5%	5%	5%	5%	5.1 %	4.9 %	4.6 %	5.6 %	16.5 %
Hs	5.7%	3.4%	5.9%	6.3%	4.4 %	5.4 %	5.4 %	5.8 %	17.4 %

output of the personality recognition system

In this figure, the clinical scale Hs has the highest value (64.60%) and the clinical scale Pa has the lowest estimation value (56.6%).

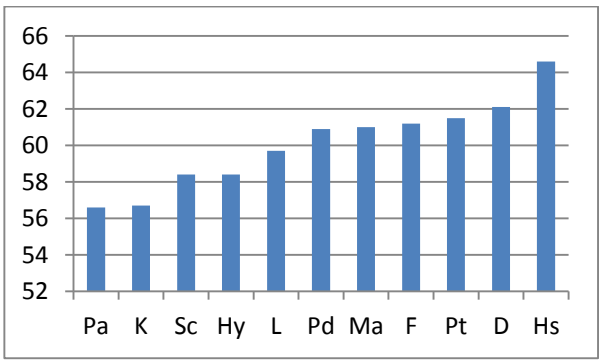


Figure 6. The average estimated scales for each test

K-means clustering is a method of vector quantization, originally from signal processing, that is popular for cluster analysis in data mining. k-means clustering aims to partition n observations into k clusters in which each observation belongs to the cluster with the nearest mean, serving as a prototype of the cluster.The problem is computationally difficult (NP-hard); however, there are efficient heuristic algorithms that are commonly employed and converge quickly to a local optimum. These are usually similar to the expectation-maximization algorithm for mixtures of Gaussian distributions via an iterative refinement approach employed by both algorithms. Additionally, they both use cluster centers to model the data; however, k-means clustering tends to find clusters of comparable spatial extent, while the expectation-maximization mechanism allows clusters to have different shapes.

In pattern recognition, the k-Nearest Neighbors algorithm (or k-NN for short) is a non-parametric method used for classification and regression.[1] In both cases, the input consists of the k closest training examples in the feature space. The output depends on whether k-NN is used for classification or regression.or classification and regression, it can be useful to assign weight to the contributions of the neighbors, so that the nearer neighbors contribute more to the average than the more distant ones.

Finally, the result of the proposed algorithm is compared with conventional methods using one database and table 6 presents the results.

Table 6. Evaluation of the proposed algorithm

Test	Efficiency	Measure
13%	20%	K-Means
40%	71%	KNN
61%	76%	Proposed method

IX. Conclusions

This research employs a personality recognition system which automatically extracts the character parameters from Persian handwritten texts. Well as due to the use of valid personality test (MMPI) in the training system,the extracted personality parameters on the test step was pretty standard, in result the proposed method has superior finality to other methods. The proposed system create feature vector using HLAC independent feature, context features such as value of margin from the top, word extraction, character sizes, line space, word space, word tilts, horizontal to vertical ratio of characters, and lie tilts. The MLP neural network is used for classification; Such that the output of this network will be the parameters of the author characters. Training and evaluation prepared for the database system is used by 70 different writers.

considering the results, the advantage of the proposed algorithm is as follows:

1- Using dependent and Independent features of text in the process of feature extraction.

2-The proposed personality recognition system is automated, particularly in the process of feature extraction (None automated systems are very unendurable and time-consuming)

3- Enhance accuracy and reliability of the personality recognition system due to the use of MMPI test on training step

4- No need to segmentation on feature extraction phase

5- Using GDA to increase the space between classes

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A Hybrid Localization Method for a Soccer Playing Robot

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***Abstract*—self-localization is the process of estimating the robot position employing noisy measurements. It is a key issue for a soccer playing robots. Some probabilistic approaches have been developed among the years to address it. Monte Carlo Localization (MCL) based methods show good ability in dealing with kidnap problem, however, most of them are unstable when the number of samples are limited. On the other hand Kalman filter extensions are among the best light weight estimator for position tracking. Their drawback is that they are unimodal and can't be used for global and kidnaped problems. Combining the advantage of these two approaches can lead to a valuable method. In this paper we propose a new hybrid localization method that utilizes the MCL and UKF to reach a stable, multimodal, and low weight localization method. The advantages of our method are evaluated in several experiments.**

Keywords*—Self-localization; soccer playing robot; Monte Carlo Localization; Unscented Kalman Filter; kidnap*;

I. INTRODUCTION

Self-Localization is the problem of estimating robot position in a known environment. This problem is a key component in autonomous soccer playing robots. A Robot who is not aware about its position cannot makes proper decisions. To achieve this goal, a robot has access to relative and absolute measurements [1]. Relative measurements contain information about the location with respect to the previous state. In soccer playing robots, these measurements are usually gathered by odometry. Absolute measurements are acquired from the environment with sensors like camera and contain information about the robot pose independent of prior estimation. Given these measurements, the robot must estimate its location efficiently. What make this goal difficult are ambiguous and noisy measurements alongside the robot interactions with a dynamic environment. With respect to the difficulty, the localization problem is categorized in three different problems. In the simplest case the robot knows his initial location [1, 2]. Therefore, the only thing that must be done is tracking the position. This problem is known as the local localization. In the more difficult one that is called global localization, the initial pose of the robot is not specified and robot is located in a vague location. Finally the most complex localization problem is the kidnaped problem in which the robot may be teleported without its knowledge and must be recovered from this situation as quickly as possible.

The environment of a soccer playing robot is a dynamic and symmetric field. There are some other robots that may affect on the location of the robot and can make its measurements corrupted. Moreover sensor measurements are noisy and the robot can be teleported to other locations by external agents. With respect to the mentioned issues, determining the robot pose in a unique point is infeasible. So the belief of the robot about its position is estimated by probabilistic methods. In term of probability, the localization problem stated as keeping the probabilistic belief as acquiring noisy measurements. Bayes filter is the basis of all common localization methods. This filter is a recursive model estimating the posterior probability distribution over all possible states due to the collected measurements so far [3]. In favor of the posterior representation, Bayes filter can be implemented in two different approaches: continuous and discrete [3]. In most continoius approaches, the belief is represented by the parameters of a normal distrubution efficiently. these continious methods are unimodal, so thay are only applicable in local localization problem. Extended Kalman Filter (EKF) and Unsecnted Kalman Filter (UKF) are the most populare continious methods. On the other hands, discrete approaches are non-parametric filters that represent the belife with discretizing state space. Their advantages lie in the ability to estimate arbitary distribution and consequently deal with all localization problems. Monte Carlo Localization (MCL) is the most widely discrete approach implemented in the soccer playing robots.

Combining the efficiency of continious approach with the ability of solving kidnap in discrete ones can lead to a valuable localization method. In this paper, we propose a new hybrid localization method based on a population of UKF models and MCL, utilizaing advantage of both methods while overcoming their weaknesses. Efficiency of our approach evaluated in various experiments.

II. RELATED WORKS

Triangulation is the most trivial localization method that calculates a single point that is closest to the current location of the robot using geometric relations and absolute measurements [2]. But in dynamic systems like soccer playing robots, due to the existence of noise and uncertainty in sensors and environment the position of the robot can't be determined uniquely. Hence several probabilistic and fuzzy approaches have been introduced over the last years.

Kalman filter [3] and its extensions are among the most used estimators in state tracking. Kalman filter is a mathematical tool that tracks the state of a dynamic linear system optimally. Linearity condition rarely exists in the robotic systems. To deal with this problem, Extended Kalman Filter and Unscented Kalman Filter are developed. They overcome this lack by linearizing non-linear systems. The EKF uses Taylor expansion

to linearize the system. This type of linearization is subject to the approximation error and amount of it depends on the complexity of the functions that have been approximated and the degree of normal variable uncertainty [1]. A superior method that decreases the effect of linearization is UKF [4]. It approximates normal variable with a set of point called sigma points. The sigma points are propagated through the non-linear functions and the parameters of the normal variable retrieved from the transformed sigma points. The time complexity of UKF is more than EKF with a constant magnitude. Both EKF and UKF are unimodal and can be used only in local localization problem. This issue is addressed in [5] by utilizing a set of UKFs. In this method the location of a robot is estimated with a set of weighted UKFs. The weight of each UKF is smoothly updated according to the absolute measurements. To recover from a probable kidnap, new low weighted UKFs are injected with respect to the last observations. To manage the size of the population the low weighted UKFs are removed. A major drawback of this model arises when the number of positions that are obtained from sensor model is high. In this case, to estimate true posterior, many UKFs are needed that is critical in real-time soccer playing robots with low processing power.

Another popular filter that is used for dealing with global and kidnaped robot localization problems is MCL [6]. MCL is a non-parametric filter that estimates the belief of the robot position with a finite set of weighted samples. There are several variant of this filter. The basic MCL filter called Sampling Importance Resampling (SIR) has a resampling step in which each sample is duplicated proportional to its weight. SIR suffers from kidnapping, because after some iterations, all of the samples are converged and in this situation if the robot is teleported, there is no chance to retrieve true position. In [7] this problem is addressed with generating a fixed percentage of samples with respect to the absolute measurements in the resampling step. Their proposed method is known as Sensor Resetting Localization (SRL). A more formal method similar to the SRL is presented in [8]. In contrast it weights the new samples from relative measurements. Actually it is a more accurate version of Bayes filter implementation that especially makes robustness in state estimation for highly accurate sensors.

Adding a fixed part of samples from the observations in the case that the absolute measurements are noisy can decrease the robustness of estimation. In [9], the authors introduced augmented MCL (AMCL). The AMCL solves this problem by keeping the short and long term averages of observation likelihood. The number of samples to be added is determined with respect to the ratio of these averages. Also in [10], a new method is proposed for weighting each sample. Instead of changing the weight instantly it is increased or decreased smoothly. It is clear that using this strategy reduces the sensitivity to the sensor noise. However, using this method makes independent different object observation correlated. To reduce the incorrect correlation among observations, a temporal smoothing MCL (TSMCL) is proposed in [11] that fades out memory of past measurements in the sample weights. Moreover they suggest a new resampling algorithm called lazy resampling that limits the number of samples duplicated from a particle.

The efficiency of MCL based methods is related to the sample size. Having large samples in initial state of localization when there is no prior information about the location is a good idea. However, in tracking state when the samples density are converged, there is no such a requirement. The Kulback Leiber Distance (KLD) sampling [12] adapts the sample size during the localization process. It chooses the number of samples using the uncertainty of samples density. More formally KLD sampling determines the number of samples such that the distance between the true posterior and sample-based approximation doesn't exceed a pre-defined threshold. Here the true posterior is the samples generated after incorporating last relative measurement.

Combining advantages of several localization methods can lead to a more efficient method. In [13] a hybrid localization method relying on a 2D grid-based Markov Localization (in short ML) and MCL is introduced. The ML represents the state space with a 2D grid and uses histogram filter to approximate the posterior [1]. They named their method Reverse MCL (RMCL). As the name of RMCL implies, it reverses the MCL process, i.e. instead of distributing samples uniformly in the state space and then converging them; RMCL first finds the location of where samples should be converged with a coarse grained ML and then samples are drawn there. In other words, RMCL satisfies global and kidnaped localization problems with a 2D grid and satisfies position tracking with MCL. When the MCL filter is initialized with the ML, this filter is deactivated until the quality of the MCL filter is decreased. A similar approach has been developed in [14]. In contrast it uses an EKF for position tracking and both ML and EKF are executed simultaneously. The key component of their method is a controller that filters the mismatched observations and initializes the EKF in kidnap situations. If the controller mistakes in reinitializing EKF due the outliers then it can make position estimating unstable. In [15] this problem is solved with using a population of EKFs. Instead of reinitializing old EKF in other location a new EKF is created. If the new filter has been created because of the sensor noise the uncertainty of this filter is increased and after some iterations it is removed, while the old ones estimate the true location. Also a combination of grid-based Fuzzy-Markov method and a population of EKFs is established in [16]. It is identical with previous mentioned methods in which the Fuzzy-Markov controls the creation and removing of EKFs. All of these combined methods use the grid based Localization to initialize a tracker filter like EKF or MCL and recovering from kidnap, however, the fine-grained grid localization suffers from processing time overhead.

III. Hybrid Localization

As discussed in previous section, Kalman filter extensions such as EKF and UKF have some unique advantages that make them suitable in state tracking. They assume that the distribution of the robot location is a normal variable, therefore, they estimate the location with high efficiency. Moreover, they are light weight in time complexity. The major problem of these filters is that they are only strong for local localization problem. On the other hand, MCL based methods can deal with all localization problems. The weakness of these filters is that achieving high accuracy has much time complexity that is a big issue for soccer playing robots with low resources. In addition

most of them suffer from sensor noises when using small set of particles. So they are unstable while stability in localization makes stability in behavioral unit of the robot. In this section we propose a hybrid localization method that utilizes the advantages of both MCL and UKF while overcomes their weaknesses.

The main goal of this paper is introducing an accurate and multimodal localization method with low time overhead. In this section we individually evaluate each MCL and UKF filters on the case of humanoid soccer robot and then present the hybrid localization method in details. The proposed method can be used in every other type of robots employing proper motion and sensor models.

A. Monte Carlo Localization

The MCL represents the belief X_t about robot pose with a finite set of M weighted particles (samples) at time t:

$$X_t = p_t^1, p_t^2, \dots, p_t^M \quad (1)$$

Each particle $p_t^i = (x\ y\ \theta)^T$ is a hypothesis about a possible location of the robot in the field. Here $(x\ y)$ are the Cartesian coordinates and θ is the orientation of the sample in the field of play. Also each sample has a weight w_t^i that shows the likelihood of observing last absolute measurement from the sample position. Initially the samples are distributed uniformly in the whole state space. If there is a prior knowledge about the robot position, the distribution of samples can be done according to it. Then the samples are updated with the incoming measurements. This process can be stated in three steps: predication, weighting and resampling.

In prediction step we incorporate last relative measurement u_t in sample set using the motion model:

$$p_t^i = p_{t-1}^i + \begin{pmatrix} u_{t,x}\,\mathrm{R}_{1,1}\left(p_{t-1,\theta}^i\right) + u_{t,y}\,\mathrm{R}_{1,2}\left(p_{t-1,\theta}^i\right) \\ u_{t,x}\,\mathrm{R}_{2,1}\left(p_{t-1,\theta}^i\right) + u_{t,y}\,\mathrm{R}_{2,2}\left(p_{t-1,\theta}^i\right) \\ u_{t,\theta} \end{pmatrix} + \varepsilon_t \quad (2)$$

Where $u_{t,x}$, $u_{t,y}$ and $u_{t,\theta}$ are the translational and rotational displacements respectively acquired from odometry. Also ε_t is a normal random variable that reflects the noise of the odometry data and R(.) is a rotation around φ defined as:

$$R(\varphi) = \begin{bmatrix} cos\varphi & -sin\varphi \\ sin\varphi & cos\varphi \end{bmatrix} \quad (3)$$

To weight the samples we incorporate absolute measurements. Here absolute measurements gathered from a camera. The captured image can contains landmarks of the filed that placed in some known positions. Each detected landmark is a member of percept classes Γ (eg. Goalpost, filed line and etc.). For every sample p_t^i and landmark $j \in \Gamma$ we maintain the filtered importance weight $w_t^{i,j}$. This weight updated smoothly with respect to the detected landmarks as presented in [11]. Assuming conditional independence of the percept classes the sample weight w_t^i is calculated as:

$$w_t^i = \prod_j w_t^{i,j} \quad (4)$$

Finally in resampling step the samples duplicated with respect to their weights. Here we employed low variance resampling [1]. To accelerate the convergence of the samples, new samples generated by absolute measurements when the average weight of samples becomes less than a threshold.

B. Unscented Kalman Filter

Applying non-linear functions on a normal distribution can lead to a non-normal distribution. The UKF is a unimodal filter that represents the state space with a normal variable and solves this issue by using $2L + 1$ carefully chosen sigma points. Here $L = 3$ is the dimension of the state space. These points capture the true mean and covariance of a multivariate normal distribution. Then the points are propagated through the non-linear functions. Finally the parameter of the desired distribution can be retrieved with high accuracy from theses points.

Assume $X_t \sim \mathcal{N}(s_t, \mathrm{P}_t)$ be the normal variable that we like to estimate. The $s_t = (x\ y\ \theta)^T$ is the mean vector of the normal variable showing estimated pose of the robot and P_t determines the uncertainty of the state variable. Using this normal variable the sigma points can be generated as follows:

$$sp_i = \begin{Bmatrix} s_t & i = 0 \\ s_t + \sqrt{(L+\lambda)P_t} & i = 1, \dots, L \\ s_t - \sqrt{(L+\lambda)P_t} & i = L+1, \dots, 2L \end{Bmatrix} \quad (5)$$

The $\lambda = \alpha^2(L + \kappa) - L$ is the scaling parameter. α and κ are tuning parameters. The square root of P_t can be calculated by Choolsky decomposition.

There are two functions that affect the belief X_t: predict function and correct function. The predict function transforms the X_{t-1} to X_t with respect to the last relative measurement that is gathered from the odometry. The correct function incorporates absolute measurements in X_t to refine it. To apply predict function on X_{t-1}, we have done the following steps:

1. Generate sigma points.
2. Transform every sp_i using predict function.
3. Calculate prior parameters of the normal state variable.

The transformation of the sigma point sp_i is done by:

$$sp_i = sp_i + \begin{pmatrix} u_{t,x}\,\mathrm{R}_{1,1}\left(sp_{i,\theta}\right) + u_{t,y}\,\mathrm{R}_{1,2}\left(sp_{i,\theta}\right) \\ u_{t,x}\,\mathrm{R}_{2,1}\left(sp_{i,\theta}\right) + u_{t,y}\,\mathrm{R}_{2,2}\left(sp_{i,\theta}\right) \\ u_{t,\theta} \end{pmatrix} \quad (6)$$

Then new parameters are estimated as follows:

$$\begin{aligned} s_t &= \textstyle\sum_{i=0}^{2L} w_m^i sp_i \\ P_t &= \textstyle\sum_{i=0}^{2L} w_c^i (sp_i - s_t)(sp_i - s_t)^T + R_t \\ w_m^0 &= \tfrac{\lambda}{L+\lambda} \\ w_c^0 &= \tfrac{\lambda}{L+\lambda} + (1 - \alpha^2 + \beta) \\ w_m^i &= w_c^i = \tfrac{1}{2(L+\lambda)}, \qquad i = 1,2,\dots,2L \end{aligned} \quad (7)$$

Where R_t is the noise covariance matrix of the odometry data. Also β is the non-negative weighting parameter can be used to incorporate prior knowledge of X_t. w_m^i and w_c^i are the

weights that specify the participants of each sigma point in the estimated mean and covariance of the normal variable respectively.

To correct the estimated parameters we use the absolute measurements. It contains landmarks information. Each detected landmark l described by the vector $z_t^l = (\Delta x\ \Delta y)^T$ that shows the x/y distances to the landmark l. For each landmark detected at time t we follow these steps:

1. Generate sigma points from prior parameters.
2. Calculate predicted $\bar{z}_t^{l,i}$ for each sp_iusing correct function.
3. Calculate the Kalman gain.
4. Calculate posterior parameters of the normal variable.

The predicted $\bar{z}_t^{l,i}$ for each sigma point sp_i is computed as:

$$\begin{aligned} dx &= x_l - sp_{i,x} \\ dy &= y_l - sp_{i,y} \\ \bar{z}_t^{l,i} &= \begin{pmatrix} \mathrm{dx\ R}_{1,1}(sp_{i,\theta}) + dy\ \mathrm{R}_{1,2}(sp_{i,\theta}) \\ dx\ \mathrm{R}_{2,1}(sp_{i,\theta}) + dy\ \mathrm{R}_{2,2}(sp_{i,\theta}) \end{pmatrix} \end{aligned} \quad (8)$$

Where x_l and y_l are the Cartesian coordinates of the landmark l in the field.

The Kalman gain determines how much utilize the landmark l to correct the desired parameters and is measured by the following equation:

$$\begin{aligned} \hat{z}_t^l &= \sum_{i=0}^{2L} w_m^i \bar{z}_t^{l,i} \\ P_{z_t^l, z_t^l} &= \sum_{i=0}^{2L} w_c^i (\bar{z}_t^{l,i} - \hat{z}_t^l)(\bar{z}_t^{l,i} - \hat{z}_t^l)^T + Q_t \\ P_{sp, z_t^l} &= \sum_{i=0}^{2L} w_c^i (sp_i - s_t)(\bar{z}_t^{l,i} - \hat{z}_t^l)^T \\ K_t &= P_{sp, z_t^l} {P_{z_t^l, z_t^l}}^{-1} \end{aligned} \quad (9)$$

Where Q_t is the noise covariance matrix of the landmark l and K_t is the desired gain. Finally the posterior parameters are calculated:

$$\begin{aligned} s_t &= s_t + K_t(z_t^l - \hat{z}_t^l) \\ P_t &= P_t - K_t P_{z_t^l, z_t^l} {K_t}^T \end{aligned} \quad (10)$$

If there is more than one correspondence for a detected landmark in the field (like line corners) the correction is accomplished only for the ones with maximum likelihood.

C. combining MCL and UKF

The key idea of this paper is that kidnap and global localization problems can be handled by MCL as quickly as possible and the position tracking can be done with UKF models efficiently. When the uncertainty of the belief is high or a kidnap detected the belief is represented by MCL samples to discover the most probable positions. When the samples are converged in the small number of clusters, they estimated with UKF models efficiently. The overall process of our method is presented in algorithm 1. Initially the samples of MCL are distributed uniformly in the state space (if we haven't any prior information) and there isn't any UKF models (lines 1-3). Line 6 updates the MCL samples with measurements. Lines 7-16 manage the creation of new UKF models. If the MCL samples are converged to a number of pre-defined clusters, they can be replaced with UKF models. For every valid cluster if the number of active UKF models not exceed a maximum threshold, a UKF hypothesis is replaced by it. The validity of a cluster is determined by the average weight of it's samples. To calculate the parameters of the new UKF we have used Maximum Likelihood Estimation of the samples of corresponding cluster. The efficiency of the proposed method is depended to the clustering algorithm. Because it isn't a trivial task and can take a huge time. In [17] a clustering algorithm is introduced that uses the intrinsic features of MCL and clusters the samples in linear time. We have used their method in our algorithm. Lines 19-21 incorporate measurements in UKF models. To control the population of UKF models, low-weighted models are eliminated and similar ones are merged in line 22 and 23 respectively. Similarity of two UKF models i and j are defined with a simplified Mahalanobis distance metric [18]:

Algorithm 1: Hybrid Localization

```
1.  Init_MCL();
2.  is_mcl_actived = true;
3.  ukf_models = ∅;
4.  while true do
5.    if is_mcl_actived then
6.      Update_MCL();
7.      mcl_clusters = Get_MCL_Clusters();
8.      If Count( mcl_clusters) < thredshold_Clusters then
9.        foreach cluster_i in mcl_clusters do
10.         if Count(ukf_models) < thredshold_ukfs then
11.           If Validity(cluster_i) > thredshold_validity and
12.             Replace_New_UKF(ukf_models, cluster_i);
13.             is_mcl_actived = false;
14.           end if
15.         end if
16.       end for
17.     end if
18.   endif
19.   foreach ukf_i in ukf_models do
20.     Update (ukf_i)
21.   end for
22.   Remove_Waste_UKFs();
23.   Merge_UKFs();
24.   if Weight_Best_UKF() < thredshold_reset and not
      (is_mcl_actived) then
25.     Init_MCL();
26.   end if
27. end while
```

$$Dis_{i,j} = (w_i w_j)\left(s_t^i - s_t^j\right)^T (w_i D_i + w_j D_j)(s_t^i - s_t^j) \quad (11)$$

Where w_i is the weight of the model i and D_i is a matrix formed by diagonal component of the covariance matrix of model i. To avoid computationally expensive merging algorithm the parameters of new model simply equal to the parameters of the model with more weight. Also The new weight is the sum of w_i and w_j.

Line 24-26 are responsible for recovering from a kidnap. We have associated a weight to each UKF. This weight updated

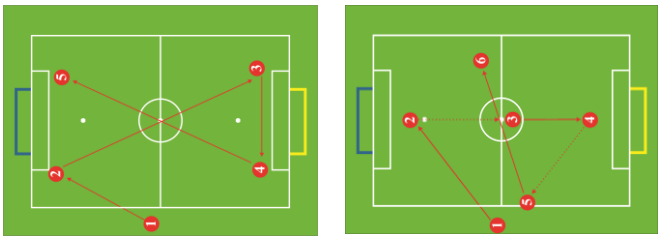


Fig.1. Paths followed in the first and second experiments. The numbers indicate the order.

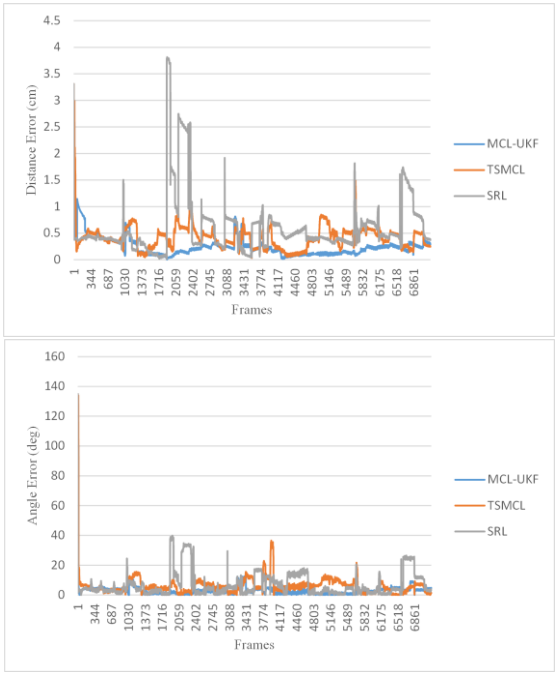


Fig. 2. Error in one trial of the first experiment. Distance Error (top) and Angel Error (bottom).

smoothly analogous to a sample of MCL. If the weight of the best UKF (a model with maximum weight) is lower than a threshold there is the probability that a kidnap has been occurred. If so, MCL samples reinitialized.

IV. Experiments

The proposed method is implemented on Darwin-op humanoid robot which is used by some teams in RoboCup competitions. To access ground truth information the experiments are performed on the webots simulator [19]. The simulated process runs on a pc equipped with Intel Core 2Due T9550 2.66 GHz processor and 4GB DDR2 Ram. The environment is a 9×6 Robocup humanoid soccer field. Here we haven't concerned about field symmetry. So the color of goals are distinguishable. In all experiments the only landmark used for localization are the goal posts. For all method we have used 200 samples.

To analyze the efficiency of the proposed hybrid localization (MCL-UKF) we have done some experiments that evaluate the accuracy, relocalization ability and run time complexity criteria. Our method is compared against TSMCL the state of the art particle filter and SRL. All methods are executed simultaneously, so they incorporate the same measurements.

TABLE I. Average of distance and angle errors in the first experiment

Method	Distance (cm)			Angle (deg)		
	Mean	*Median*	*SD*	*Mean*	*Median*	*SD*
MCL-UKF	0.258	0.208	0.309	3.007	2.018	7.045
TSMCL	0.406	0.386	0.235	5.812	4.273	6.489
SRL	0.644	0.474	0.587	10.56	4.449	14.026

TABLE II. Average of distance and angle errors in the second experiment

Method	Distance (cm)			Angle (deg)		
	Mean	*Median*	*SD*	*Mean*	*Median*	*SD*
MCL-UKF	0.507	0.263	0.848	9.026	3.053	25.541
TSMCL	0.576	0.373	0.699	10.546	4.779	17.685
SRL	0.615	0.398	0.744	9.176	3.454	17.664

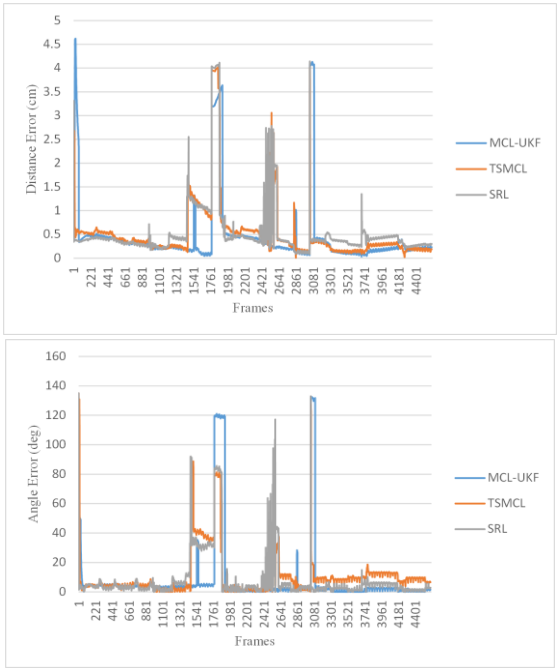


Fig. 3. Error in the second experiment. Distance Error (top) and Angle Error (bottom).

In the first experiment the robot is placed on the side line, near the middle of the field. Initially it hasn't any knowledge about its position. The robot traverses the path illustrated in Fig.1, left. This experiment repeated for 10 times. The results of one trial of the experiment are plotted on Fig. 2. As presented, all algorithms have converged to the near of the true position after a few updates. However, MCL-UKF outperforms the TSMCL and SRL in tracking the position. It is more accurate and has a better stability on noisy measurements. The error in position and orientation of the 10 executions of this experiment have been summarized in Table I.

The second experiment shows the ability to recovering from kidnap, where the robot is moved suddenly without its knowledge. The path used for this experiment is illustrated in

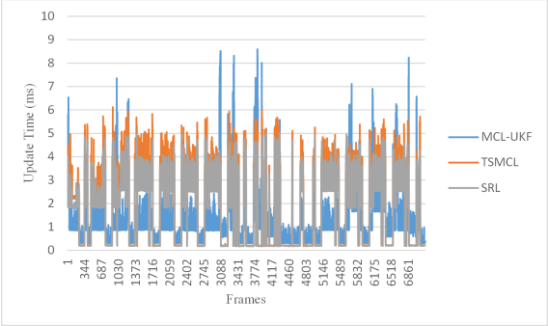


Fig. 4. CPU time of the one trial of the first experiment.

TABLE III. AVERAGE OF UPDATE TIME IN THE FIRST EXPERIMENT

Method	Mean	Median	SD	Min	Max
MCL-UKF	0.992	0.805	0.985	0.29	10.428
TSMCL	1.567	0.222	1.638	0.182	8.552
SRL	1.393	0.219	1.446	0.181	8.521

Fig. 1 right. The robot starts from point one, goes to point two. At this point it is teleported to point three manually and this scenario is repeated from the point four to five. This experiment was repeated 10 times. The results of the one trial of this experiment are depicted in Fig. 3. The two kidnaps occurred in frames 1776 and 3050 respectively. According to the results, all methods have been recovered from the kidnaps successfully. However MCL-UKF and TSMCL retrieved the true location slower than SRL due to the smooth weighting. The result of all trial of this experiment have been summarized in Table II.

In the last experiment the processing time of the methods are tested. Time complexity is critical for a soccer playing robot. A time consuming localization method can affect other functional unit of the robot. To analyze the CPU time we have used the update time of the executions of the first experiment. The details of processing time in each frame for one trial of the experiment are demonstrated in fig. 4. Also The result of update time summarized in Table III. The CPU performance of our method improves about 30% and 37% compared to SRL and TSMCL respectively. The maximum update time in a frame is recorded for MCL-UKF. In some frames some UKF models and MCL samples updated at the same time that leads to increase in update time. However this situation occurs rarely and in more than 90% of the frames the average update time is in the interval (0, 2.5) while this is (0, 4.5) and (0, 4) for TSMCL and SRL respectively.

V. CONCLUTION

In this paper a new hybrid localization method based on MCL and UKF has been presented. The proposed method combines the advantages of both algorithms to reach an accurate, stable and real-time localization method that can deal with all types of localization problems. The global and kidnaped problems are managed by initializing MCL samples while the accurate and robust position tracking are accomplished by UKF models. These UKF Hypothesis are created with respect to the state of the MCL samples such that, whenever they are converged to some predefined clusters new UKF models are initialized in the position of the valid clusters. The efficiency of the hybrid method is evaluated by some experiments and the results show the efficiency of this method. The proposed method is implemented on real robot and tested on the simulator for easy access of ground truth.

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Adaptive Search in Unstructured Peer-to-Peer Networks based on Ant colony and Learning Automata

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***Abstract*— an unstructured peer-to-peer network is an overlay network where all nodes play equal roles, and the topology and data location do not follow restrictive rules. So, in a traditional file search mechanism, such as flooding, a peer broadcasts a query to its neighbors through an unstructured peer-to-peer (P2P) network until the time-to-live decreases to zero. A major disadvantage of flooding is that, in a large-scale network, this blind-choice strategy usually incurs an enormous traffic overhead. AntP2PR is a protocol to search based on the ant colony in unstructured peer to peer networks, which faces with some problems such as high communication overhead and low success rate due to the lack of an appropriate decision-making mechanism. In this paper, two adaptive improved version of AntP2PR named DLAntP2P and LAntP2P to improve the search problem in unstructured peer-to-peer networks are proposed. The DLAntP2P and LAntP2P protocols utilize the Distributed Learning Automata (DLA) and Learning Automata (LA), respectively, as an adaptive decision-making mechanism to determine number of ant and enhance the way of selecting the neighbors to forward the query messages. Simulations show the effectiveness of proposed protocols in terms of communication overhead and success rate, compared to AntP2PR and K-walker random walk.**

Keywords—Unstructured Peer-To-Peer Network, Ant Colony, Distributed Learning Automata (DLA), Learning Automata (LA), Search

I. INTRODUCTION

Peer-to-peer (P2P) networks are overlay networks that are built on top of communication networks that are called underlay networks[1]. Main purpose of these networks is sharing information and resources [2]. One of the most common ways to classify P2P networks has been based on the structure of the topology of the overlay. Accordingly, P2P networks can be categorized as being either structured or unstructured [3],[4]. A structured P2P network, represented by DHT network, strictly defines the mapping relationship between a peer and its managed file indices, and thus it could achieve a high retrieval success rate. However, the structured P2P network could not adapt well to the environment with high churn rate. An unstructured P2P network is the one that all the nodes are loosely connected and no rigidly organized structure is needed. Unstructured P2P networks could well cope with the churn problem and thus are being [5]. In a sense, in unstructured P2P networks, there is neither a centralized index nor any strict control over the network topology or file placement. Nodes joining the network, following some loose rules, form the network. The resulting topology has certain properties, though the placement of objects is not based on any knowledge of the topology [6].

In unstructured p2p networks, search problem is more complicated as any peer might share any file in any location of the network [7]. Search techniques for unstructured P2P overlays are typically categorized in blind and informed. In blind searches, peers do not store information about the P2P network or the probable locations of objects for routing queries. while in informed searches; peers store some metadata that facilitates the search [8]. Blind search schemes employ flooding or random-based techniques to relay queries to peers in the network[9],[10].

Flooding is the typical mechanism used to send queries across the overlay with a limited scope (e.g. Gnutella). It consists in a Breadth First Search (BFS) of the overlay network: when a peer receives a query, it returns the results if present, otherwise it retransmits the query to all of its neighbors, except for the sender, until the Time-To-Live (TTL) associated with the query expires [11]. Flooding scheme has significant merits such as simple algorithm, large coverage, high reliability, moderate latency, and deterministic results [12]. Although flooding is a simple algorithm, it generates a large number of messages (many are duplicate messages) and does not scale well [13]. So far, several approaches Such as, SPUN [14], k-walker Random Walk [15],[16] AntNet [17], SemAnt [18], IAPS [8], and AntP2PR [19] have been proposed to address this problem.

AntP2PR [19] is an ant colony based approach to route query messages for search in unstructured peer-to-peer networks which aims to reduce the overhead caused by the flooding is presented. The authors aim to reduce the overhead caused by flooding two new values lower bound and higher bound for pheromone probability have introduced. These predefine values are used to determine whether the TTL value will be increased or decreased by one, or left unchanged before the final decrease and send to all nodes. However, since there are no descriptions on

how to cope with the churn problem, it cannot be applied to maintain replica consistency in real-world P2P networks [5]. Furthermore, AntP2PR doesn't employ any appropriate decision-making mechanism in neighbor selection and thus, broadcasting query messages, has been led to high communication overhead in AntP2PR protocol.

In this paper, two adaptive improved version of AntP2PR named DLAntP2P and LAntP2P to improve the search problem in unstructured peer-to-peer networks are proposed. The DLAntP2P and LAntP2P protocols utilize the Distributed Learning Automata (DLA) and Learning Automata (LA), respectively, as an adaptive decision-making mechanism to determine number of ant and enhance the way of selecting the neighbors to forward the query message So that, in addition to reducing overhead messages to achieve high success rates.

The rest of this paper is organized as follows: In Section II an overview about ant colony optimization, learning automata and distributed learning automata as the fundamental strategy used is briefly described. Section III describes AntP2PR protocol. The proposed protocols will be explained in section IV. Section V gives the results of experimentations. Section X concludes the paper.

II. PRELIMINARIES

In this section, in order to provide basic information for the remainder of the paper, we present a brief overview of ACO, LA, DLA.

2.1 Ant Colony Optimization

ACO model presents a set of artificial ant systems for solving discrete optimization problems. It is motivated by the manner in which some ant species search for food. In the process of searching, the ants make a deposit of pheromone in the paths followed. The amount of pheromone deposited in a path signifies a favorable path between the source and destination. ACO exploits this approach in addressing optimization problems. The problem is described as a graph where edges are formed by ants represented as mobile agents that can connect the different vertices of the graph. The job assigned to the ants is to find the shortest path connecting two different vertices in the graph. In a way similar to the natural pheromone trail used by ants, a variable τ_{xy} is associated with every edge (x, y), connecting vertex x and vertex y. The movement of the ants is guided by a probabilistic decision policy that depends on the amount of pheromone trail perceived on the edges of the graph. Positive feedback is thus improved by the reinforcing a trail on those edges which are used. To avoid some premature convergence this pheromone trail evaporates over time and ants, transitions to other nodes in the graph happen stochastically. The trail information is communicated locally and indirectly, mediated by physical adjustment of the pheromone trail value on every edge. The ant colony concept has motivated different routing algorithms for network systems [20].

2.2 Learning Automata

A learning automaton [21] can be modeled as an abstract entity with finite number of actions. Learning automaton operates by selecting one of its actions and employing it to the environment. The action is evaluated by the environment and the learning automaton uses the environment response to select the next action. Along this procedure learning automata gradually learns to select optimal action. LA has wide range of applications in wireless sensor networks [22], Grid computing, cognitive networks [23], peer-to-peer networks [24],[25],[26] and etc. Moreover, learning automaton has application in global optimization problems, such as particle optimization (PSO).

2.3 Variable structure learning automata

Variable structure learning automata (VSLA) [21] can be modeled as a quadruple $\{\alpha, \beta, P, T\}$ where $\alpha = \{\alpha_1, \alpha_2, \ldots, \alpha_r\}$ is the set of actions, $\beta = \{\beta_1, \beta_2, \ldots, \beta_r\}$ is the set of inputs, $p = \{p_1, p_2, \ldots, p_r\}$ is the set of action probabilities and $p(n+1) = T[\alpha(n), \beta(n), p(n)]$ is the learning algorithm. If $p(n+1)$ is a linear function of $p(n)$ the schema is called linear, otherwise it is nonlinear. In the simplest form of VSLA consider an automaton with r actions in a stationary environment where, $\beta \in \{0, 1\}$ is included as inputs. After selecting an action by automaton, the *positive* and *negative responses* ($\beta = 0$ and $\beta = 1$) are updated through (1) and (2), respectively:

$$P_i(n+1) = p_i(n) + a[1-p_i(n)] \qquad (1)$$
$$P_j(n+1) = (1-a)\, p_j(n)$$

$$P_i(n+1) = (1-b)\, p_i(n) \qquad (2)$$
$$P_j(n+1) = (b/r-1) + (1-b)\, p_j(n)$$

In (1) and (2), a and b are called *learning parameters* and they are associated with the reward and penalty signals. A linear reward–penalty (L_{RP}) learning algorithm is considered that a and b are equal.

2.4 Distributed learning automata (DLA)

A Distributed learning automata (DLA) [27] is a network of LA which collectively cooperate to solve a particular problem. A DLA can be modeled by a directed graph in which the set of graph nodes constitutes the set of LA and the set of outgoing edges for each node constitutes the set of actions for corresponding learning automaton. When a learning automaton selects one of its actions, another learning automaton on the other end of edge corresponding to the selected action will be activated.

Formally a DLA with n LA can be defined by a graph (A, E), where $A = \{A_1, A_2, \ldots, A_n\}$ is the set of automata and $E \subset A \times A$ is the set of edges in the graph in which an edge (i, j) corresponds to action α_j of automaton A_i . Let action probability vector for learning automaton A_i represents by p_i where a component p_i^j of p_i denotes the probability of choosing action α_j, that is the probability of choosing edge (j, m). Since introducing DLA by Beigy and Meybodi [27], DLA has received a lot of applications in solving various problems such as: shortest path problem [27], traveling salesman person (TSP), Steiner tree problem, minimum spanning tree, vehicle routing problem, and web page recommendation.

III. ANTP2PR PROTOCOL

Loukos et al. [19] in their attempt to achieve less overhead of the peers and deal with the free rider peers in the unstructured P2P networks, have proposed AntP2PR protocol which is a searching method based on the Ant colony. In this protocol when a peer receives a query, first it is processed locally. If the answer is found, it returns a hit message. In the following, according to the TTL value, it forwards the query message to all the neighbors except the neighbor that has sent this message to the current peer. With the completion of the TTL field, if no response is not found, a miss message returns. In order to use the pheromone table, two new values of high and low bounds are defined, which are used for adaptive determination of the TTL value. In this way, the TTL value of the query message for the neighbor who its pheromone value is less than the low bound, will be decreased by two, and vice versa it will not be decreased for the neighbor who its TTL value is more than high bound. Otherwise the TTL value will be normally decreased by one.

Each peer, after the end of processing a query, runs the update procedure based on the delta function delta $(q_h) = q_1 * e^{q_2 * qh}$ where q_1 and q_2 are two parameters assigned by the user, and q_h is the number of hit messages (Fig.1). Since the values of pheromone table are increased based on the number of hit messages, the routes with less results which create the trails with low deposited pheromone, will be shortened. Thus, AntP2PR is able to identify and limit the routing of messages to the routes which will most probably fail in returning the results (dealing with the free rider peers) and therefore will reduce the traffic of resource discovery.

IV. The proposed protocols

4.1 DLAntP2P

In the DLAntP2P protocol, the DLA is used for training the peers during the searching process and the peer-to-peer network plays the role of a random environment for the DLA. In this protocol, each peer will be equipped to a variable structure learning automaton in the DLA with the P-L_{RP} learning algorithm, such that each of the output edges of that peer is one of the actions of this learning automata. Also in each peer a table is maintained to store the probability values of the pheromones and the neighbor links actions.

When a peer creates a query, first searches it among the available objects. If there is a response, the result is displayed to the user and returns a hit message. In the following, to forward the query message, its most probable neighbors are selected based on the highest value of the pheromone, and for each of them creates an ant and initializes their parameters such as the identification number, the requested object, the source peer, searching route, the number of steps, time to live (TTL) and the number of responses. Then it sends each of these ants through the related neighbor's link. With the arrival of an ant to the neighbor's node, the peer's learning automata is activated and routes the ant by selecting one of its actions. Selecting an action of the learning automata activates the learning automata of one of the neighbor's nodes of the current node. This process namely selecting an action and activating a learning automata, repeats till the end of ant searching process. In this way, the created ants are routed through the DLA in the first step and will follow the second step to the last step (Fig.2). During the route in the case of finding the response, the response number parameter of this ant will be increase by one. In the end of the searching if the ant did not find any response, a miss message return.

After the end of searching for an ant, the probabilities of selected actions via each of the learning automata in the ant's route are updated based on the number of obtained responses and according to the standard learning algorithm. It must be noted that in this protocol the updating way of pheromone and adaptive determination of the TTL field is regarded similar to the AntP2PR. Fig.3 and Fig.4 respectively demonstrate the pseudo code of the source peer function and the pseudo code of the intermediate peers function.

Updating phase in AntP2PR protocol

Input: Node n

```
for all m ∈ n.neighbors do
    qh ← n.queryHitCount[m]  //number of hit messages
    delta ← q1 * e^(q2 * qh)
    n.pherTable[m] ← n.pherTable[m] + delta
end for
```

Fig.1. Pheromone table update in AntP2PR [19]

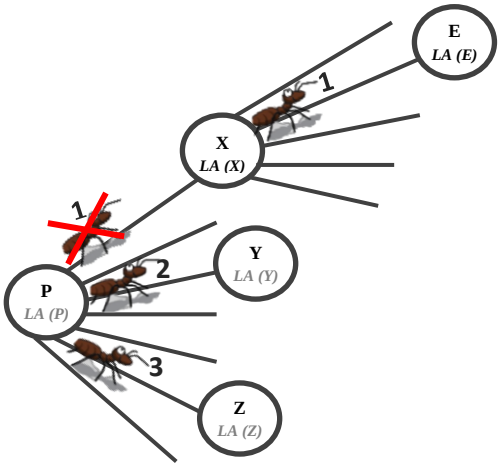


Fig.2.The routing in DLAntP2P protocol

Source peer function in DLAntP2P

```
//S: querying peer, q: query
User submits a query message (q)
Peer S is searching in own local Objects for q
IF q is not in S
    //Forwarding q via S.neighbors
    Generate random number R, 0<R<1
    Select any S.neighbors (M) with pheromone >R
    Generate M number of AntF(j), 1≤j≤M
    Initialize AntF(j), 1≤j≤M, parameters
    Determine Adaptive value of AntF(j).TTL
    Forward these AntFs via M selected neighbors
End if
```

Fig.3. Pseudo-code of source peer function in DLAntP2P

Intermediate peers function in DLAntP2P

```
01 //P: Intermediate peer, τij: pheromone, ρ: evaporation rate
02 AntF(x) enters the peer P
03 IF AntF(x) .TTL>0
04    AntF(x) .TTL= AntF(x) .TTL-1
05    //Peer P is searching in own local objects for AntF(x).object
06    IF AntF(x).object is in P
07       AntF(x).hit= AntF(x).hit+1
08       Sent back result for source peer
09    End if
10    //Forwarding AntF(x) via one of S.neighbors chosen by LAant(P)
11    LAant(P) choose an action
12    IF the selected neighbor by LAant(P) is enabled
13       Generate one AntF(y)
14       Initialize AntF(y)
15       Determine adaptive value of AntF(y).TTL
16       Forward AntF(y)//via the selected neighbor by LAant(P)
17    End if
18 Else if TTL=0 //or search is finished
19    //Update LAant()s in the Ant path in reverse order
20    For all peer in the reverse path except Source peer
21       If  AntF(x).hit# > 0
22          Rewarding selected action
23       Else if AntF(x).hit# = 0
24          Penalizing selected action
25       End if
26    //Update Pheromone probability
27    Update pheromone //according to AntP2PR protocol
28 End if
```

Fig.4. pseudo-code of intermediate peer Function

4.2 LAntP2P

There is a difference between the way of routing the source peer and the intermediate peers in the first protocol, DLAntP2P, such that the source peer merely relies on the pheromone value of its links to select the most probable neighbors, and doesn't benefit from learning automata. In this section, to resolve this problem, another adaptive version of AntP2P protocol called LAntP2P is presented which is an adaptive searching method based on the ant colony in the unstructured peer-to-peer networks with an approach based on the learning automata. In this protocol each neighbor's link in a peer is equipped to a variable structure learning automaton with the P-L_{RP} algorithm that has two actions of "creating the ant" and "lack of creating the ant". Thus, the all learning automata at each node locally decide about the participation or lack of participation of the related neighbor's link in the searching process.

When a peer creates a query, first searches it among the available objects. If there is a response, the result is displayed to the user and returns a hit message. In the following, to forward the query message, for each of the peer output link which its learning automata selected the action of "creating the ant", an ant is created and its parameters are initialized similar to DLAntP2P protocol. Then the ants are sent through the related links. In the intermediate nodes the working method is similar as well. It should be noted here that in the intermediate nodes the new ant is not created, but merely the input ant to this node will be replicated (Fig.5). After finishing the search the probabilities of selected actions via all the learning automata on the inverse route of the ant moving are updated based on the number of obtained responses as shown in Fig.6. In other cases, this protocol completely works similar to the DLAntP2P protocol.

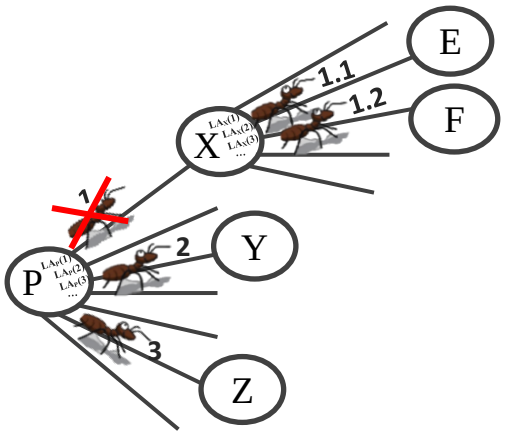


Fig.5.The routing in LAntP2P protocol

Updating phase for each peer p in LAntP2P protocol

```
01  If Peer(p).LAant(link(i)).action="CreateAnt"
02     If  AntF(link(i)).hit#>0
03           Rewarding selected action
04     Else if AntF(link(i)).hit#=0
05           Penalizing selected action
06     End if
07  Else if  Peer(p).LAant(link(i)).action="NotCreateAnt"
08        If hit# more than half of p.neighbors who have chosen-
          "CreateAnt" action is >0
09           Rewarding selected action
11     Else
12           Penalizing selected action
13     End if
14  End if
```

Fig.6. Pseudo-code of updating phase of LAntP2P protocol

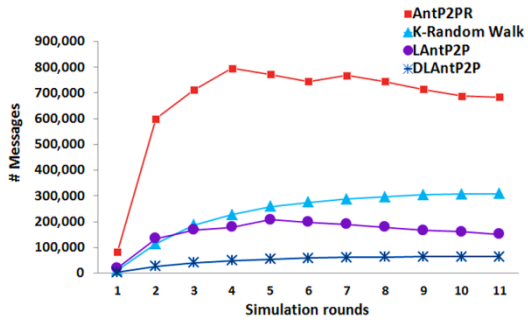
V. Experimental Results

In this section we have developed our proposed protocol using computer simulation to evaluate efficiency of DLAntP2P and LAntP2P in comparison with the AntP2PR and well-known approach, K-walker Random Walk. Two different distributions, power-law (with parameter α=2) and uniform are applied to initialize the number of objects peers. In general, maximum shared objects of 100, network size of 10^3, link number of 200 and power-law distribution is used as default configuration. Peer failure Mode and churn has been considered. For this Purpose, at all experiments, 20% of the nodes on the network have been randomly out of reach. Results reported are averaged over ten different runs. For all experiments, each peer is equipped with a variable structure learning automaton of type L_{RP} with a reward parameter a = 0.25 and a penalty parameter b = 0.25. The algorithms are compared with respect to five metrics: 1) Message overhead, 2) Response number (hit), 3) Success rate, 4) Failure message (miss), and 5) Ant number.

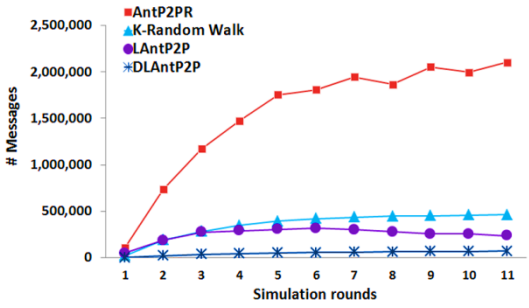
5.1 Experiment 1

In the first experiment, the proposed protocols are compared with AntP2PR and K-walker Random Walk protocols with respect to message overhead. According to the results of this experiment which are shown in Fig.7, it is concluded that in term of message overhead, in the both objects distributions, the proposed protocols have a better performance than the AntP2PR and K-walker Random Walk protocols except for the early periods of

the network operation in the second proposed protocol (LAntP2P). This is because of the fact that in the first proposed protocol, DLAntP2P, each source peer utilizes pheromone probability and each Intermediate peer in the search path utilizes a learning automaton in the DLA to route the ants which are created in first step of search for the parameter adaptation (m: The number of ants in the ant colony). Adaptation of the parameter m helps each peer to find appropriate neighbors to be used for query message forward leading to lower overhead and higher response. In contrast to AntP2PR, and K-walker Random Walk protocols, which do not utilize adaptive mechanisms to improve their functionality (flooding in the AntP2PR, blind and random selection of neighbors and Constant parameter K in the K-walker Random Walk), the second proposed protocol, LAntP2P, similar to DLAntP2P (by utilizing an adaptive mechanism) is able to improve the quality of the search (with respect to a low message) and decrease its overhead. In comparing the proposed protocols, since in DlAntP2P the ant is only created in the source node and in the intermediate nodes the created ants in the first step are merely routing, thus DLAntP2P protocol in both of the objects distributions, has the less message overhead than the LAntP2P protocol. In addition, as expected, when using power-law distribution all protocols have higher overhead message. Because, in this case, only a small number of peers have a comparably objects but in uniform distribution objects assigned uniformly. So, it is concluded that the both of the proposed protocols can be appropriate for this problem.



a)

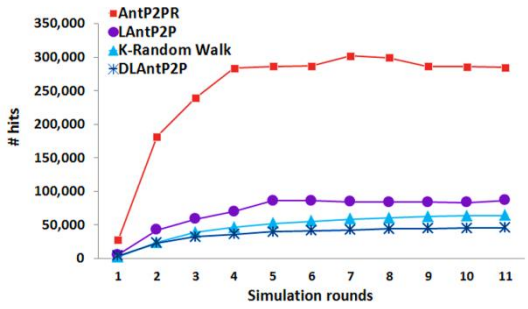


b)

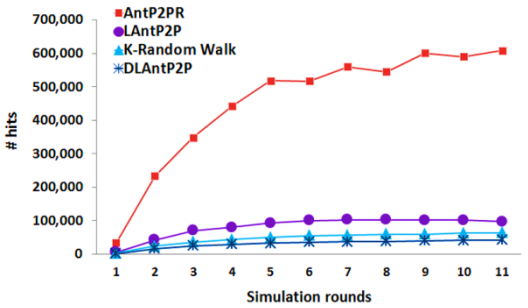
Fig.7. Message overhead, a) Uniform, b) Power-law

5.2 Experiment 2

In the second experiment the proposed protocols are compared with AntP2PR and K-walker Random Walk protocols with respect to number of responses (hit). According to the results of this experiment which are shown in Fig.8, it is concluded that in term of the number of responses, in the both objects distributions, both of the proposed protocols show a poorer performance than the AntP2PR protocol. In fact, the reason is that none of the proposed protocols couldn't obtain the responses as much as AntP2PR, which seems to be caused by the large number of the ants that are created and reproduced in the AntP2PR for each query. On the one hand, the K-walker Random Walk protocol that in the previous scenario had a slightly higher overhead message than the LAntP2P protocol, has failed to achieve the LAntP2P response number in this experiment. The constant parameter of K and blind selection of the neighbors in the K-walker Random Walk protocol on one hand and the informed selection of the neighbors, adaptive determination of the number of the ants and using of the previous search results in LAntP2P protocol on the other hand are among the factors of this conclusion.



a)



b)

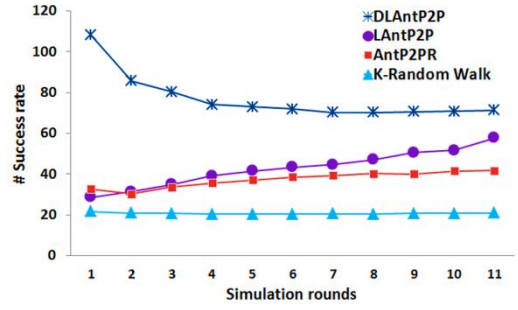
Fig.8. Number of responses (Hits), a) Uniform, b) Power-law

5.3 Experiment 3

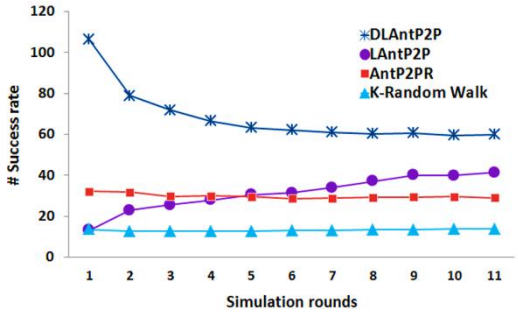
In the third experiment, it is compared the proposed protocols with AntP2PR and K-walker Random Walk with respect to success rate. Success rate is considered as the percentage of the number of responses among total number of messages. The results of this experiment are shown in Fig.9. Also, Table 1 shows the average success rate of protocols in the both objects distributions. According to the result we may conclude the following:

- In term of success rate, in the both objects distributions, the first proposed protocol, DLAntP2P, shows better performance than the other protocols.
- At the beginning of the simulation, DLAntP2PR protocol has a very high success rate due to the low message overhead, which gradually and with the increasing number of queries, it slightly decrease and converges after learning of the nodes.

- At the beginning of the simulation, the success rate of the second proposed protocol, LAntP2P, is lower than the AntP2PR, but over time and with learning of the nodes this rate increases. So that eventually according to the table 1 the success rate average of the LAntP2P will be higher than AntP2PR. Also, LAntP2P similar to DLAntP2P, compared with the K-walker Random Walk has a higher success rate.
- In terms of the way of the distribution of objects as shown in Table 1, all of the protocols have a higher success rate in uniform objects distribution.



a)



b)

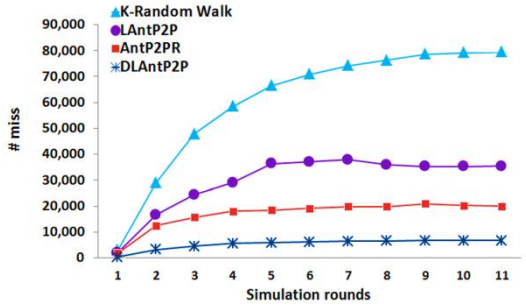
Fig.9. Success rate, a) Uniform, b) Power-law

TABLE1. the average success rate of all protocols

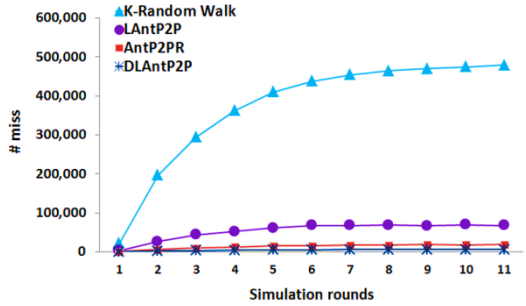
	power-law	Uniform
DLAntP2P	%67	%75
LAntP2P	%32	%43
AntP2PR	%30	%37
K-RandomWalk	%13	%21

5.4 Experiment 4

In the fourth experiment, the proposed protocols are compared with AntP2PR and K-walker Random Walk protocols with respect to failure message (miss). If after the end of the search by an ant (or walker), no response has not been found; a failure message (miss) is returned. According to the results of this experiment which are shown in Fig.10, we may conclude that in term of miss message, in the both objects distributions, the first proposed protocol, DLAntP2P, performs better than all of protocols. So, we may conclude that the DLAntP2P protocol can be appropriate for this problem. One thing to note is that AntP2PR performs better than LAntP2P. This is due to the high probability of finding at least one response in the AntP2PR protocol. Since this protocol for a query create or reproduced a large number of ants. In this scenario, K-walker Random Walk has demonstrated the largest number of failure message.



a)



b)

Fig.10. number of Failure messages (miss), a) Uniform, b) Power-law

5.5 Experiment 5

In the fifth experiment the proposed protocols are compared with AntP2PR and K-walker Random Walk with respect to number of created or reproduced ants (or walkers). According to the results of this experiment which are shown in Fig.11, we may conclude that in term of number of ants, in the both objects distributions, the first proposed protocol, DLAntP2P, performs better than all of the other protocols. So, we may conclude that the DLAntP2P protocol can be appropriate for this problem.

Table 2 indicates the summary of conclusions of the different simulation scenarios.

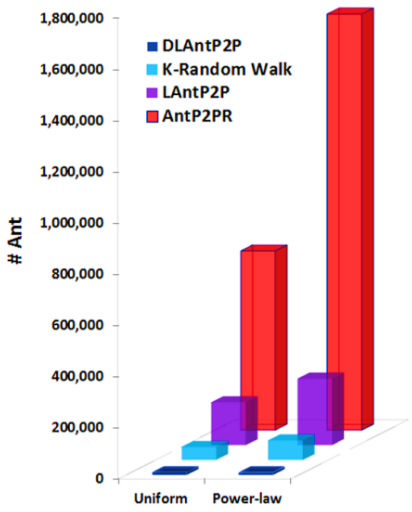


Fig.11 Number of Ants (Walker) a) Uniform, b) Power-law

TABLE2. Summary of the different simulation scenarios

	Power-law	Uniform
Lower Overhead	1. DLAntP2P 2. LAntP2P 3. K-RandomWalk 4. AntP2PR	1. DLAntP2P 2. LAntP2P 3. K-RandomWalk 4. AntP2PR
Lower number of Ant	1. DLAntP2P 2. K-RandomWalk 3. LAntP2P 4. AntP2PR	1. DLAntP2P 2. K-RandomWalk 3. LAntP2P 4. AntP2PR
Higher Success Rate	1. DLAntP2P 2. LAntP2P 3. AntP2PR 4. K-RandomWalk	1. DLAntP2P 2. LAntP2P 3. AntP2PR 4. K-RandomWalk
Higher Hits Message	1. AntP2PR 2. LAntP2P 3. K-RandomWalk 4. DLAntP2P	1. AntP2PR 2. LAntP2P 3. K-RandomWalk 4. DLAntP2P
Lower Miss Message	1. DLAntP2P 2. AntP2PR 2. LAntP2P 4. K-RandomWalk	1. DLAntP2P 2. AntP2PR 2. LAntP2P 4. K-RandomWalk

VI. Conclusion

In this paper two adaptive improved version of AntP2PR protocol are proposed. One of them is based on the DLA and the other is based on the LA to resolve the searching problem in unstructured peer-to-peer networks. The proposed protocols utilize the learning automata to enhance the way of selecting the neighbors to forward the query message. Our purpose is to select the minimum number of the neighbors among the most probable ones based on the results of previous searches, such that can lead to decrease the message overhead and increase the success rate of the protocol as well. In order to evaluate the proposed protocols, several experiments were carried out using computer. The results shows that the proposed protocols in terms of the message overhead, the number of ants and the success rate (and the number of miss message in the first proposed protocol) place in a better performance position than the AntP2PR and the K-RW.

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Using Machine Learning Approaches to Detect Opponent Formation

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***Abstract*—Making a correct decision is a difficult task in a Soccer Simulation 2D environment due to the fact that there is a lack of information for each agent. Therefore, coach agent can take role as a mediator for agents to analyze data and inform players about crucial events by sending command messages. This paper proposes a new method to detect the formation of opponents which is not still possible for agents to extract. In the experimental results of this paper, we show that team formation is successfully learned by various well-known classification algorithms.**

***Keywords*—Formation Detection, Classification, Multi-Agent Systems , RoboCup, Soccer Simulation.**

I. Introduction

Nowadays, a wide range of applications involve the concept of decision making under uncertainty in which each agent faces with partially observable and non-deterministic environment. Optimal decision making under uncertainty can be classified into two from agents' perspective. The first category contains cooperative decision making in which a set of agents share their knowledge and communicate with each other so as to gain a certain goal; for instance a wide range of problems can be solved in cooperative manner [1], [2], [3], [4]. The second type is non-cooperative one which models each agent as an individual unit [5]. In this article, we encounter with cooperative and competitive situation in which there exist some predefined agents with common sensors to monitor the surroundings. We can also categorize the problem of decision making from designer viewpoint. The first type is centralized one where a designer gathers all information from environment and decides accordingly. The second type is named distributed decision making that each agent collects local information and performs the best action with or without cooperation. In this work, we are going to detect online formation of opponents in *Soccer 2D Simulation* environment. *Soccer 2D Simulation* is a partially observable, non-deterministic and dynamic environment which is very popular in multi-agent environments. In this environment, there are 22 football players who receive noisy information from surroundings by their sensors. Each agent has some predefined behaviours and they can be individual or team behaviours [6]. Individual behaviours consist of *tackle*, *shoot*, *pass* and *hold ball*. On the other hand, *team formation*, *defence* and *offense* are determined as team behaviours. Each team has one coach which can communicate with agents by broadcasting certain messages which contain a specific meaning for players and they can accomplish the best action respectively. The environment for coach agent is fully observable; consequently we can utilize coach knowledge and aid agents to conduct the best behaviour.
It is of paramount importance to detect formation of opponents so that we can predict the behaviours of opponent agents better. Knowing the formation of opponents helps us to figure out the strengths and weaknesses of opponent teams and on the other hand the best action such as changing our formation can be carried out. In this paper, we create the train and test data by considering the players and the ball positions. It is important to note that formation detection can be considered as a classification problem, therefore we carry out some well-known classification algorithms such as Support Vector Machine [7], K-Nearest-Neighbors [8] and Neural Networks [9] on our data sets in order to evaluate them.

This paper is organized as follows: related work is described in section II. Section III explains our proposed method in detail. Subsequently we depict experimental results on our data set in section IV. Eventually, the conclusion and future work are given in section V.

II. Related Work

The problem of detecting opponent formation has been widely used in the last decade. For instance, in [10], authors extract 10 various formation as class label and enjoy support vector machine, Naive Bayes [11], k nearest neighbor and neural network as classification algorithms. They also extract the positions (both x and y) of all players and the ball and center of the mass of the team as features. The evaluation metric of this paper is accuracy and time. Unfortunately this approach is not applicable for online prediction due to the fact that it has countless of features and is very time consuming. In [12], author uses triangulation model and extracts a specific network topology; This work utilizes Growing Neural Gas Network [13] in order to estimate positions of opponent's agents but it can not estimate the generic formation of opponents. The main benefit of this method is its computation speed and ability to on-line performing.
Tomoharu et. at [14] propose off-line algorithm in order to predict the mapping from the position of the ball to the position of opponents by using log file. In this approach, three-layered neural network with back-propagation is used. One neural network is learned per agent in order to use them to predict the destination of passes. Therefore, 11 neural networks are used

for all players so as to learn the opponent team formation. Relying on 11 training data sets is the major drawback of this approach due to the fact that it needs to estimate a wide range of parameters.

III. Proposed Method

This section considers our proposed method for opponent formation detection. In this paper, we utilize the term team formation so as to point to the positioning of players according to the ball position in different points. The goal of this paper is to detect opponent's team formation in each cycle in an on-line manner. However, the learning approach which is proposed here is offline. Although a few range of teams in Soccer 2D Simulation League use the coach capabilities, this method wants to utilize it as much as possible. In order to reduce the search space, Instead of using Expert Systems [15] approach and creating some grids in soccer field to find the opponent formation which are exhaustive, using machine Learning methods is very optimized and effective. Most related work have employed x and y coordinates of players positions and ball position as the input of their algorithms which is more expensive and time consuming to be learned. Accordingly, our proposed method only applies x coordinate of opponent players and ball. The advantage of this approach is that it reduces the number of states and consequently declines the amount of inputs for learning systems. The reason of exploiting just x coordinate is that y coordinate is not very effective in formation detection since the vertical distance of player positions is in a normal range most of the times. On the other hand, as a rule of thumb, the horizontal distance of players positions is the way most people use to guess and detect any team's formations.

A. Agents

All teams in Soccer 2D Simulation League have two main agents which are players and coach. In order to describe our approach it is necessary to know their differences and their pros and cons.

Players: Each team has 11 players which are selected from 18 random types. Each type has its own properties and features that are implemented to make the simulation league more similar to the reality. As the goal of this league is to improve the intelligence and cooperation of agents, low-level actions like walking or running are not the main target and most of the details of physical actions are ignored to simplify the environment and to cause more focus on strategies and high-level actions like decision making. Each player has some physical properties like body direction(that affects movement), neck direction(that affects view), stamina(total and temporary energy) and some other useful capabilities such as the ability to say and hear(to communicate with teammates and coach), the ability to point to a specific place(that is useful for debugging) and a vast variety of other features that help them to affect the environment and get affected by it.

Coach: In real soccer matches coaches play a vital role in making and changing the teams' strategies. By doing some specific analysis on opponents strategies and actions and also by finding their weaknesses and strengths, coaches may decide to substitute players or change the way of the game so as to win the match. Fortunately, a coach agent is implemented in Soccer 2D Simulation League but, it has some specific advantages and disadvantages. For instance, having accurate information of the environment, a fully observable view and the ability to communicate with player agents are some of its positive properties. On the other hand, it is noticeable that there are some limits for coach. For example, coach is restricted to send unlimited messages to the agents and by default, it can send 128 messages according to the server parameters.

Additionally, each message size cannot be more than 8 bytes and consequently there should be a complex map to code various kinds of messages. As it is mentioned before, coach can watch the game in a fully observable and continual view that aids it to trace the game and make a strategic decision. One of the goals of this paper is to use this ability to enhance the performance and reflexibility of the team; Therefore, we strive to exploit it as much as feasible in our research.

B. Data set

At first, we divided the field into 21*17 grids (each grid has the length of 5 and width of 4). Then, vertices of these grids were being used as target points which we put the ball and get the x coordinate of ball and players as training and test data set inputs. Consequently, each formation can generate a maximum number of 396 samples and each sample consists of 11 features(x coordinates of opponent players and ball) and 3 labels(number of players in each layer). In order to generate training and test data sets, formations of some famous and credible teams of Soccer 2D Simulation League are being used. These teams are AUT, Axiom, Agent2d version 3, csuyunlu, gduttiji, Gliders, gpr2d, HELIOS, Perspolis, Riton and YuShan. The number of total, train, validation and test data sets are being shown in I.

TABLE I: The Amount and Percentage of Data Set

	Total Data set	Train Data Set	Validation Set	Test Data set
Amount	7551	5285	1133	1133
Percentage	70%	70%	15%	15%

It is important to notice that this table just used for offline learning and another data set is generated with the amount of 4752 samples. The last data set is created using 12 different formations with 15 static points which were initialized by authors. These formations are being shown in II. Each formation has three layers in which layer one (left number) is the number of Defenders, layer two (middle number) is the number of Midfielders and layer three (right number) is the number of offenders. We assumed that none of these layers can be zero and also as it is obvious in II, to simplify the outputs, formations with more or less than three layers are not used in our data set.

C. Methods

K Nearest Neighbor is a lazy learning or Instance-based learning algorithm and it is one of the simplest algorithms in machine learning. In this method, whenever we have a new point to classify, we find its K nearest neighbors from the training data. The distance can be calculated using various methods such as Euclidean Distance [16], Minkowski [17] and Mahalanobis [18], etc. In this paper, Euclidean distance was

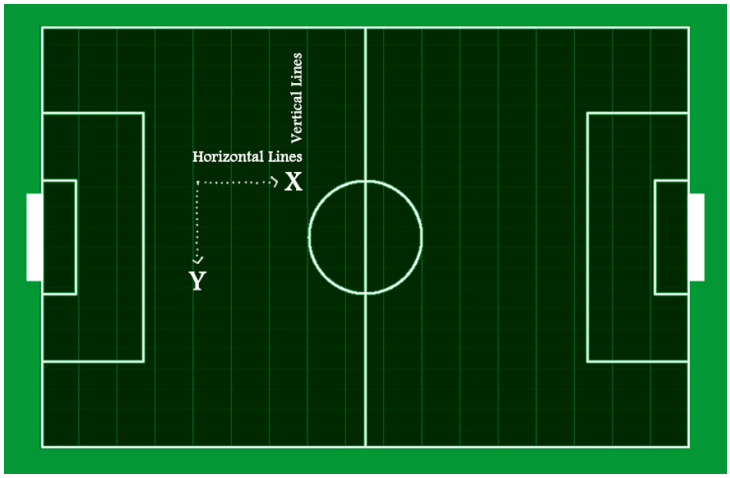


Fig. 1: Grid System and Cartesian Coordination of the game field

TABLE II: The relation between formations and classes

Class Label	1	2	3	4	5	6	7	8	9	10	11	12
Formation	361	352	343	451	442	433	424	415	541	532	523	613

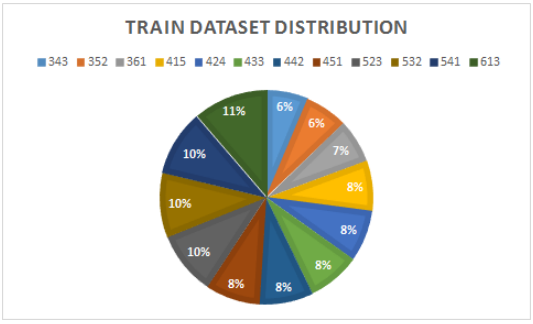


Fig. 2: Distribution of various class labels in train data set

Method	Parameter	Time (secs)	Error
KNN	k = 1	1.064439	0.49453
	k = 2	1.111923	0.49958
	k = 3	1.125685	0.50316
Multi SVM - Kernel	RBF	145.671776	0.51318
	Linear	54.798239	0.47548
	Polynomial	85.884489	0.46157
Neural Networks	Bayesian Regularization	173	0.09321
	Lavenberg - Marquardt	19	0.08099
	Scaled Conjugate Gradient	14	0.14042

used as a valid metric to evaluate the similarity of data. [19] It is well to note that three different Ks was used as parameters of KNN algorithm and compared in this paper.
Another algorithm which is used in this paper is Support Vector Machine (svm). The support-vector network or support vector machine is a learning algorithm for two-group classification problems and it is based on the idea that input vectors are non-linearly mapped to a very high-dimension feature space.[20] Because the problem here is multi-class, an extended version of original svm was used. It is of paramount importance that the technique of one-against-all utilized and it constructs K SVM models where K is equal to the number of classes. Various kernel functions like Linear, Polynomial and RBF is utilized to compare and evaluate the performance of different algorithms so as to choose the best one. [21][22]
The Neural Network was utilized to predict opponent formation and reach the objectives of the paper too. Three different learning algorithm was used to train the networks. Lavenberg-Marquardt, Bayesian Regularization and Scaled Conjugate Gradient utilized in this paper as a network training functions. Lavenberg-Marquardt which employed here is fastest backpropagation algorithm that updates weight and bias values according to Lavenberg-Marquardt optimization.[23] Other supervised learning algorithm with name of Scaled Conjugate Gradient was utilized to test performance of different algorithms for our specified problem. [24]

IV. Experimental Results

To demonstrate the best algorithm to predict opponent formation, we conduct various machine learning algorithms on our generated data set and the result because of data set simplicity for these algorithms doesn't showing any obvious difference. The performance diagram of Neural Networks training algorithm was shown in figures 3, 7 and 5 for Bayesian Regularization, Lavenberg-Marquardt and Scaled Conjugate Gradient ,respectively. This diagrams shows the best performance and training epochs for different training algorithms. Histogram of error also is depicted in figures 4, 6 and **??**. Because the acquired accuracy can not discriminate the best algorithm clearly, therefore we used histogram chart in order to compare algorithm comprehensively.

V. Conclusion & Future Work

The problem of this paper was detecting opponent's formation in soccer 2d simulation league. Generating dataset and

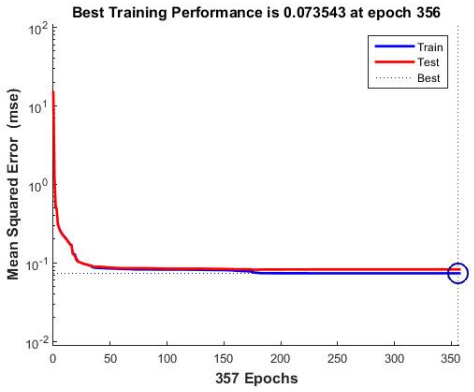


Fig. 3: Performance diagram for Bayesian Regulation

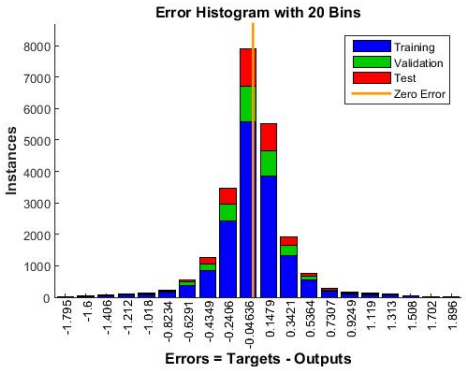


Fig. 6: Error histogram for Scaled Conjugate Gradient

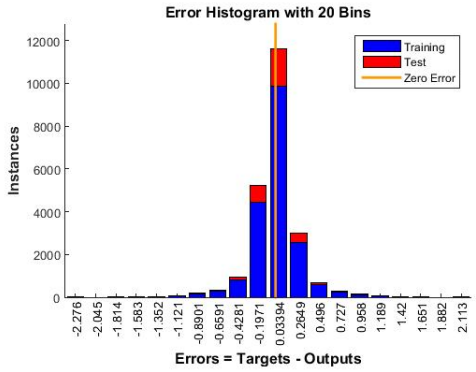


Fig. 4: Error histogram for Bayesian Regulation

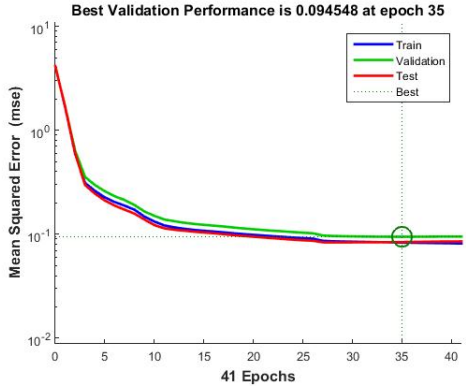


Fig. 7: Performance diagram for Lavenberg

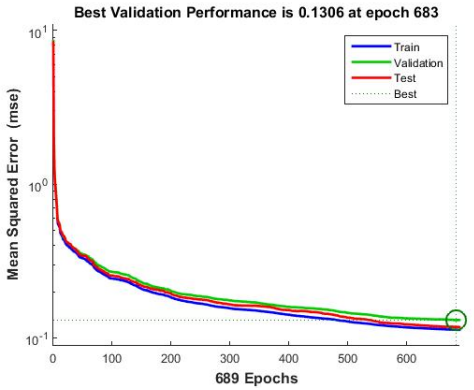


Fig. 5: Performance diagram for Scaled Conjugate Gradient

finding the best features and machine learning algorithms to train systems was challenge here. The above result shows performance of various machine learning techniques for the goal of this paper. The main challenge was solved with above 99% accuracy. Above all, using major voting technique can help to increase performance of the implemented algorithms. In this problem, the real-time formation detection time was not really challenging and all algorithms was trained offline and all of them satisfy the detection time and perform the answer only in one cycle in the 2d soccer simulation. For future work it is of paramount importance to change our team strategy as counter strategy using this proposed method to make our strategies more effective. Moreover, it is possible to utilize this approach as an offline learning which is our prior knowledge and this is an initial point for on-line prediction based algorithms like Gradient Decent [25]. For instance, updating the weights and parameters of Neural Networks using Gradient Decent and improving the performance. As an other improvement, it is feasible to predict the position of opponents players by combining all above approaches. Eventually, since our proposed method is just for three-layer formations, a big advance can be done by extending the algorithm for formations with more number of layers like 4-2-3-1 which contains four defenders, two defensive midfielders, three offensive midfielder and one offender.

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Development of Myoelectric Interface Based on Pattern Recognition and Regression Based Models

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***Abstract*—This paper proposes a combinatorial strategy for myoelectric control of robotic arm. Activation of main muscles responsible for 1 DOF of elbow joint is recorded. The goal was to create a mapping between muscles' Surface Electromyogram (sEMG) data and kinematics of the joints. The proposed strategy includes two main phases. In the first phase, Linear Discriminant Analysis (LDA) was utilized to classify several classes in user's arm motions. Due to fast training, simple implementation and robustness against long term effect of non-stationary characteristics of sEMG signals, LDA is a common classifier in myoelectric signal classification researches. In the second phase, two Time Delayed Artificial Neural Networks (TDANN) were trained to estimate proportional and continuous angle and velocity related to joint motion classes. Furthermore, two additional methods were used to enhance the prediction results accuracy. First, noise reduction of sEMG signals plays a key role in accurate joint kinematics prediction. Therefore, a new noise reduction approach is investigated based on classification results. Second, final predicted angles were achieved by data fusion of angles and angle difference rates, estimated by TDANN. Results show that, LDA classifies the motion classes with 95% accuracy and final estimated angular positions are significantly close to actual values. Therefore, proposed method is able to create a mapping between muscles' sEMG data and joint kinematics with acceptable error. Practical results confirm the performance of the proposed method.**

Keywords—Myoelectric Control, Linear Discriminant Analysis, Time Delayed Artificail Neural Network, Data Fusion, Noise Reduction.

I. INTRODUCTION

Myoelectric control is a new controller interface that is capable of accommodating the patient's abilities. In other words, Muscle activity data, map into desired function of a device. One of the main advantages of electromyography (EMG)-based control which distinguishes it from other portable control devices, is hands free control. There is a lot of information about user's moving intention in EMG signals' content. User should just be able to activate some of his muscles. In this research, in order to measure EMG signals surface electromyography (sEMG) is used. This method of data acquisition is inexpensive and noninvasive. Also, it provides sufficient information for EMG interface.

Pattern recognition based approach maps the EMG feature vector into the specific classes of motion by a classifier. There are number of studies which utilized LDA as classifier due to simple implementation and fast training [1], [2]. These characteristics make LDA a good choice to meet real-time contractions. Kaufmann et al. compared the ability of LDA classifier in long term use and showed that LDA was the most robust classifier against fluctuating sEMG signals in long-term use [3]. Young et al. studied the Classifier accuracy in presence of electrode shifts and found that LDA outperform the MLP classifier. Support vector machines (SVM) and hidden Markov models (HMM) are also selected as classifier in number of myoelectric researches [4], [5], [6]. Oskoei et al. compared the classification accuracy for different feature vectors and segmentation length with SVM classifier [7]. Literature survey showed that SVM, HMM are not as common as LDA. However, there are number of surveys which claim that with sufficient number of channels and proper features, most of the classifiers have the same accuracy [8],[9].

The main drawback of pattern recognition based classifiers is that, they are not able to make continuous output signals, therefore, they are not appropriate for coordinated tasks. Regression based methods provide continuous estimation of user's motions. They need training datasets that relationship between EMG and desired kinematics is known. Kirsch [10], developed a time delayed artificial neural network (TDANN) because of the ability of the network to estimate any nonlinear relationships and training the network with dynamic properties. Kirsch used raw EMG signals, instead of feature vectors. Many studies that used regression based sEMG control, utilized multilayer perceptron (MLP) for regression [11], [12]. Artemiadis et al. studied various parametric models for shoulder and elbow angle estimation and proposed the state space model as the appropriate model to map EMG-to-joint kinematics [13].

Yoshikawa presented a two phase myoelectric interface [6]. In the first part, motion classification has been done by SVM and in the second part a simple linear model was used to estimate joint angles correspond to the motion in the first phase.

The proposed strategy is based on utilizing the benefits of both pattern recognition and regression based methods to develop an interface for myoelectric control of robotic arm. Fig. 1 illustrates the schematic diagram of the proposed method. First, EMG data are recorded from probes installed on target muscles

of operators arm. Next, the features of the signals are extracted, which consists various time domain features. In the next step, the feature vector is classified based on the decisions made by LDA classifier. The results of classifier were used in two critical steps of this strategy. First, the classifier predicts the motion classes. Second, the classifier determines the direction of movement in any class in order to design an adaptive filter. Finally, joint angle and velocity of particular class is predicted by TDANN corresponding to the class. Final angular position results are achieved by data fusion of angles and velocities with a complementary filter. The estimated kinematics of joint was used to control a robotic arm.

We focused our research in upper-limb motion. There are seven degree of freedom (DOF) in human upper limb, excluding the hand. 3DOF relate to shoulder joint and 2DOF relate to elbow and 2 DOF in the wrist joint. The basic motions of upper limb except the hand, can be divided into 8 class of motions; shoulder vertical flexion/extension, shoulder horizontal flexion/extension, shoulder adduction/abduction, shoulder internal/external rotation, elbow flexion/extension, forearm supination/pronation, wrist flexion/extension, and wrist ulnar/radial deviation [14]. All daily motions related to upper-limb are composed of these basic motions. Also, Human upper limb is activated by agonist-antagonist pairs. It means, while agonist muscle cause an action through contraction, the other relaxes and vice versa [15]. This fact is utilized to design a filter which is discussed in section E.

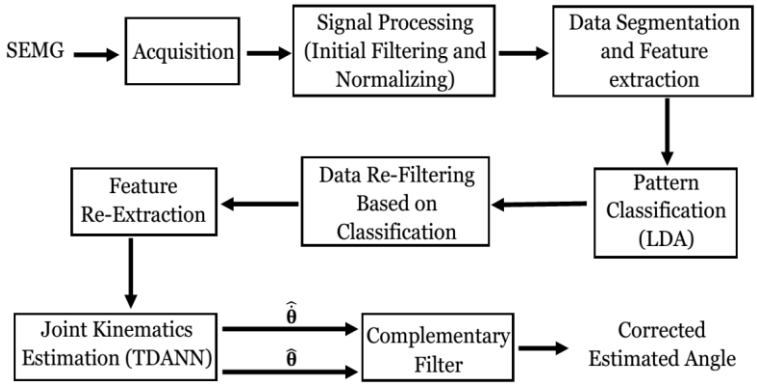


Fig. 1. Schematic diagram for myoelectric interface

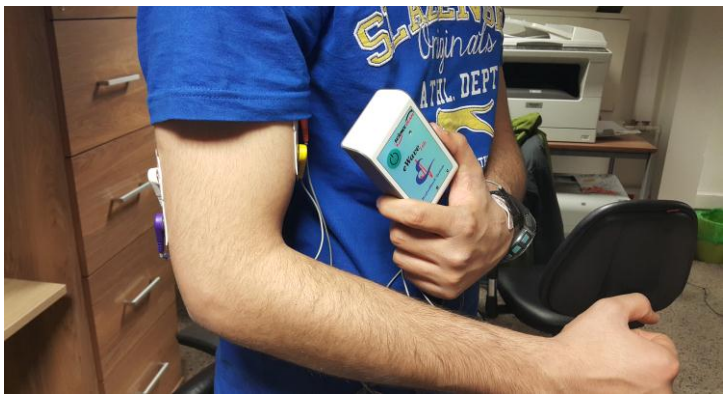


Fig. 2. EMG electrode loctions

II. METHODOLOGY

A. EMG and Motion Data Accquisition

Purpose of this research is to study the feasibility of create a mapping between muscles activity data and the resulting kinematic motions in the arm. Therefore, one basic upper-limb motions related to elbow joint (elbow flexion/extension) were studied. Biceps brachii and Triceps brachii are related to elbow flexion/extension respectively. The experiment was performed with a 25 years old male subject and he was asked to move his targeted joints in sinusoidal and random manner. Meanwhile, muscle activity data and related joint angles were recorded using differential surface electromyography electrodes connected to wireless EXG recording sensor (eWave 16b, Science beam) and wireless IMU, motion tracker (TSS-WLS-S, Yost engineering Inc.) respectively. EMG sensor and motion tracker provided the data samples with frequency of 1 kHz and 100 Hz respectively. Data acquisition program was coded in LabVIEW using queuing approach such that different sampling frequencies were compensated and both sensor data were recorded with frequency of 1 kHz. The locations of sEMG electrodes are shown in Fig. 2.

B. Data preprocessing

First of all, EMG signals were full wave rectified. Next, EMG signals should be filtered. Due to low amplitude voltage range of EMG signals (below 10 mV), they are really sensitive to noise. Noise reduction plays an important role in myoelectric control strategies. There are number of Known noise source that can be filtered in order to achieve a low noise signals. Signal variation caused by motion artifacts like electrode shift, cable movement are typically below 20 Hz. Therefore a High-pass cut-off frequency 20 Hz is usually used in EMG studies. Also, Power spectrum of sEMG recording shows that dominant frequencies and energy of relevant sEMG signals are less than 400 Hz [16]. According to the Nyqvist rule, the sampling rate should be equal or more than twice the highest frequency of the signal. Due to sampling rate 1000Hz, a low-pass filter at 400 Hz was utilized. Also another filter was used in this research that will be discussed in section E.

Pattern recognition based EMG analysis would be performed on time segments of the signal called windows, in order to achieve a one to one mapping. There are two common window techniques: adjacent and overlapped windows. While in the adjacent window technique computational data reduces significantly, overlapped window technique has better classification accuracy and proportional results in myoelectric surveys [17]. Additional to window technique, segment length has effect on EMG analysis. Segment length selection is a trade-off between estimation accuracy and real-time constraint. Overlapped window technique with 200 ms segment length and 40 ms overlap were utilized in this research by a trial error approach.

C. Feature extraction

EMG signals have random nature and as a result, they are not appropriate for training TDANN and LDA classifier. EMG features' space describes the information content more efficient than raw signals. Feature selection is an important challenge in myoelectric control strategy which leads to better estimation accuracy. There are three main groups of EMG features [18]. Any of these features sets has a characteristic that, results in different improvements in myoelectric control. Lots of researches compare different features effect in classification and proportional estimation accuracy. Time domain (TD) features are regular type of features for training classifier and network due to their simple computational progress. TD features can be divided into for main groups: 1) energy information methods, 2) frequency information methods, 3) prediction model methods, and 4) time-dependence methods. Creating a feature vector from different categories yields better estimation results.

Hudgin's features are common set of TD features which include mean absolute value (MAV), waveform length (WL), zero crossing (ZC), and signal slope change (SSC). MAV and WL are examples of energy methods and, ZC and SSC are categories of frequency information methods. Also, coefficients of 4th order autoregressive (AR) model as a prediction model method group, were selected to provide feature vector from different types, in TD features. Selected features are presented in the TABLE I. In this Stage, features are extracted from raw EMG signals to train the LDA classifier.

TABLE I: TD Features

Time domain features	Calculation method
Mean absolute value	$MAV = \sum_{i=1}^{N} \lvert x_i \rvert$
Waveform length	$WL = \sum_{i=1}^{N-1} \lvert x_{i+1} - x_i \rvert$
Zero crossing	$ZC = \sum_{i=1}^{N} sgn(-x_i x_{i+1})$ $sgn(x) = \begin{cases} 1, & if\ x > 0 \\ 0, & otherwise \end{cases}$
Slope sign change	$SSC = \sum_{i=2}^{N-1} [f(\lvert (x_i - x_{i-1})(x_i - x_{i+1}) \rvert)]$ $where\ f(x) = \begin{cases} 1, & if\ x \geq throshold \\ 0, & otherwise \end{cases}$
Autoregressive coefficients	$x_n = \sum_{i=1}^{P} a_{i,n} x_{n-i}, P = model\ order$ $a_{i,n} = ith\ AR\ coeffient\ at\ time\ instant\ n$

LDA classifier will be used to designLDA classifier will be used to design a filter that would be described in the following sections. Intended feature vector for training the network, would be extracted after the raw signals was filtered with designed filter in section E.

D. Linear Discriminant Analysis (LDA)

The purpose of classification step in pattern recognition is to analysis the input features to the classifier and make a decision for which class, the specific feature in a specific window of time belong to. In this strategy, individual TDANN should be trained for any DOF. LDA's role is to determine the DOF of user's motion and therefore, the corresponding TDANN, estimate the angular position of joint. In other words, the network that was trained with datasets of all motion classes is not as accurate as this strategy. Another reason to use classifier was to identify the direction of motion in specific class. For example, flexion and extensions are of the elbow motion classes in a DOF.

LDA is a parametric type of classifier which is based on the assumption that features belong to known probability density function like Gaussian or natural distribution. The mean and covariance matrix for any class are then found. New samples features were extracted and the sample belongs to the class with highest probability [19]. The Gaussian distribution is defined in equation (1). In this equation, $p(x|w_i)$ is probability of class w_i given the feature vector x with mean vector μ_i, and covariance matrix, $\sum_i$. The operator $|\ |$ and T are determinant and transpose, respectively. The feature vector is l dimensional and number of classes is M.

$$p(x|w_i) = \frac{1}{(2\pi)^{l/2} |\sum_i|^{1/2}} \exp\left(-\frac{1}{2}(x-\mu_i)^T \left(\sum_i (x-\mu_i) \right)^{-1} \right) \quad (1)$$

$$i = 1, \ldots, M$$

In training data, feature vectors consist of Hudgin's features combined with 4th order auto regressive coefficients.

E. Noise reduction in EMG signals

Noise reduction is a critical step in training and testing process of LDA and TDNN. Indeed one of the main causes of error in joint kinematic estimation is the noise of signals. EMG signals usually contain different types of noise which affect useful information of the signal. [20]. There are specific numbers of muscles concerning with specific DOF of any joint, according to joint motion physiology. This information can be used in order to reduce the effect of muscles which does not actuate the joint in a certain direction of movement but the channel feature data have been considered as an input to the TDANN and contain several noise types. As discussed in the introduction section, upper limb muscles are agonist-antagonist pairs. For example, Biceps brachii and Triceps brachii are responsible for elbow flexion and extension respectively. During the elbow flexion, triceps is inactive and

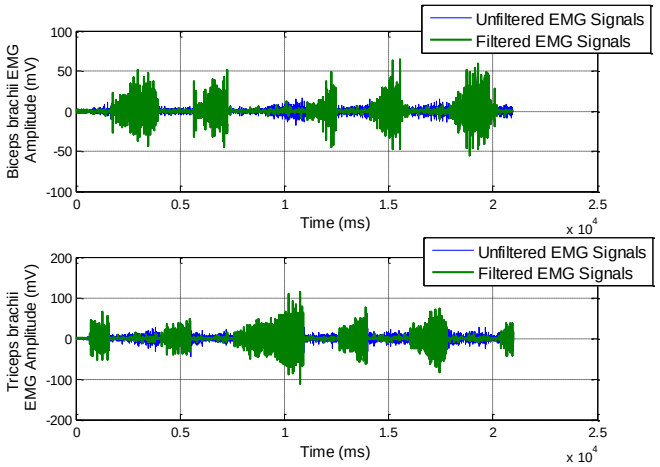


Fig. 3. Filtered and unfiltere EMG signals

during extension, Biceps brachii is relaxed. So, a little EMG activity that is presents even for inactive muscles and it is not caused by motor unit activity is considered to be noise.

The method which utilized in this paper is based on the classification results. Structure of filter designed such that in the first step Classifier decide the direction of movement in each DOF and EMG data of muscles that are in rest would be band pass filtered with a 4th order Butterworth filter in range of 10Hz to 150Hz. A sample Result of this filter is shown in Fig. 3. The results shows that filter can successfully filter the noise that presents in the data. Therefore the prediction error would be reduced significantly as will be presented in results section.

F. Time Delayed Artificial Neural Network (TDANN)

There are several approaches for proportional estimation of joint kinematics like: 1) Artificial Neural Network (ANN) 2) Fuzzy approach 3) Neuro-Fuzzy 4) regression based estimation. Many literatures proved the ability of ANN in myoelectric control researches. The other methods are not as low computational cost and accurate as ANN. In the second phase of our strategy, TDANN is used to estimate continuous kinematic values (angles, and velocity) for elbow joint from EMG signals. TDANN is able to represent nonlinear equations. Also, it is applicable to any user just by training the network with the training data collected from user. Use of delayed input signals results in training the network with dynamic properties of the system.

After re-filtering EMG data by designed filter in section E, signal features were extracted again. The estimating the kinematics with the filter demonstrated better results from the case that filter was not utilized.

Network was trained using one the fastest back propagation algorithm that updates weight and bias states according to Levenberg-Marquardt optimization. TDANN were trained until error between actual data collected with IMU motion tracker and estimated value by network, changed by less than 1e-5. Mean square error (mse) was selected as a criterion for goodness of fit between measured and estimated data. Number of delays and neurons in network were determined empirically. Scaling the inputs and targets within a specific range will result in better training and testing. Testing data were also mapped to the range before processed by the network. After the estimation, the output values were convert back into original units that were used for original targets.

Two distinct TDANN were trained for estimating velocities and angles from feature vectors of EMG signals of a specific DOF. In the following section estimated angles and velocities values were combined in order to achieve an accurate estimation of joint position.

G. Data Fusion

The idea of using data fusion algorithm in this strategy comes from a common method in IMU motion trackers for calculating exact angle values from gyroscope and accelerometer. Gyroscope integrates the angular velocity over time, therefore in long term, the angular position value start to drift. On the other hand accelerometer data has an oscillating nature. Combing these data by a complementary filter leads to utilizing benefits of both of them. Same things happen in this strategy. Two TDANN were trained to estimate angular velocity and position of joint. Integrating the estimated angular velocity has more accurate results than values estimated by TDANN, but it starts to drift after a while. On the other hand, the estimated angles by TDANN are oscillatory and they need to be filtered but they does not drift over long term use. A complementary filter was utilized for data fusion of estimated angle values and velocities in order to achieve a final angular position results.

III. Results and Discussions

In this section, LDA classifier, TDANN, and data fusion results will be discussed in order to evaluate the feasibility of this strategy for myoelectric control. LDA was trained using several datasets as training data. Fig. 4 shows the confusion matrix for testing data. Actual set 1 corresponds to flexion class and actual set 2 relate to extension class. Confusion matrix shows 98% and 90% estimation accuracy for prediction of flexion and extension classes respectively. Overall classification error is 4.91% which is acceptable error for estimation.

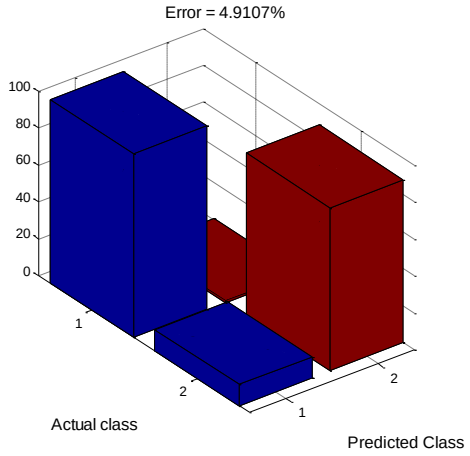


Fig. 4. LDA classifier fusion matrix

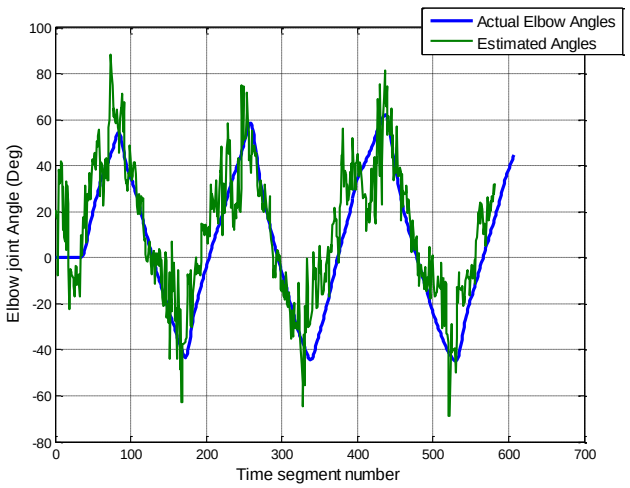


Fig. 5. Actual and estimated angles by TDANN

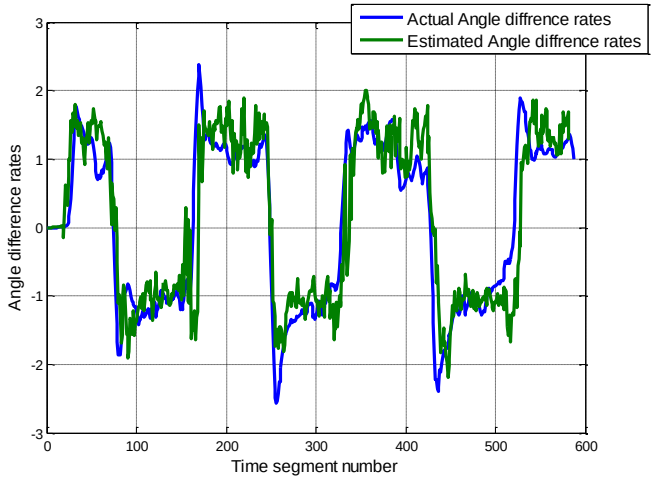


Fig. 6. Actual and estimated angle difference rates

In the second phase, data was filtered based on classification results and feature vector was re-extracted. TDANN was trained with new feature vector for estimating joint angles. Fig. 5 shows the TDANN angles prediction for sinusoidal testing data. Network estimation is oscillatory and needs be filtered by a low pass filter.

Another TDANN was trained to estimate joint velocities with new feature vector. Training targets which are actual velocities recorded by IMU motion tracker are oscillatory too and so actual velocities were low pass filtered before being utilizing as network training data. Filtering target velocities results in more accurate network. Fig. 6 shows the TDANN estimation of joint velocities for testing data.

Estimated velocities were integrated in order to gain joint angles. Fig. 7 shows the joint angles estimated by second network. Estimated angles start to drift after a while.

In the last step of this strategy, estimated angles and velocities data were combined using complementary filter to obtain final joint angular positions. Fig. 8 presents angular position estimated by data fusion algorithm. Final results proves the ability of this strategy for create a mapping between EMG signals and kinematics of the joint. Data fusion results demonstrate enhanced accuracy in myoelectric control.

The first purpose of this research was to improve the estimation accuracy of joint kinematic using EMG data.

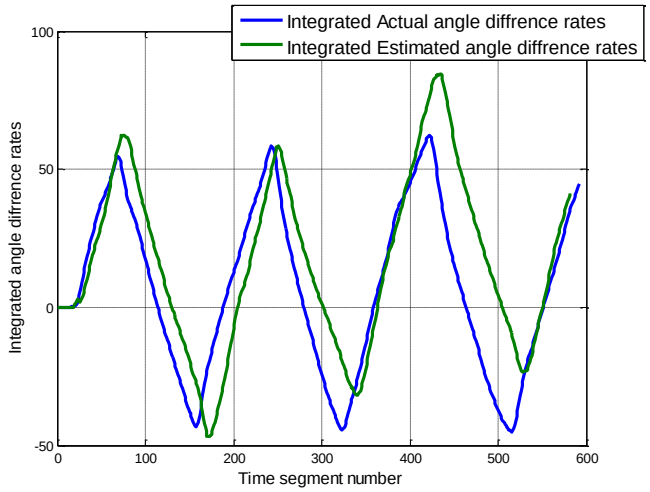


Fig. 7. Integrated Actual and estimated angle difference rates

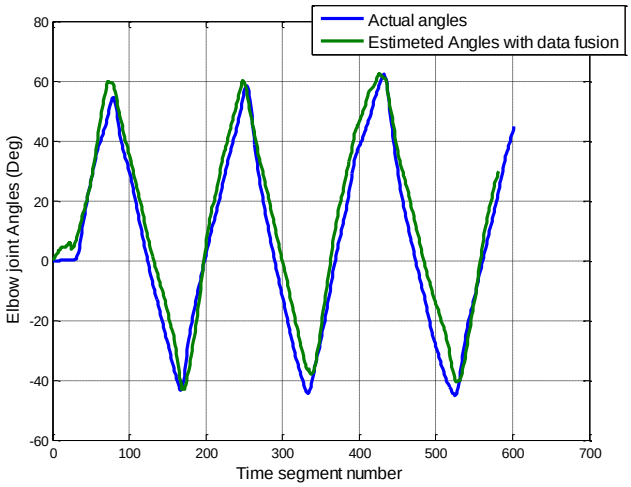


Fig. 8. Final elbow angular position obtained from data fusion

The innovation has been made in this strategy showed an improvement in estimation results utilizing benefits of both pattern recognition based and regression based methods. Comparing the results with other researches proves the ability of this strategy. In the further researches, using optimization algorithm for finding best feature vector and optimal number of neurons and delays in neural network is going to be investigated. Also, the proposed strategy is appropriate for online implementation of myoelectric control of robotic arm due to simple computations and therefore acceptable delay in online control. One of the main drawbacks of today's prosthesis is unacceptable delays in finding amputee's intention. After evaluating online performances of the strategy, the method can be used in active prosthesis without being rejected from amputees.

IV. CONCLUSION

This paper proposed an improved myoelectric interface for robotic arm control from upper-limb EMG signals. The main strategy includes two stages. In the first part elbow motion was classified using LDA with an overall error of 4.91%. In the second part, TDANN was used to estimate elbow joint kinematics (angles and velocities). Classification results were utilized to design a filter which leads to better estimation accuracy. Moreover, complementary filter was used to combine estimated angles and velocities from TDANN in order to improve prediction results. Presented results discussed in priory section show a significant reduction in estimation error.

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LQG-I Control for Attitude Stabilization of V8 Octorotor Flying Robots

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***Abstract*— Small aerial vehicles have gained strategic importance in many urban applications such as aerial photography. V8 configuration is a multirotor design hardly investigated in the field of flying robots. Dynamical model of V8 octorotor is derived and linearized using small perturbations method. Validity of linearization is proved through comparison with nonlinear behavior. Linear quadratic Gaussian control approach together with an integral action is designed to stabilize octorotor attitude angles. Control performance is compared with PID and LQR methods which indicated proposed controller provides better results while maintaining efficient energy usage.**

Keywords—V8 octorotor; linearization; small perturbations; LQG; integral action;

I. INTRODUCTION

Human's enthusiasm for flight has always been displayed in evident ways. The dream of flying has generated centuries of frustration and hundreds of dramatic attempts without being faded [1]. Emergence of Miniature flying vehicles in recent years is a sign of a new era in mankind's control over the skies. Such vehicles enable users to reach areas which are hazardous to people. Aerial photography is another domain of application where Unmanned Aerial Vehicles (UAVs) offer cheaper and unique solutions.

Classical control approaches have been numerously utilized to control rotary wing drones. Bouabdallah [2] used PID and LQ techniques to stabilize quadrotor's attitude and implemented the controllers on a real system. Zhang and Cong [3] used Linear Quadratic Regulator (LQR) to study on control sensitivity and reaction speed of QUH. Castillo et al [4] compared a nested saturation nonlinear controller with LQR and reduced oscillations by adjusting LQR gains.

Symmetric octorotors have also been subject of linear controllers. Victor and Stoica [5] used LQR to stabilize an octorotor's attitude and altitude in three different scenarios. Rinaldi et al [6] modeled and linearized an X type octorotor. LQR and PID control is used to control the vehicle and the results are compared. Linear Quadratic Gaussian (LQG), as an enhancement over LQR have been used on aerial vehicles. Nonami et al [7] made use of LQI technique, which combines LQR control with an integral term to control quadrotor. Minh et al [8] used a vision-based measurement technique to estimate position and attitude of the system and applied LQG to control attitude.

This study presents dynamical modeling and linearization of V8 octorotor. An LQG control with integral action for eliminating steady-state errors is proposed to stabilize attitude. Results of simulation are presented and show satisfactory performance of LQG-I method compared with other techniques. It is shown that stabilization is achieved while energy use is kept at reasonably low levels.

II. V8 OCTOROTOR PLATFORM

Multirotors are designed and used in a variety of configurations. Each design is suitable for a particular application. Aerial photography is an important use which needs installation of optical sensors. Conventional configurations which distribute rotors symmetrically require the balance of mass. Usually, the camera is blocked by propellers or the structure. V8 configuration which is seen in Fig. 1, offers wide field of view and out of center placement of optical devices. In addition, rotor redundancy in the vehicle allows for handling of motor failure.

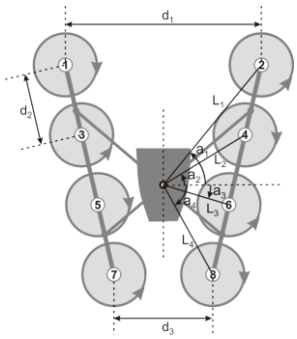


Fig. 1. V8 octorotor configuration schematic

Rotors are symmetrically placed relative to vehicle's longitudinal line of symmetry. On each side, rotor location is indicated by four lengths and four angles as shown in Fig. 1. Four rotors rotate clockwise and the other four rotate counterclockwise to maintain balance of moments in yaw direction. Dimensions of the vehicle are listed in TABLE I.

TABLE I. V8 OCTOROTOR PHYSICAL PARAMETERS

Parameter	Value (m)	Parameter	Value (deg)
$\mathbf{d_1}$	0.724	$\mathbf{L_4}$	0.407
$\mathbf{d_2}$	0.323	$\mathbf{a_1}$	52.8
$\mathbf{d_3}$	0.373	$\mathbf{a_2}$	27.4
$\mathbf{L_1}$	0.598	$\mathbf{a_3}$	33.6
$\mathbf{L_2}$	0.342	$\mathbf{a_4}$	62.7
$\mathbf{L_3}$	0.293		

III. SYSTEM DYNAMICS

A dynamical model of the robot is required in order to design the control system. Here, governing differential equations of the system are derived using Euler-Lagrange approach. V8 octorotor is a complex dynamical system that is affected by several aerodynamic and physical effects. However, certain important effects are modeled and the rest will be assumed as external disturbances which should be tackled by a robust controller.

A. Nonlinear Model

Two reference coordinates E and B are defined as earth-fixed and body-fixed frames. Generalized coordinate $q = \begin{bmatrix}\xi & \eta\end{bmatrix}^T$ includes position of the robot relative to earth-fixed frame $\xi = \begin{bmatrix}x & y & z\end{bmatrix}^T$ and Euler angles $\eta = \begin{bmatrix}\phi & \theta & \psi\end{bmatrix}^T$. Angles ϕ, θ, and ψ are called roll, pitch, and yaw, respectively. To change the vectors from B to E, a rotation transformation matrix is defined as

$$R = \begin{bmatrix} c\psi c\theta & c\psi s\theta s\phi - s\psi c\phi & c\psi s\theta c\phi + s\psi s\phi \\ s\psi s\theta & s\psi s\theta s\phi + c\psi c\phi & s\psi s\theta c\phi + c\psi s\phi \\ -s\theta & c\theta s\phi & c\theta s\phi \end{bmatrix} \quad (1)$$

where s and c are short forms of sine and cosine functions, respectively. Coordinate systems and angles are illustrated in Fig. 2. Lagrangian of the system is the sum of all kinetic energy of the vehicle subtracting potential energy. It is defined as

$$L\ q,\dot{q}\ = T_{trans} + T_{rot} - U \quad (2)$$

where T_{trans} is translational kinetic energy, T_{rot} is rotational kinetic energy and U represents potential energy determined as following.

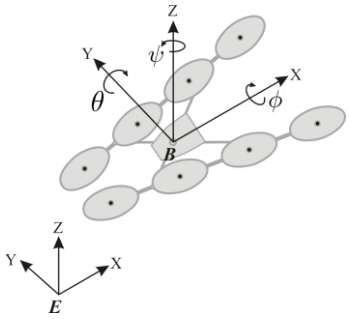


Fig. 2. Earth-fixed and body-fixed frames

$$\begin{aligned} T_{trans} &= (\frac{m}{2})\dot{\xi}^T\dot{\xi} \\ T_{rot} &= \frac{1}{2}\dot{\eta}^T J\dot{\eta} \\ U &= mgz \end{aligned} \quad (3)$$

In the above equations m is total mass of the system, and $J = W_v^T I W_v$ is a Jacobian matrix in which

$$W_v = \begin{bmatrix} 1 & 0 & -\sin\theta \\ 0 & \cos\phi & \sin\phi\cos\theta \\ 0 & -\sin\phi & \cos\phi\cos\theta \end{bmatrix}. \quad (4)$$

I is matrix of inertia. Unlike conventional multirotor systems, V8 octorotor is an asymmetrical body. Hence, off-diagonal elements of matrix of inertia become nonzero. General form of Euler-Lagrange equations is defined as

$$\frac{d}{dt}(\frac{\partial L}{\partial \dot{q}}) - \frac{\partial L}{\partial q} = \begin{bmatrix} F_\xi \\ \tau_\eta \end{bmatrix} \quad (5)$$

where $F_\xi = RF$ is the translational force and τ_η is the rotational moments applied to the vehicle and $F = \begin{bmatrix}0 & 0 & U\end{bmatrix}$. These vectors are specified as below.

$$U = \sum_{i=1}^{8} T_i \quad (6)$$

$$\begin{aligned} \tau_\phi &= L_1\cos a_1\ T_1 - T_2\ + L_2\cos a_2\ T_3 - T_4\ + \cdots \\ &\quad L_3\cos a_3\ T_5 - T_6\ + L_4\cos a_4\ T_7 - T_8 \\ \tau_\theta &= -L_1\sin a_1\ T_1 + T_2\ - L_2\sin a_2\ T_3 + T_4\ + \cdots \\ &\quad L_3\sin a_3\ T_5 + T_6\ + L_4\sin a_4\ T_7 + T_8 \\ \tau_\psi &= D_1 - D_2 - D_3 + D_4 + D_5 - D_6 - D_7 + D_8 \end{aligned} \quad (7)$$

In the above equations, T is the thrust force which is the resultant of the vertical forces acting on all blade elements

and D is the drag moment about the rotor shaft which is caused by the horizontal aerodynamic forces acting on blade elements [9]. Thrust force and drag moment produced by each rotor can be expressed by the following simplified equations

$$\begin{aligned} T_i &= k_T \Omega^2 \\ D_i &= k_D \Omega^2 \end{aligned} \tag{8}$$

where k_T is thrust coefficient, k_D is drag coefficient and both are dependent on propeller structural properties. Ω is propeller's angular velocity in rad/sec.

Differential equations explaining behavior of the robot is finally achieved and is separately formulated for translational and rotational subsystems of the octorotor.

$$m\ddot{\xi} + mg\begin{bmatrix} 0 \\ 0 \\ e_z \end{bmatrix} = F_\xi = RF \tag{9}$$

$$J\ddot{\eta} + C(\eta, \dot{\eta})\dot{\eta} = \tau_\eta \tag{10}$$

in which

$$C(\eta, \dot{\eta})\dot{\eta} = \dot{J} - \frac{1}{2}\frac{\partial}{\partial \eta}(\dot{\eta}^T J)$$

is the Coriolis term, containing gyroscopic and centrifugal terms [4]. The model is experimentally validated in [10]. Since attitude control of the octorotor is carried out in this study, only rotational subsystem, equation (13), is considered hereafter as the system dynamics.

B. Model Linearization

Nonlinear systems can produce completely different responses for different inputs. Linear approximations are desired for many applications since their behavior is more predictable. There are different approaches to obtaining a linear estimate of a system which are used depending on system characteristics. The model extracted in previous section leads to complicated differential equations containing very large terms and high orders of triangular expressions.

Therefore, using analytical methods can be highly laborious and prone to errors. Here, a numerical approach called small perturbations is employed to linearize the highly complex dynamics. In this method, coefficient matrices of the linear system are obtained by making a small perturbation in system states and inputs, and measuring system response. To describe the linearized system, a new set of variables of the states, inputs, and outputs are defined centered about the operating point:

$$\begin{aligned} \delta x\ t &= x\ t - x_0 \\ \delta u\ t &= u\ t - u_0 \\ \delta y\ t &= y\ t - y_0 \end{aligned} \tag{11}$$

The linearized state-space equations in terms of these new variables are:

$$\begin{aligned} \delta \dot{x}\ t &= A\delta x\ t + B\delta u\ t \\ \delta y\ t &= C\delta x\ t + D\delta u\ t \end{aligned} \tag{12}$$

Small perturbations method can be implemented in MATLAB software using *linmodv5* command. To compute the state-space matrices during linearization, the software performs these operations [11]:

1) Perturbs the states and inputs, one at a time, and measures the response of the system to this perturbation by computing $\delta \dot{x}$ and δy.

2) Computes the state-space matrices using the perturbation and the response.

$$\begin{aligned} A(:,i) &= \frac{\dot{x}\big|_{x_{p,i}} - \dot{x}_0}{x_{p,i} - x_0} \quad , \quad B(:,i) = \frac{\dot{x}\big|_{u_{p,i}} - \dot{x}_0}{u_{p,i} - u_0} \\ C(:,i) &= \frac{y\big|_{x_{p,i}} - y_0}{x_{p,i} - x_0} \quad , \quad D(:,i) = \frac{y\big|_{u_{p,i}} - y_0}{u_{p,i} - u_0} \end{aligned} \tag{13}$$

where $._{p,i}$ are the vectors whose ith component is perturbed from the operating point value, and $._0$ are the vectors at the operating point. Coefficient matrices of linearized system are obtained as the following.

$$A = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & -1.38\times10^{-6} & 0 & -1.65\times10^{-8} & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 4.47\times10^{-6} & 0 & -1.76\times10^{-8} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & -3.08\times10^{-4} & 0 & 1.38\times10^{-5} & 0 & 0 \end{bmatrix}$$

$$B = \begin{bmatrix} 0 & 0 & 0 \\ 2.1624 & -0.9634 & -0.2998 \\ 0 & 0 & 0 \\ -0.9634 & 2.2409 & -0.3194 \\ 0 & 0 & 0 \\ -0.2998 & -0.3194 & 250.1548 \end{bmatrix} \tag{14}$$

$$C = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \end{bmatrix} \quad , \quad D = 0$$

To ensure accuracy of linearization, comparison between linear and nonlinear systems' outputs is carried out. First, the

closed loop systems with PID controllers are compared which are seen in Fig. 3.

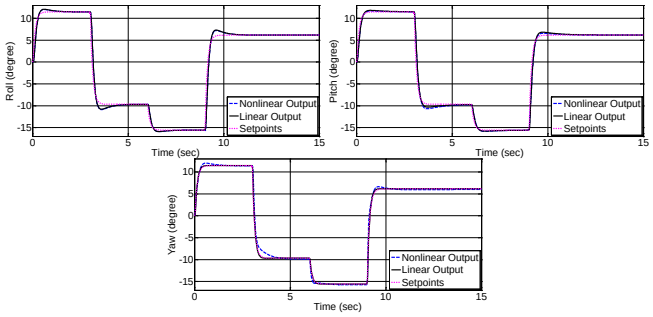


Fig. 3. Comparison between closed loop linear and nonlinear systems

Also, outputs of open loop linear and nonlinear systems with sinusoidal inputs are compared and shown in Fig. 4.

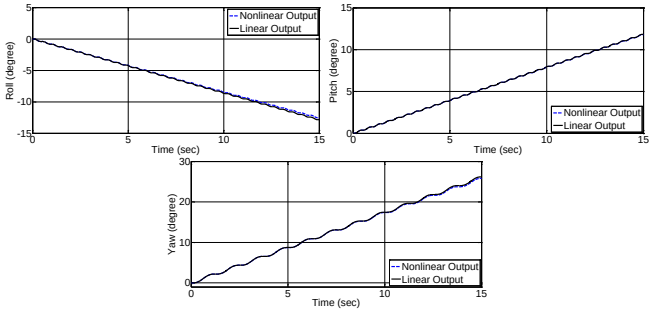


Fig. 4. Comparison between open loop linear and nonlinear systems

It is evident from the plots of responses that linear approximation of the system successfully estimates behavior of the nonlinear dynamics. Therefore, the linear system is used to design controller in the following sections.

IV. LQG WITH INTEGRAL ACTION

A. LQR

Consider a state space model for a system with m inputs l outputs and n states

$$\begin{aligned} \dot{x} &= Ax + Bu \\ y &= Cx. \end{aligned} \tag{15}$$

Fig. 5 shows a state feedback scheme for LQR controller.

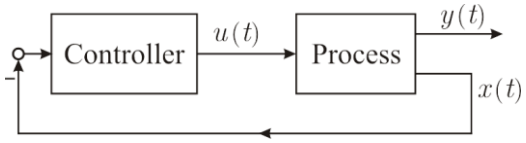


Fig. 5. State feedback scheme

LQR problem is defined as finding the controller that makes the following criteria as small as possible

$$J_{LQR} := \int_0^\infty x^T Q x + \rho u^T R u dt \tag{16}$$

where ρ is a positive constant, Q is an $l \times l$ symmetric positive-definite matrix, R an $m \times m$ symmetric positive-definite matrix [12]. Solution to optimal state feedback LQR problem is a simple matrix gain of the form $u\ t\ = -Kx$ where K is the $m \times n$ matrix given by

$$K = \rho R^{-1} B^T P. \tag{17}$$

The positive-definite matrix P is determined by solving Algebraic Riccati Equation (ARE) [13].

$$A^T P + PA - PBR^{-1}B^T P + Q = 0 \tag{18}$$

B. State Estimation and Kalman Filter

The Problem with the abovementioned state feedback scheme is that it requires all system states to be measurable. A possible approach to overcome this difficulty is to estimate system states solely based on the measured output y, and use

$$u\ t\ = -K\hat{x}\ t \tag{19}$$

where $\hat{x}\ t$ denotes an estimate of states $x\ t$. An estimator dynamics can be considered as:

$$\begin{aligned} \dot{\hat{x}} &= A\hat{x} + Bu + L(y - \hat{y}) \\ \hat{y} &= C\hat{x} \end{aligned} \tag{20}$$

where estimator gain L is an $n \times l$ matrix. Finally, estimator dynamics is obtained as the following.

$$\dot{\hat{x}} = A - LC - BK\ \hat{x} + Ly \tag{21}$$

A well-known estimation method for system states is Kalman filter which is the dual to LQR problem. It forms an optimal estimator in the presence of process and measurement noises. Consider a system with state-space description:

$$\begin{aligned} \dot{x} &= Ax + Bu + w \\ y &= Cx + v \end{aligned} \tag{22}$$

where w and v are process and measurement noises, respectively and are assumed to be white noises. It means that they are signals with zero mean and Gaussian distributions. Optimal estimator gain L is given by solving ARE as follows [12].

$$L = P_L C^T Q_v^{-1} \tag{23}$$

$$AP_L + P_L A^T - P_L C^T Q_v^{-1} C P_L + Q_w = 0 \tag{24}$$

where Q_w and Q_v are process and measurement noise covariance matrices, respectively. These noises are considered as stochastic variables. Covariance of a vector of stochastic variables $X = X_1, X_2, \ldots, X_n$ is defined as

$$\text{cov}\ X = E\left[X - E\ X \quad X - E\ X \ ^T \right] \quad (25)$$

where E . is the expectation of stochastic variable.

C. Integral Action

Pure LQG control strategy described above led to steady-state error in preliminary simulations of the system. In order to resolve this problem, an integral action is added to the control loop. Integral term is known to be a decent approach to tackle accumulative errors, although if wound up, it can result in increased overshoots. Saturation of the output of the integral action is used as anti-windup solution.

Therefore, LQG control combined with an integral action (LQG-I) is used to stabilize octorotor attitude. Block diagram of system and the LQG-I controller is illustrated in Fig. 6.

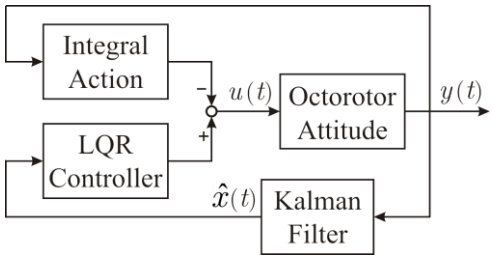


Fig. 6. Block diagram of system and control scheme

V. Controller Desgin

In previous section, theoretical background for LQG-I control strategy was established. Here, the design process which includes obtaining various matrices of the system is presented.

A. Covariance Matrices

Measurement noise covariance for V8 octorotor is obtained from experimental data. The octorotor platform which is shown in Fig. 7 is fixed on a 3 DOF stand and data is captured via a USB port. Octorotor's structure and 12×4.7 propellers are made of carbon fiber. The robot is actuated by brushless DC motors and the electronic board comprises 8 bit microcontroller ATmega2560, angular sensors (gyroscope, accelerometer, and compass) and barometer.

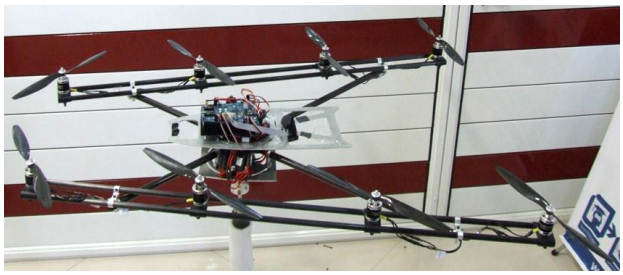


Fig. 7. SIMORGH™ [14] V8 octorotor platform

To obtain a sample of measurement noise, angle values acquired from the robot is subtracted from mean values of each individual signal and shown in Fig. 8. Then, covariance matrices for these values are obtained. In addition, covariance matrix for process noises is assumed to be an identity matrix of the order 10^{-3}.

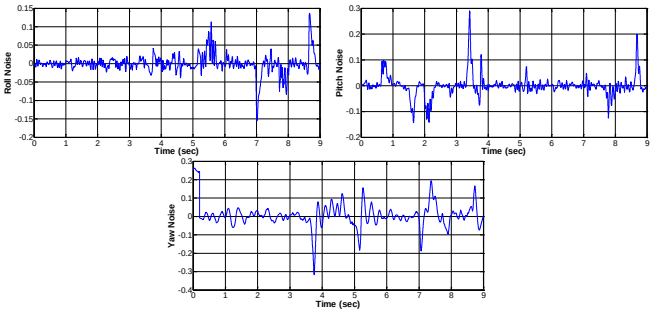


Fig. 8. Measurement noise for angles

$$Q_v = \begin{bmatrix} 0.0062 & 0 & 0 \\ 0 & 0.016 & 0 \\ 0 & 0 & 0.042 \end{bmatrix}, \quad Q_w = 10^{-3} \times I_{6\times 6}$$

B. LQR Weighting Matrices

Various techniques can be used to determine proper weighting matrices Q and R for LQR part of the controller which include trial and error, pole placement, Bryson's method, etc. Here, a numerical approach using genetic algorithm optimization is used in which initial values of matrices are obtained using Bryson's formula [12] and improved with GA. The objective function used for the optimization was

$$f = mse = \frac{1}{N}\sum_{i=1}^{N} e_{\phi i}^{\ 2} + \frac{1}{N}\sum_{i=1}^{N} e_{\theta i}^{\ 2} + \frac{1}{N}\sum_{i=1}^{N} e_{\psi i}^{\ 2} \quad (26)$$

where $e_{\eta i}$ denotes the respective attitude error. Weighting matrices are obtained as below.

$$Q = \begin{bmatrix} 804.21 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0.01 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1021.02 & 0 & 0 & 0 \\ 0 & 0 & 0 & 14.32 & 0 & 0 \\ 0 & 0 & 0 & 0 & 950 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1.05 \end{bmatrix}$$

$$R = \begin{bmatrix} 30 & 0 & 0 \\ 0 & 1.3 & 0 \\ 0 & 0 & 362.69 \end{bmatrix}$$

VI. Results

V8 Octorotor dynamics and LQG-I controller achieved in previous sections are simulated in Simulink software. The variable-step third order solver of type Bogacki-Shampine is used to perform simulation and the relative tolerance is set to $1E^{-3}$. A schematic diagram of simulation is shown in Fig. 9. Results are compared with PID and LQR techniques to give insight into the performance of the proposed controller.

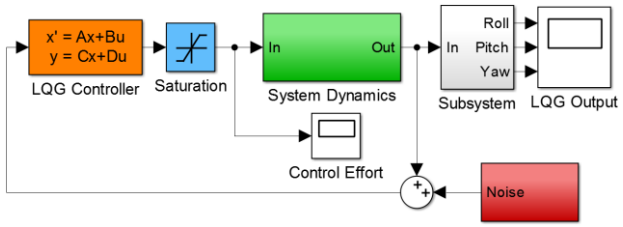


Fig. 9. Schematic diagram of the system in Simulink

The first experiment includes regulation of vehicle attitude angles from non-zero initial condition. Results are shown in Fig. 10. Also, control efforts and their Mean Squared values are compared in Fig. 11 and TABLE II. , respectively. Since most of control effort is produced in the first second, only this portion is shown for better legibility. It is seen that LQG-I controller can stabilize system attitude angles sooner that other techniques while producing smaller control effort.

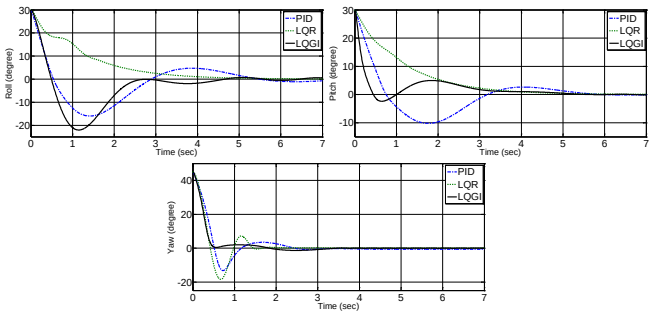


Fig. 10. System response for attitude regulation

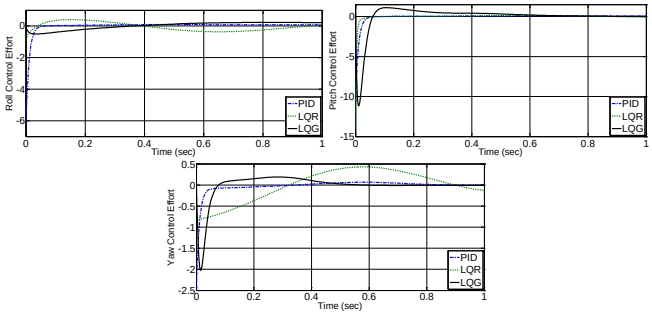


Fig. 11. Control Efforts

TABLE II. MSE OF CONTROL EFFORTS FOR ATTITUDE REGULATION

Algorithm	Roll	Pitch	Yaw
PID	4.543×10^{-1}	1.252	6.884×10^{-2}
LQR	2.109×10^{-2}	1.627	3.007×10^{-2}
LQG	9.771×10^{-3}	0.877	2.696×10^{-2}

Control performance is also tested in the presence of measurement and process noises. Measurement white noise with a variance of 5% of initial values of the state is applied to the system and results are shown in Fig. 12. It can be observed that LQG-I technique is capable to deal with measurement noise better than PID and LQR algorithms.

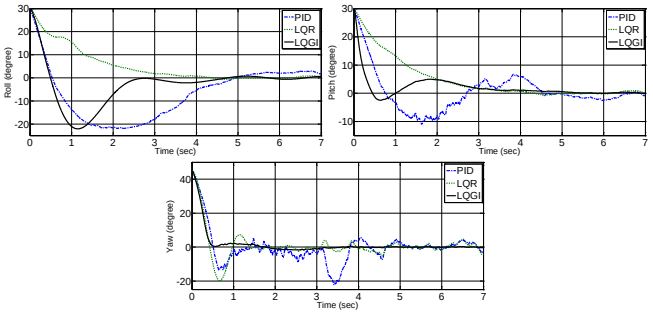


Fig. 12. System response with measurement noise

Process noise variance is chosen to be 20% of initial values of states. Fig. 13 illustrates the result of the simulation in which PID have made unstable responses while LQR and LQG-I techniques have satisfactorily diminished external disturbances.

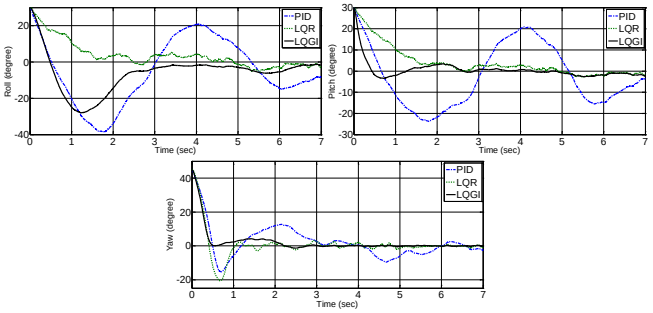


Fig. 13. System response with process noise

VII. CONCLUSION

Dynamical modeling of V8 octorotor flying robot was presented using Euler-Lagrange method. Since the model is a complicated system, it was linearized using a numerical method called small perturbations. Open-loop and closed-loop comparison between linear and nonlinear models showed convincing compatibility. Measurement noise covariance for V8 octorotor was estimated from experimental data. Using optimization, the best weighting matrices for LQR part of the controller were obtained.

LQG controller was designed to control robot's attitude with a complementary integral action to eliminate steady-state error. It was shown that the proposed LQG-I scheme could provide better results even though using less control effort than other algorithms. This means that proposed method can perform stabilization task in an energy efficient way which can be of utmost importance in multirotor systems.

Future work includes precise estimation of process and measurement noise through in-depth statistical analysis, methods to recover stability margin which may be lost using LQG, and implementation of controller on real platform.

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Continuous Estimation of Ankle Joint Angular Position Based on the Myoelectric Signals

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***Abstract*—this article proposes a strategy for classification of lower limb Surface Electromyogram (sEMG) data and estimating the corresponding ankle joints kinematics in sagittal plane. The objective is to improve the myoelectric control of leg-prosthesis in the future. The sEMG signals of three main muscles involved in the ankle motion have been recorded. Classification of EMG data and corresponding motion has been done by Support Vector Machine (SVM) algorithm. Time domain features extracted reduce dimensionality of data and Time-Delayed Artificial Neural Network (TDANN) approximates angles and velocities of the joint opening and closing. It is necessary to filter and de-noise EMG data before feeding to neural network. In addition to initial filtering, a new method based on classified data, is utilized to transform raw signals to clean/noiseless data. After filtering the signals, features were re-extracted and considered as neural network's input. The selected classifier has an accuracy of 95.4%. The neural networks estimate angles and velocities by acceptable precision. This shows that the estimation of angular displacement of ankle with high accuracy is possible which can further improve the proportional control of multi-function prostheses.**

Keywords— ankle joint; sEMG signlas; data segmentation; time domain features ; pattern classifcation; neural network

I. INTRODUCTION

While many developments have been made in lower limb prosthesis, majority of commercial lower limb prostheses are passive types [1]. Precise prediction of user's intended motion is main difficulty in controlling active lower limb prosthesis systems [2]. Since EMG signals are related to user's intention, they are capable of being use in prosthesis control [3]. EMG signal is electrical potential generated by muscle cells, when the muscle contracts. In fact, the sEMG signal is summation of motor unit action potentials (MUAPs) within the pick-up range of the surface electrodes [2]. The sEMG amplitude and frequency content change with contraction-force level [3, 4]. There are two kind of EMG; surface EMG and intramuscular EMG [2]. Surface EMG estimates level of muscle contraction by recording muscle activity from the surface above the muscle on the skin. In order to benefit from EMG data, after data acquisition, data processing and classification techniques is necessary to recognize user's intent. Englehart et al [5] designed a pattern recognition algorithm for myoelectric control of powered upper limbs by using a linear discriminant analysis (LDA) classifier, before feeding data to classifier, they used principal component analysis (PCA) on a wavelet-based feature set to reduce dimensionality.

Chu et al. [6] presented an algorithm for control of a multifunctional myoelectric hand, using the wavelet packet transform for feature extraction, they used a multilayer neural network classifier, and combined a linear-nonlinear feature projection algorithm (PCA) to a nonlinear ones (self-organizing map). Hargrove et al. [7] combined time-domain features and AR coefficients and by using a LDA classifier, evaluate the effect of electrode displacements on pattern classification accuracy.

Despite the significant research in pattern recognition of upper limb motion, limited papers documented pattern recognition of lower limb motion. Huang et al. [8] determined and classified steady state walking modes of transfemoral amputees with 90% accuracy, utilizing efficient machine learning algorithms with new strategy. To recognize transition modes and non-steady state, Huang et al presented a continuous algorithm based on fusion of EMG data and load cell measurements [9]. Their method had high computational cost and isn't usable in real-time applications.

There are a few researches on continuous prediction of joint kinematics compared to pattern recognition based, myoelectric surveys. Alberto L. Delis et al estimated intended knee angle by exclusive sEMG data and also fusion of sEMG data and IMU sensor data [10]. They reduced dimensionality of extracted time-domain features by SOM algorithm and estimated knee angle by importing reduced features to a Levenberg–Marquardt (LM) neural network.

The goal of this paper is to develop a computationally efficient myoelectric kinematics estimator that is capable of using in the real world for transtibial amputee. To this aim, the tools of data acquisition, feature extraction, pattern classification and joint's kinematics estimation have been utilized. Data dimensionality is reduced by combined time-domain features (mean absolute value, root mean square and-

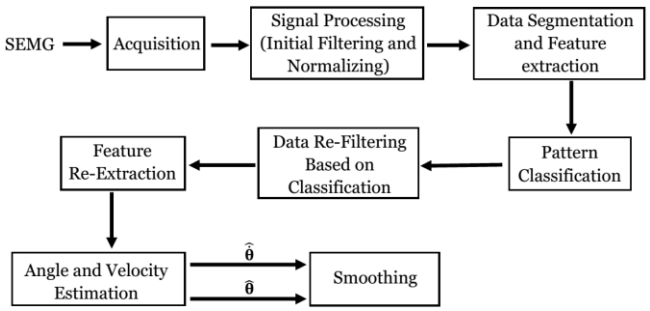


Fig. 1. Schematic diagram for myoelectric interface

Wavelength) with number of zero crossings, number of slope sign changes and auto-regressive coefficients. Then a trained Support Vector Machine can distinguish plantar-flexion and dorsiflexion and resting mode of ankle joint. Based on the classification results, sEMG signals are filtered once again. Next, the time-domain feature are re-extracted and in the last step two time-delayed artificial neural networks estimate the angles and velocities. (Fig. 1) illustrate the mentioned steps, schematically.

II. METHODOLOGY

A. Measurment System

The purpose of the acquisition system and signal processing is to provide a high quality data. We need two kinds of data; myoelectric signals and mechanical signals (recorded from gyro sensors). The most common methods used in sEMG recording are bipolar, monopolar, and Laplacian configurations [11]. We used bipolar derivation in which sEMG signal is the voltage difference between a pair of surface electrodes [11]. The EMG data recording device (eWave 16b, Science beam) have nine channels, eight of them attaches to muscles and one to a bone (as a reference point) by surface electrode. So it is only possible to record up to four muscles data in a function simultaneously. Besides EMG device, in order to train and validate of TDANN, two gyro sensors (TSS-WL-s, Yost Engineering Inc.) have been used to record angles of the shank and the foot. Ankle position is obtained by subtracting two motion trackers data.

B. sEMG Electrodes and Mechanical Sensors Placement

The signal to noise ratio can improved by mounting electrodes near sEMG signal source, as much as possible [11]. Tibialis Anterior, Gastrocnemius Medialis and Gastrocnemius Latealis have a significant role in the ankle motion. Tibialis Anterior results in dorsiflexion and the other two muscles force ankle to plantar-flexion. Data have been recorded from these muscles by bipolar sEMG electrode placed parallel to muscles fibers. Proper location of electrodes was determined based on the method in [12]. False locations decrease validation of data. Before planting electrodes, it is necessary to shave and clean the contact locations to reduce the noise as much as possible. Two electrodes were mounted on each muscle. Besides surface electrodes, two gyro sensors are attached to the foot and the shank to obtain angular displacement of the ankle.



Fig. 2. SEMG electrodes location

C. Experimental course and data collection

At first, it's necessary to determine the maximum voluntary contraction (MVC) of each muscle in order to normalize EMG data. There are list of exercises that lead to maximum innervation of each muscle, so MVC value of each muscle was determined by the algorithm described in [12].

Next, muscle activity data and corresponding ankle angles were recorded, using wireless EMG recording system (eWave 16b, Science beam) and motion tracker (TSS-WL-s, Yost Engineering Inc.) During the trials, the subject performs plantar-flexion action and dorsiflexion action, repeatedly. At the beginning and end of each trial, the subject maintain his leg in the resting mode. SEMG sensor provided the data at 1 KHz and motion tracker sampled angles at the frequency of 100 Hz.

D. Signal Processing

1) Filtering:

SEMG signals are extremely sensitive to artifact motions due to low amplitude (below 10mV). Artifact motions defined as movement of the electrodes and their cables that their corresponding frequency ranges between in 0 and 20Hz [13, 14]. In order to reduce effects of artifact motion, EMG data amplified and a Butterworth high pass filter by cut-of frequency of 50Hz is implemented to remove components of artifact motions. Dominant energy of sEMG signal is under 500 Hz frequency, so others components above 500Hz frequency can be assumed as noise [15]. Hence a Butterworth low pass filter by cut-of frequency of 500Hz with 4^{th} order implemented to eliminate high frequency noise. According to Nyquist rule, sampling rate must be larger than 1000Hz to avoid aliasing. In addition, power line noise at 50Hz is removed by a notch filter.

2) Normalizing

EMG normalization is the process by which the EMG signals are expressed as a percentage of maximum voluntary contraction to provide an expression of relative muscle activation [16]. Normalized EMG signals are appropriate for comparison of activity between variant muscles and between

different subjects. Therefore each channel data is normalized by MVC of its corresponding muscle.

E. Data Segmentation

The first step in pattern recognition based myoelectric data is segmenting the EMG signals. Overlapping windowing is an efficient method in segmentation that has been used in this article. The length of segmented windows and overlapping is assumed 200ms and 60ms respectively, based on [17]. Long segmented window and short overlapping windows result in a long post processing time delay and controller delay, while short segmented window reduce accuracy of prediction and amplitude of overlapping is limited by processing time [17].

F. Feature Extraction

In order to reduce dimensionality and complexity of segmented data, it is required to extract proper features from each segment that results in decreased training time and reduced random characteristics of input of the classifier and neural network. Features describe signal content more efficiently than random, complex and raw signals [17]. Extracted features have been categorized into three groups; time domain, frequency domain and time-frequency domain [17]. Extracting frequency features and time-frequency features requires more time with respect to extracting time features. In other words, time frequency features are more suitable for real time applications. So in this paper time domain features (such as mean absolute value, root mean square and wavelength) are extracted for processing time reduction

In order to have features similar to frequency contents without Fourier Transform, other time domain features, such as number of zero crossing, number of slope sign changes and auto-regressive coefficients (6^{th} order) have been extracted from the segments. While these features do not provide frequency contents exactly, they contain the frequency of the signal changes and require significantly less computational power to calculate when compared to Fourier transforms. The formulation of selected features has been shown in TABLE I.

G. Pattern classification

Machine learning techniques are powerful instruments for clustering and classification problems. These classifiers are trained by a sample set data to finally predict label of new data set. Depending on weather the targets are known or not, machine learning algorithms are categorized into supervised learning and unsupervised learning, respectively. Linear Discriminant Analysis (LDA) and Support Vector Machine (SVM) are supervised learning algorithms that have been used frequently in pattern recognition of EMG signals due to their high functionality and low computational cost [17]. SVM classifiers are the extension of LDA classifier with two differences; SVM optimizes the boundary between defined classes, and also allows for nonlinear separation through use of kernels. Kernels provide a mapping from the original feature space into a new space which appears linear in its projection. The used kernel is considered a linear function. However, SVM inherently can solve classification problems having two kinds of target. So we need multiclass algorithms to distinguish three modes from each other. In this paper using One Against All (OAA) multiclass algorithm, dorsiflexion, plantar-flexion and resting modes of the ankle are recognized.

TABLE I. Calculation method of extracted features

Time domain features	Calculation method
Mean absolute value	$MAV = \sum_{i=1}^{N} \lvert x_i \rvert$
Root mean square	$RMS = \sqrt{\frac{1}{N}\sum_{i=1}^{N} x_i^2}$
Waveform length	$WL = \sum_{i=1}^{N-1} \lvert x_{i+1} - x_i \rvert$
Zero crossing	$ZC = \sum_{i=1}^{N} sgn(-x_i x_{i+1})$ $sgn(x) = \begin{cases} 1, & if\ x > 0 \\ 0, & otherwise \end{cases}$
Slope sign change	$SSC = \sum_{i=2}^{N-1} [f(\lvert (x_i - x_{i-1})(x_i - x_{i+1}) \rvert)]$ $where\ f(x) = \begin{cases} 1, & if\ x \geq throshold \\ 0, & otherwise \end{cases}$
Autoregressive coefficients	$x_n = \sum_{i=1}^{P} a_{i,n} x_{n-i}, P = model\ order$ $a_{i,n} = ith\ AR\ coeffient\ at\ time\ instant\ n$

H. Re-filtering and feaures re-extraction

The sEMG signals have small noise, even after using Butterworth filter. In this step the sEMG data is filtered once again by a new method based on the class of signal. The muscle that results in dorsiflexion do not have any role in plantar-flexion and vice versa. Based on the EMG label recognized in classifier, data of muscle's channel don't take apart in that mode, filtered by strong low pass filter with low cut-off frequency. The new data is more suitable than previous data to importing into the TDANN. Therefore previous features re-extracted from the new signals.

I. Kinamatics estimation

Dynamic neural network can be used for predicting future values of time series variables. Dynamic network are categorized in two types; those that have feed-forward connections, and those that have feedback connections. In this paper, we utilized two feed-forward time delayed artificial neural networks to estimate ankle's kinematics (one for angle estimation and another for velocity estimation) based on extracted features from re-filtered EMG data. The two networks have two layers, with a sigmoid transfer function in hidden layer and a linear transfer function in the output layer. The number of hidden neurons for angle estimation and velocity estimation is set 30 and 50, respectively. Number of input delays is set to 4 for the two networks. Networks performance is affected by these numbers. Increasing the number of neurons and the number of delays requires more computation, and probably results in over-fitting. Bayesian Regularization algorithm is used to train the networks due to

noisy characteristic of EMG data, although this algorithm raises the training time. The MSE stop criterion is considered 10e-5. Recorded angles and its derivative (velocity) have been used as target of the trained networks. The training is repeated until the error autocorrelation and input-error cross-correlation (as verification of network performance) become negligible except for error autocorrelation at zero lag.

III. Results

EMG data and angle of ankle joint are recorded by experimental trials discussed in methodology. During this trial, the subject was moving his ankle joint by performing plantar-flexion, dorsiflexion of the ankle and holding it in the resting mode. Recorded Angular displacement of the ankle and filtered corresponding recorded sEMG signals from Tibialis Anterior, Gastrocnemius Medialis and Gastrocnemius Latealis muscles are illustrated in Fig. 3. As expected, recorded sEMG data have extreme random characteristic. During dorsiflexion, sEMG data related to Tibialis Anterior have large magnitudes compared to other muscle's sEMG data and during dorsiflexion, amplitude of Tibialis Anterior data reduced significantly. We have no sEMG data (except the noise) when the ankle is in the resting mode.

Prior to classification and angle estimation, features extraction is performed to reduce dimensionality. Since the recorded EMG data have large dimension. In addition, training classifier and neural network by extracted features is more efficient and more accurate compared to randomly sEMG data. Feature vectors on classifier accuracy, confusion matrix of classifier is shown in Fig. 4 when RMS is the only extracted feature, in which label 1, label 2 and label3 correspond to plantar flexion, dorsiflexion and resting mode, respectively.

Feature vector selection plays a key role in classification accuracy. Fig. 4 shows the classification accuracy, while RMS was selected as only feature in feature vector. The diagonal elements of this matrix shows the percentage of correct estimations and the other elements are misclassification of EMG pattern between targeted class i and estimated class j. Classifier has low classification accuracy while trained with few numbers of features. Perhaps, utilizing all of the mentioned features for training the classifier, results in high classifications accuracy. So SVM was trained with 6 features (RMS, MVA, WL, ZC, SSC and 6th order AR coefficients) and tested by new data. Fig. 5 illustrates the classification accuracy, while all feature mentioned in methodology, was selected as feature vector. Total misclassification is only 4.7%. That it means the ratio of number of misclassified testing data to total number of testing data.

After determining class of each segment, data of muscles which are not involved in that mode, is filtered by a strong low pass filter. In dorsiflexion mode Tibialis Anterior and plantar-flexion mode Gastrocnemius Medialis and Gastrocnemius Latealis are not involved. Fig .6 shows re-filtered sEMG signal of Tibialis Anterior muscle. Features are re-extracted from re-filtered signals to construct input vectors of the neural network.

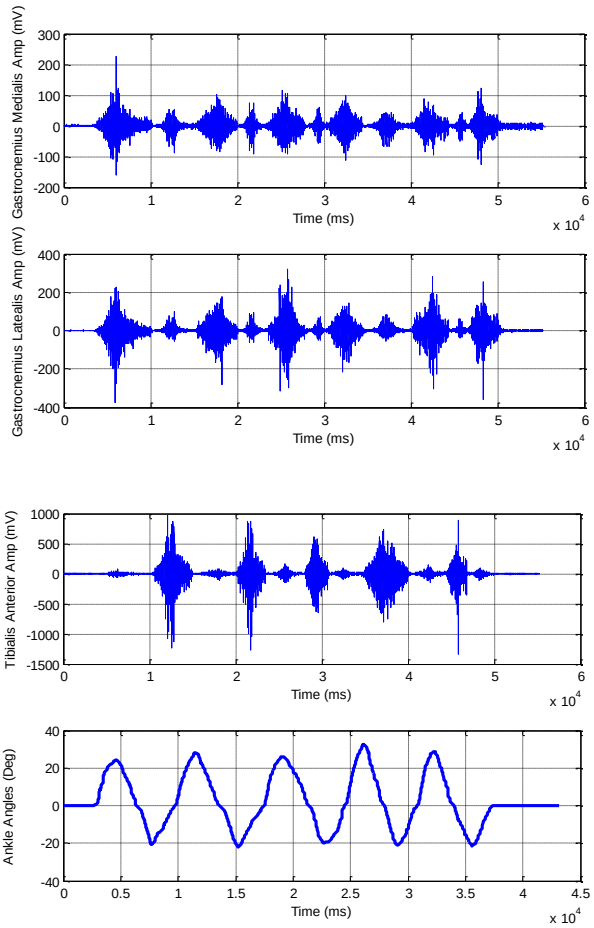


Fig. 3. Recorded sEMG signals and correspondig postion of ankle joint: (a) Gastrocnemius Medialisand Gastrocnemius Latealis ; (b) Tibialis Anterior and angle of the ankle

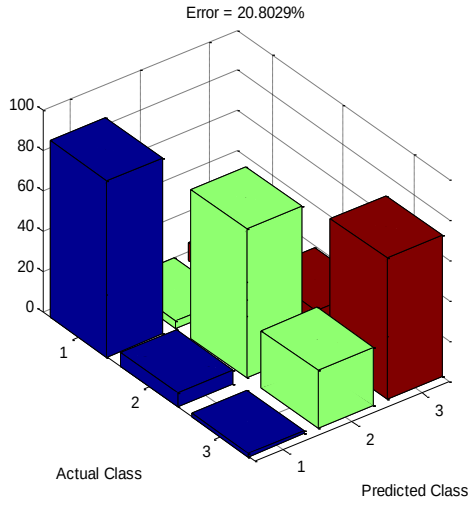


Fig. 4. SVM classifier fusion matrix based only on RMS feature

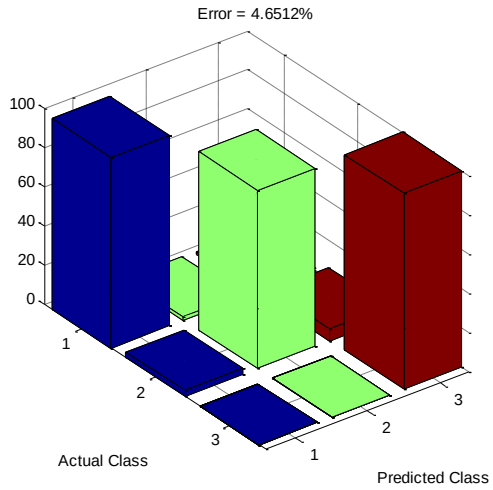


Fig. 5. SVM classifier fusion matrix based on RMS, MVA, WL, ZC, SCC and AR cofficients

During TDANN network training, the outputs from the feature extraction step were used as inputs, and the corresponding angular displacement from the motion tracker were used as the target outputs. The same segment length (200ms) and overlapping (40ms) were used for training and testing. The output of neural network in the testing process, fluctuated around the true angular displacement, which is recorded to evaluate estimation algorithm. Because these fluctuations are not desirable in real world, the noise removed from estimated angle, by a low pass filter. Fig. 7 presents filtered estimated angle that is more usable than unfiltered ones in prosthesis control.

As discussed in methodology, alongside angle estimation, another TDANN can be designed to estimated ankle angular velocity. Derivative of recorded angular displacement was used as targets of the neural network. After training, the network is tested by new sample data. Fig. 8 illustrates smooth estimated velocity after filtering neural network output. Results show that, angles estimation is more accurate than velocity estimation. Targets of trained neural network obtained from angle derivative and, so they are more fluctuating.

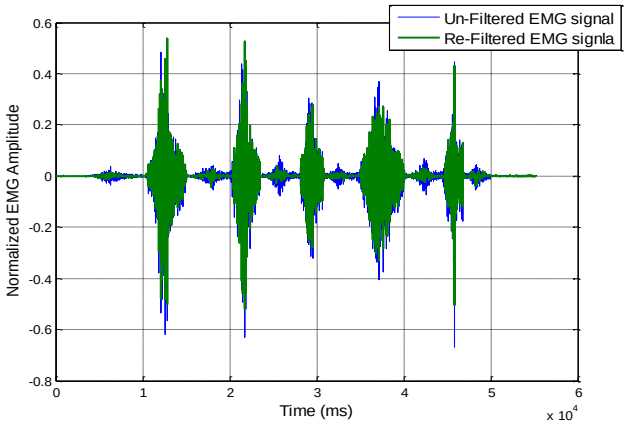


Fig. 6. Refiltered sEMG signal of Tibialis Anterior

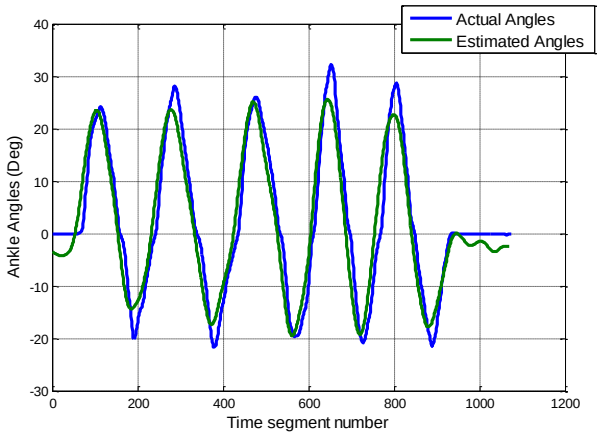


Fig. 7. Estimated angular displacement of the ankle joint by TDANN

Fluctuating nature of the targets in the second case is the reason to less estimation accuracy. The accuracy of ankle kinematics estimation shows that it is possible to recognize intended motion of subjects and improve control prosthesis with myoelectric signals.

IV. Conclusion

This paper presented a myoelectric algorithm based on sEMG data to recognize intended motion of the able-body subject and estimate corresponding ankle kinematics variables. Feature extraction has been done in time domain to reduce computational cost. This is because other domain features such as frequency and time-scale domains, increase processing time significantly. Extracted features consist of RMS, MVA, WL, ZC, SSC and AR coefficients. Feature vector selection plays a key role in classification accuracy. Classification based only on RMS features did not have acceptable and desirable accuracy. However, by combining and increasing number of features, classifier precision increases from 80% to 95%. After classification, two Time-Delayed Artificial Neural Networks are designed to estimate angular displacement and angular velocity of the ankle joint.

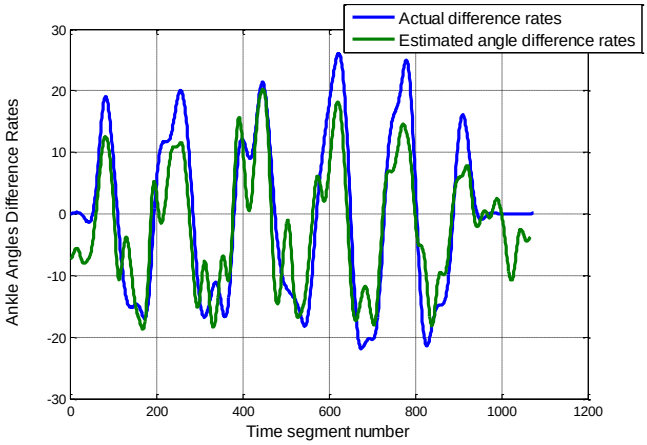


Fig. 8. Estimated angular velocity of the ankle joint by TDANN

Estimated kinematics variables are filtered and smoothed due to fluctuating output of the neural network. We have demonstrated that it is possible to continuously predict ankle position and velocity from sEMG signals. The results of this paper may be useful in the controlling active leg prostheses, in which signals from many different sensors may be combined to predict pattern of the intended motion.

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H_∞ Output Feedback Controller Design for Flexible Needles Guidance

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***Abstract*— Precise and reliable needle insertion into human body, especially soft and inhomogeneous tissues, in order to keep away the needle from sensitive organs is a controversial issue for medical tasks, such as percutaneous interventions, biopsy and some kinds of radiation therapy (brachytherapy). Steerable or flexible bevel-tip needles have an asymmetric tip that causes the needle to bend, and needles can reach the target by deflection over insertion. Getting feedback from imaging devices can improve the objectives. In 2D motion planning it is so important to keep and stabilize the needle in a desired plan. Since the tissue type changes during insertion that causes uncertainty parameter so it is a big problem to keep the needle in the desired plan. In this paper we propose a robust controller with the H-infinity output feedback approach to overcome the uncertainty and disturbances. This controller is applied to a linearized model of steerable needles. Simulation results are presented to show the feasibility of the scheme.**

Keywords—Robust Control; Surgical Robot; H-Infinity; Output Feedback; Steerable Needles.

I. INTRODUCTION

Consider a thin and flexible needle with bevel tip. If the needle curvature change over insertion it can follow different paths due to the flexibility and maneuverability [1]. In most of subcutaneous actions in medical tasks, needle plays a key role, tasks such as biopsy [2], anesthesia and some kinds of radiotherapy methods for example brachytherapy. In medical procedures accuracy is very important because there is sensitive organ inside human body and in special cases these organs are so close to each other and should not be damaged [3,4]. However there are errors in insertion location, needle curvature and tissue deformation that should to be controlled.

One of the important advantages of using flexible needles compared to conventional and rigid needles is high maneuverability inside the tissue. So it can be manipulated inside the body to reach a specific target. Asymmetry of the tip makes the needle to bend and follow a circular arc with constant curvature [5]. These kind of needles with bevel tip have attracted huge attention in recent years. On the other hand with proportional rotation and insertion of the needle from the base the desired trajectory to reach the target could be achieved, due to the asymmetry of the needle tip [6], [7]. In [1] nonholonomic unicycle and bicycle models for this type of flexible needles developed and evaluated. This famous model is the basis of many studies in this area. In [8] a survey about needle insertion has been studied. In [9] an algorithm have been proposed that argues about 3D motion planning with spherical obstacles. Planners in order to keep the needle in a desired plane especially 2D plane have been developed and an algorithm of circular arcs have been purposed to get the target without collision with the obstacles [7]. To have a precise needle insertion in medical tasks, we can manipulate the needle from outside the patient body during the insertion. Some of researchers have presented approaches to steer needles on a desired plane according to existing difficulties in 3D navigation for human operator and difficulties of finding optimal 3D path for automated insertion [6], [10]. All of these approaches do not discuss keeping the needle in the desired plane, so any deviation even so small causes the needle to bend and diverge from the goal as shown in [11]. So, for precise manipulating the flexible bevel tip needle in 2D workspace, keeping the needle on a desired plane is a key factor. In the other words, the first step in 2D motion planning is stabilizing the needle on the desired plane. In [11] a controller based on feedback linearization approach have been purposed to guide the needle to a desired plane. The controller was built on the reduced order system of flexible needle model introduce in [11]. In the purposed algorithm uncertainty is not considered. Since the uncertainty exists in real insertion procedure, so this approach is not practical in real simulations. In [12], [13] it is shown that due to inhomogeneity, needle torsion and tissue deformation, the uncertainty always exists. In the process of needle insertion into tissue in clinical usage, the needle should pass through different tissues. As tissue types changes during the needle insertion, some of model parameters are changing in this process too. Thus, considering the uncertainties in the model for real simulation is very important. In [14], [15] a Kalman filter under consideration white noises for robust state estimation have been studied.

In this paper we used a reduced order system that is derived from the famous nonholonomic needle steering model introduced in [1]. In section II, we will depict the flexible bevel tip needle model and derive reduced order system. In section III, we will describe and derive linearized system from original nonlinear system by linearization in the system equilibrium point. In section IV, a robust control with H infinity approach is designed to overcome the system uncertainty, including the uncertainty of tissue, uncertainty in system's model and measurement noise. In section V simulation results will show the feasibility of the purpose approach.

II. SYSTEM DESCRIPTION AND BEVEL TIP NEEDLE MODEL

Due to the flexibility and maneuverability, flexible bevel tip needles can follow different paths. The needle can be guided by rotation and insertion at the base outside the body of the patient. The needle enters into tissue at a constant curvature. The curvature is dependent on type of tissue and needle. So we can change this curvature by rotating the needle from outside the body of the patient and consequently different trajectories could be achieved.

In [1] a nonholonomic model for guiding flexible bevel tip needles have been purposed. As mentioned before in 2D motion planning it is vital to maintain the flexible needle on a desired plane. So a reduced order system is derived based on this model for steering the needle to the desired plane.

General details of the model for better understanding of the problem and reader convenience is mentioned and reproduced here. A kinematic bicycle model for bevel tip needles is shown in Fig.1.

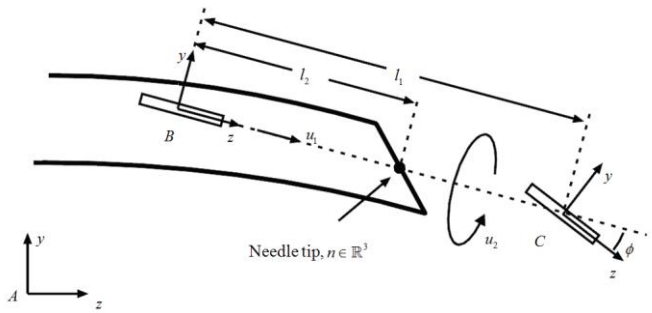


Fig. 1. Configuration of a bevel tip needle during the steering shows the front and back "wheels" at frames B and C of a superimposed bicycle-like nonholonomic model. Frame A is the reference frame. In this particular configuration, the x-axes for all three frames are pointing toward the page [1].

In the Configuration of a bevel tip needle, ϕ is the front wheel angle, ℓ_1 and ℓ_2 are parameters which define the position of the wheels about the needle tip. By using of Lie group theory the following kinematic model have been found for the system in [1].

$$V = \begin{bmatrix} v \\ \omega \end{bmatrix} = u_1 V_1 + u_2 V_2 \tag{1}$$

Where $v, \omega \in \mathbb{R}^3$ and v represents the linear velocity and ω denotes the angular velocity and, u_1 is the insertion and u_2 rotation speed of the needle tip, now consider

$$V_1 = \begin{bmatrix} \hat{e}_3 \\ k e_1 \end{bmatrix} \quad \text{and} \quad V_2 = \begin{bmatrix} 0_{3\times3} \\ \hat{e}_3 \end{bmatrix}$$

The vectors $e_1 = [1 \quad 0 \quad 0]^T$ and $e_3 = [0 \quad 0 \quad 1]^T$ are the standard basis. State vector of the model includes position and orientation vectors is $q = [x, y, z, \alpha, \beta, \gamma]$, where x, y, and z are the position vector and α, β and γ are the orientation vector and α, β, γ are the yaw, pitch and roll of the needle. Position vector is relative to the reference frame. Moreover k is the needle curvature. Body frame velocity define as

$$\begin{bmatrix} v \\ \omega \end{bmatrix} = J\dot{q} \tag{2}$$

Here

$$J = \begin{bmatrix} R^T{}_{AB} & 0_{3\times3} \\ 0_{3\times3} & S \end{bmatrix}$$

$$J = \begin{bmatrix} \cos\beta.\cos\gamma & \sin\gamma & 0 \\ -\cos\beta.\sin\gamma & \cos\gamma & 0 \\ \sin\beta & 0 & 1 \end{bmatrix}$$

Where $R^T{}_{AB}$ is the rotation matrix between frame A and frame B. The steerable needle's model can be derived from (1) and (2), so we have:

$$\dot{q} = J^{-1}V_1 u_1 + J^{-1}V_2 u_2 \tag{3}$$

$$= \begin{bmatrix} \sin\beta & 0 \\ -\cos\beta\sin\alpha & 0 \\ \cos\alpha\cos\beta & 0 \\ k\cos\gamma\sec\beta & 0 \\ k\sin\gamma & 0 \\ -k\cos\gamma\tan\beta & 1 \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \end{bmatrix}$$

Since the needle should stay in a 2D desired plane, we can ignore some of the states that have no effect on the dynamics of the other states. On the other hand, the goal is to keep the needle in y-z plane. So we can disregard the states y, z and α, because these states are just changing inside the y-z plane and can't make the needle to go out from the plane [11]. Therefore we can define $p = [p_1 \quad p_2 \quad p_3]^T = [x \quad \beta \quad \gamma]$ as the state vector of the reduced-order system that shown blow:

$$\dot{p} = \begin{bmatrix} \sin(p_2) \\ k\sin(p_3) \\ -k\cos(p_3)\tan(p_2) \end{bmatrix} u_1 + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} u_2 \tag{4}$$

Consider $\dot{p} = \frac{dp}{dl}$, where the insertion distance l is an independent variable. In order to parameterize the reduced-order system in terms of the insertion distance (l), we divide both sides of the state equation of (4) by u_1. Moreover insertion speed u_1 is $u_1 = \frac{dl}{dt}$ and we can consider the insertion distance as time for convenience, so u_1 is not the input signal anymore. Hence the reduced-order system is defined as following:

$$\dot{p} = \begin{bmatrix} \sin(\mathrm{p}_2) \\ k\sin(\mathrm{p}_3) \\ -k\cos(\mathrm{p}_3)\tan(\mathrm{p}_2) \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} u \tag{5}$$

Where $u = \frac{u_2}{u_1}$.

We assume that all the states is reachable by using medical images and image processing. So the output of the reduced-order system is all of the states.

III. LINEARIZED MODEL

In this paper we are going to design a H_∞ output feedback controller in state space for maintain the flexible bevel tip needle in a desired plane. In the previous section it was noted that the flexible needles have a nonlinear model. So we should linearize the model to design the controller, then we can apply the controller to the nonlinear system.

A. Equlibrium Point

Since the goal is to stabilize and maintain the flexible needle on a desired 2D plane that it's mentioned here as *y-z* plane and on the other side, to keep the needle on the plane, all the output states should go to zero. Thus, we consider $p_0^T = [0 \quad 0 \quad 0]$ as the system equilibrium point.

B. Model Linearization

One of the practical and successful methods for linearization of a nonlinear system is utilization of Taylor expansion at the equilibrium point [16]. Consider the system's model in (5), let's regard it in below form:

$$\dot{p} = f(p,u) \tag{6}$$

Then the system dynamics can be written as:

$$\dot{p} = \left(\frac{\partial f}{\partial p}\right)_{(\text{at Equilibrium Point})} p + \left(\frac{\partial f}{\partial u}\right)_{(\text{at Equilibrium Point})} u + f_{h.o.t}(x,u)$$

where $f_{h.o.t}$ stands for higher-order terms in x and u. Letting A denote the Jacobian matrix of f with respect to x at equilibrium point, and B denote the Jacobian matrix of f with respect to u at the same point.

$$A = \left(\frac{\partial f}{\partial p}\right)_{(\mathrm{p}_0)} \qquad B = \left(\frac{\partial f}{\partial u}\right)_{(\mathrm{p}_0)}$$

$$A = \begin{bmatrix} 0 & \cos(\mathrm{p}_2) & 0 \\ 0 & 0 & k\cos(p_3) \\ 0 & -k\cos(p_3)(1+\tan^2(\mathrm{p}_2)) & k\sin(p_3)\tan(p_2) \end{bmatrix}_{p_0} \tag{7}$$

The system:

$$\begin{aligned} \dot{p} &= Ap + Bu \\ y &= Cp \end{aligned} \tag{8}$$

Where

$$A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & k \\ 0 & -k & 0 \end{bmatrix} \text{ and } B = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

$$C = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

is the linearization or linear approximation of the original nonlinear system at equilibrium point(p_0).

IV. THE PROPOSED CONTROLLER SCHEME

In this section we are going to design a H_∞ output feedback controller. The problem of the H_∞ control can be solved either in the time domain or frequency domain. In this paper we consider state space with LMI approach to overcome the system uncertainty. Let's look at the proposed controller scheme that is shown in Fig.2 [17], [18].

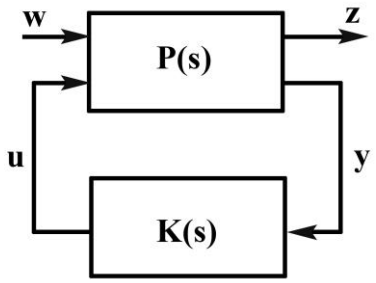


Fig. 2: Standard View of H_∞ output feedback controller design [17].

$P(s)$ shows the system to be controlled, $K(s)$ is the compensator to be determined. The system outputs are represented by output variables available for the control (variables y) and by the interest variables (variables z). The objective of the control is to minimize the effect of the exogenous inputs (variables w) on the interest variables, acting through the manipulable inputs (or control signals), represented by the variables u [17].

The effect of the exogenous inputs on the variables of interest is represented by the transfer matrix from w to z, denoted by $T_{z\omega}(s)$. We refer to the H_∞ norm as a measure of the size of the transfer matrix from w to z. The control problem H_∞ consists in determining the compensator K(s) which stabilizes the closed-loop system of Fig.2 and guarantees $\|T_{z\omega}\|_\infty \le \gamma$ [17].

The state equations of the system P(s) in the H_∞ control scheme are given by:

$$\begin{cases} \dot{x} = Ax + B_1 w + B_2 u \\ z = C_1 x + D_{11} w + D_{12} u \\ y = C_2 x + D_{21} w + D_{22} u \end{cases} \tag{9}$$

where the dimensions of the vectors x, w, u, z and y is selected according to the system. Defining a compact notation given by the realization matrix, we can rewrite the system as:

$$P(s) = \left[\begin{array}{c|cc} A & B_1 & B_2 \\ \hline C_1 & D_{11} & D_{12} \\ C_2 & D_{21} & D_{22} \end{array}\right] \tag{10}$$

A. Uncertainty Description

As it mentioned in section II, k is the only parameter of the system that denotes the curvature that needle follows. On the other word, there is uncertainty in value of k due to tissue uncertainty. So we should consider this parameter as $k = k_0 + \Delta k$, where k_0 denotes the basis value of the curvature, and Δk denotes the perturbation parameter.

B. Design the proposed scheme

Consider the compact notation of system equation and controller as follow: [19], [18], [20].

$$P(s) = \left[\begin{array}{c|cc} A & B_1 & B_2 \\ \hline C_1 & D_{11} & D_{12} \\ C_2 & D_{21} & 0 \end{array}\right] \qquad K(s) = \left[\begin{array}{c|c} A_k & B_k \\ \hline C_k & D_k \end{array}\right]$$

In order to parameterize the controller we define:

$$A_e = \begin{bmatrix} A & 0 \\ 0 & 0 \end{bmatrix}, \quad B_{1e} = \begin{bmatrix} B_1 \\ 0 \end{bmatrix}, \quad B_{2e} = \begin{bmatrix} 0 & B_2 \\ I & 0 \end{bmatrix}$$
$$C_{1e} = \begin{bmatrix} C_1 & 0 \end{bmatrix}, \qquad C_{2e} = \begin{bmatrix} 0 & I \\ C_2 & 0 \end{bmatrix}$$
$$D_{12e} = \begin{bmatrix} 0 & D_{12} \end{bmatrix}, \qquad D_{21e} = \begin{bmatrix} 0 \\ D_{21} \end{bmatrix} \tag{11}$$

Consider desirable parameterization as:

$$\begin{aligned} A_c &= A_e + B_{2e} J C_{2e}\,, \quad & B_c &= B_{1e} + B_{2e} J D_{21e} \\ C_c &= C_{1e} + D_{12e} J C_{2e}\,, \quad & D_c &= D_{11} + D_{12e} J D_{21e} \end{aligned} \tag{12}$$

The closed loop system, $T_{z\omega}(s)$ represented by:

$$T_{zw} = \left[\begin{array}{c|c} A_c & B_c \\ \hline C_c & D_c \end{array}\right] = \left[\begin{array}{ccc} A + B_2 D_k C_2 & B_2 C_K & B_1 + B_2 D_k D_{21} \\ B_k C_2 & A_k & B_k D_{21} \\ \hline C_1 + D_{12} D_k C_2 & D_{12} C_k & D_{11} + D_{12} D_k D_{21} \end{array}\right] \tag{13}$$

Then (14) and (15) are equivalent:

$$A_c \text{ is stable}\,, \quad \|T_{z\omega}\|_\infty \le 1 \tag{14}$$

$$Z > 0\,, \quad \begin{bmatrix} A_c^T Z + Z A_c & ZBc & C_c^T \\ B_c^T Z & -I & D_c^T \\ C_c & D_c & -I \end{bmatrix} < 0 \tag{15}$$

Consider $\|T_{z\omega}\|_\infty \le \gamma$, then:

$$\begin{bmatrix} A_c^T Z + Z A_c & ZBc & C_c^T \\ B_c^T Z & -I & D_c^T \\ C_c & D_c & -\gamma I^2 \end{bmatrix} < 0 \tag{16}$$

Assume the Z matrix as:

$$Z = \begin{bmatrix} X & X_2 \\ X_2^T & X_3 \end{bmatrix}\,, \quad Z^{-1} = \begin{bmatrix} Y & Y_2 \\ Y_2^T & Y_3 \end{bmatrix}$$
$$\textit{and} \tag{17}$$
$$X - Y^{-1} = X_2 X_2^T \;\rightarrow\; Z^{-1} = \begin{bmatrix} X & X_2 \\ X_2^T & I \end{bmatrix}$$

We derive the controller $K(s)$ by solving the Linear Matrix Inequality (16) under the mentioned conditions. In other word $K(s) = Z$.

Consider state space form of the H_∞ output feedback controller as:

$$\begin{aligned} \dot{X}_k &= A_k x + B_k u \\ y_k &= C_k x + D_k u \end{aligned} \tag{18}$$

Since the equation is so complicated to solve, it's necessary to use a software package. After solving the LMI, we can acquire state space form of the controller that shown below:

$$A_k = \begin{bmatrix} -8.189680135792926 & 47.996491556333012 \\ 0.200815687027556 & -2.465499359555917 \end{bmatrix}$$

$$B_k = \begin{bmatrix} 49.504538569442687 \\ -2.349421004304009 \end{bmatrix}$$

$$C_k = \begin{bmatrix} 11.641235317691617 & -68.212148665380312 \end{bmatrix}$$

$$D_k = -70.45635618071217$$

$$\gamma = 1.109 \times 10^{-3}$$

V. Simulation Results

The proposed H_∞ output feedback controller scheme utilized to solve the problem of keeping a Flexible Bevel Tip Needle in a desired plane. Since the goal is to maintain the needle in a 2D plane, we can only consider the states that can cause the needle to go out from the plane. So, we can ignore those states that haven't any effects on other dynamics and consider reduce order system. To apply the H_∞ output feedback controller to the reduce order system, we should derive the linear approximation from original nonlinear system. As it's mentioned in previous section we consider the system parameter k as: $k = k_0 + \Delta k$. This parameter depends on tissue type and flexibility of the needle. To reflect this uncertainty, we will use a sine wave that represents Δk inside the Simulink that changes inside it's interval during system simulation such as when the needle passes through different tissues. Fig.3 shows the sine wave or perturbation parameter.

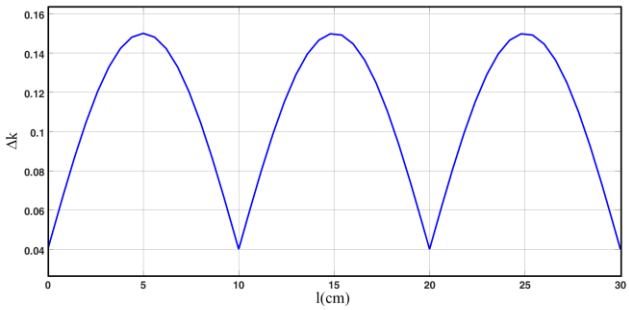


Fig. 3. Δk , Perturbation Parameter

We consider $k_0 = 0.06$ as the nominal value of k, and according to earlier works, perturbation parameter interval selected as: $\Delta k = \begin{bmatrix} 0.04 & 0.15 \end{bmatrix}$. Exogenous input that represents disturbance and measurement noise is considered as: $w^T = \begin{bmatrix} 0.5 & 0.01 \end{bmatrix}$.

The controller must keep the needle in the y-z plane in the acceptable range. In other words, the controller must take the system's initial conditions to zero during needle insertion into tissue, to prevent the needle to go out from the y-z plane. The acceptance range in this paper is about micro scale from desired plane. Note that the system's initial conditions are the position and orientation of the states. Let's take a look at the behavior of the open-loop system in the presence of uncertainty at $p_0 = \begin{bmatrix} -0.2 & -0.2 & -0.2 \end{bmatrix}$. Fig.4 shows the open-loop system.

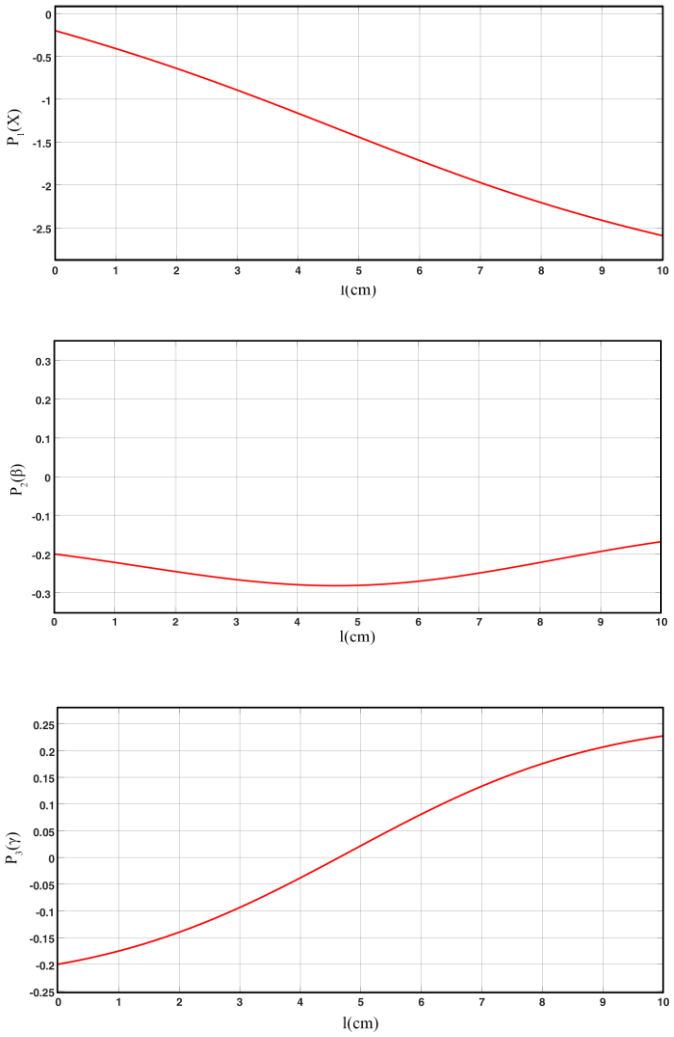
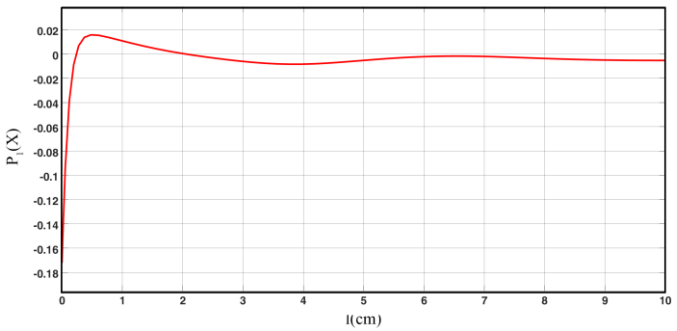


Fig. 4. Open loop system

Our goal is to return the needle into desired plane from milli-scale initial conditions. The results of the closed loop system in the presence of uncertainty and measurement noise is shown in Fig.5 at $p_0 = \begin{bmatrix} -0.17 & -0.17 & -0.22 \end{bmatrix}$.



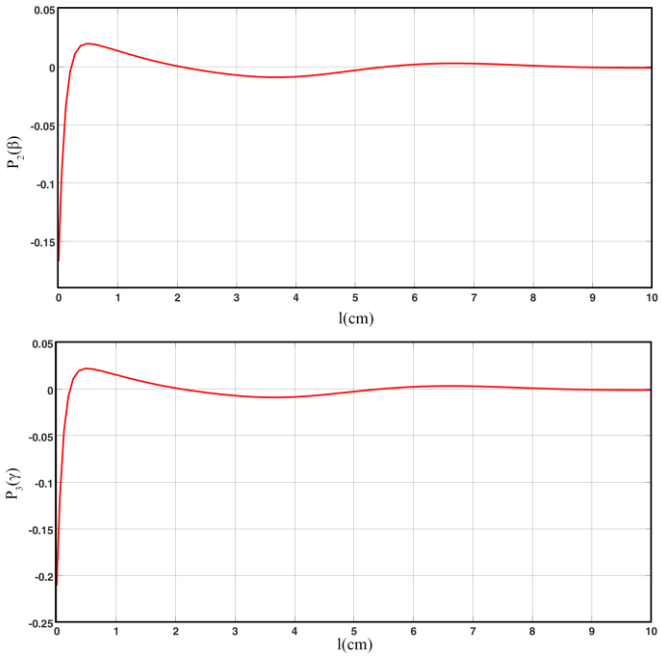


Fig. 5. Closed Loop System

VI. CONCLUSION

In this paper an H_∞ Output Feedback control scheme is proposed for the flexible bevel-tip needle system. A reduced order model is derived from the original nonholonomic model for the flexible bevel tip needled. Since, there is different types of tissues inside human body, we have uncertainty in tissue type, so the curvature of the needle cannot be constant. As a result, the needle curvature is the only parameter of the reduced order model. To reflect this uncertainty we consider a sine wave in the simulation that changes over insertion procedure. In the simulation results, it is shown that our proposed controller is appropriate to keep and maintain the flexible needle in the desired plane.

Our next step is to evaluate the proposed methodology with real data. Currently working on proposed scheme to improve it for bigger initial condition and achieve nonlinear H_∞ Output Feedback controller to compare with this methodology.

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License Plate Automatic Recognition based on Edge Detection

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Abstract—In this paper, we present an Automatic License Plate Recognition System (ALPRS) to identify license plates which is an application of image processing. The main process of ALPRS is divided into four steps:The noise in the image is removed by using FMH filter. A simple algorithm is used for background subtraction.Canny edge detection is used to localizethe license plate location.Finally, letters and digits are extracted through template matching technique. Theproposed algorithms have two advantages: First, the method has strong robustness against noise. Second, it can deal with license plates with different colors. The performance of the algorithm is tested in a real-time video stream. Based on the result, our algorithm shows the missing rate is almost 16% from 70vehicle images.

Keywords—image processing; image subtraction; canny edge detection; license plate recgonition;

I. INTRODUCTION

In the Intelligent Transportation Systems (ITS), the Automatic License Plate Recognition System (ALPRS) is a must. Nowadays, vehicles play an important role in transportation and their application is increasing rapidly. ALPRS usage have shown to have positive effect on controlling vehicle traffic. It is also very important for the development in the transportation infrastructure globally, especially in the developing countries such as Iran, where the ITS have been rising since few years ago. ALPRS is an image processing technology that identifies vehicles by tracking their number plate without direct human intervention. ALPRS is also known by other various terms such as automatic license plate recognition, automatic license plate reader, number plate tracking, car plate recognition, vehicle number plate recognition, automatic vehicle identification, etc. The features of a standard number plate are as follows: background color, character color, character size, aspect ratio of number plate, font style, etc. Aspect ratio is a very important factor in vehicle's number plates and it is deducted by dividing number plates' width by it's height. Recognition of Iranian vehicle's number plates is difficult in comparison to foreign number plates because it follows particular standard shown in Figure 1 in which: represent two-digit state district code, represent one-letter code,represent three-digits code and represent actual registration number that is unique for each city of Iran.

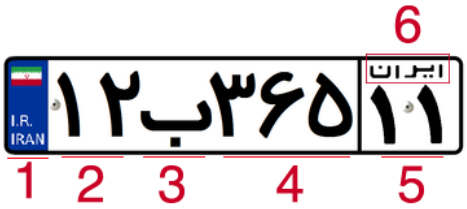


Fig. 1. Iran number plat

There are four types of number plates being used in Iran :

1. Private vehicle's number plate consists of white background with black letters and digits on it.
2. Public transportations number plate consists of yellow background with black letters and digits on it.
3. Governmental vehicles have a red background with white letters and digits constitute their number plates.
4. Police vehicles number plates are composed of a green background and white letters and digits.

The ALPRS has many applications including traffic monitoring, controlling and stolen vehicles detection. For a human being it is very easy to detect the number plate but for a machine it is really a difficult task because of the following reasons :

1. Weather conditions (rain, snow, fog) responsible for incurringimage noise.
2. Noise that can occur during camera capture.
3. Lighting conditions that will change image contrasts.
4. Wrong plate or camera position that results into distortion.
5. Dirty plates may difficulties in image detection.
6. Low resolution of the vehicle image.

The framework for this research is adapted as shown in Figure 2 which includes 4 phases:

1. Pre-processing

2. Vehicle detection and tracking
3. License plate location
4. Character extraction

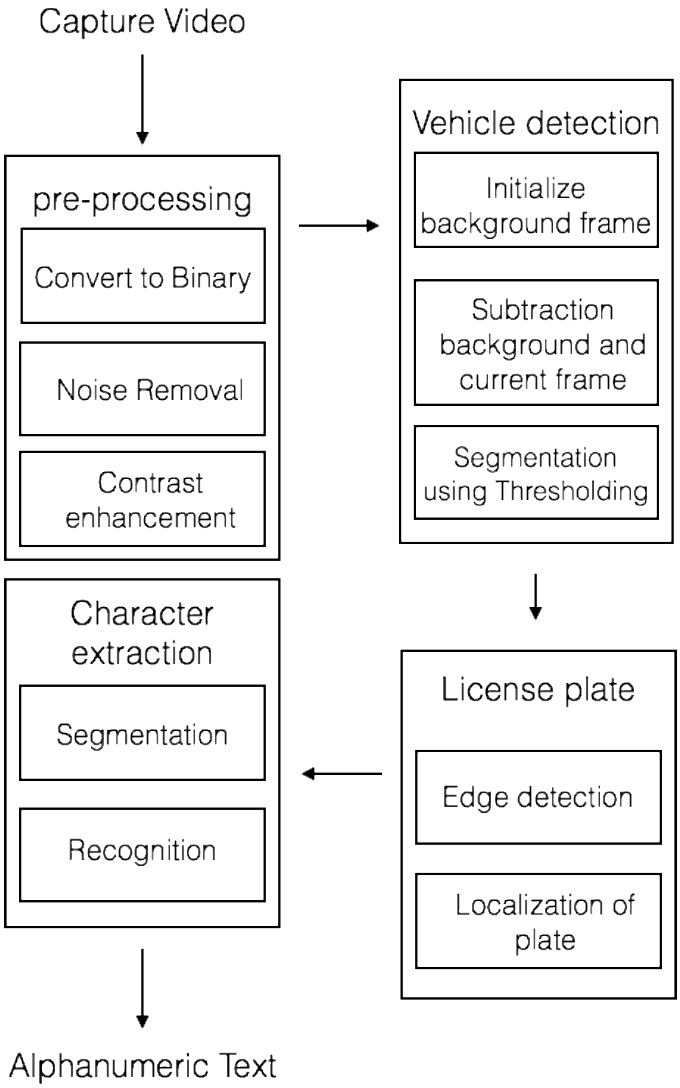


Fig. 2. Flow chart of proposed method

In this paper, we propose a multi-phase solution approach for our ALPRS. The proposed algorithms have two advantages: First, the method has strong robustness against noise. Second, it can deal with license plates with different colors.

The remainder of this work is organized as follows:Section 2 discus is mainly used to improve the contrast of the image, enhance the processing speed, and to reduce the noise in the image. Present vehicle detection and tracking in section 3, In Section 4 the exact location of number plate is detected from whole vehicle image and then extracted that portion of image, introduce an efficient way to filter out the segmentation results, Results of the methods described in this paper are presented in Section 5. Finally, future works and conclusions are given in Section 6.

II. PRE-PROCESSING

In Pre-Processing firstly Red Green Blue (RGB) image is converted into gray scale image and then the noise of an image is removed using median filter, finally contrast enhancement is done using histogram equalization.

A. Convert RGB to gray scale

The captured input image is RGB type. The purpose of converting RGB image into gray scale image is to reduce the number of colors. Red, Green and Blue components are separated from 24bit color value of each pixel and 8bit color value is converted.

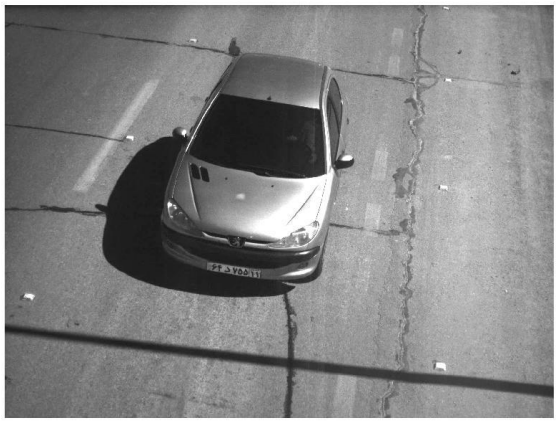


Fig. 3. Gray scale image

B. Noise removal

There are various noise removal techniques but the median filter choice because it does not blur edge of vehicles.It's the weak point is that it might remove narrow lines and corners, for solution of problem FIR median hybrid (FMH) [1] filters were used. The evolution of a FMH filter:

$$f_{FMH}(x,y) = median\left[g(x,y), g_1(x,y), g_2(m,n)\right]$$
$$g_1(x,y) = median\left[g(x,y), g_{ew}(x,y), g_{ns}(m,n)\right]$$
$$g_2(x,y) = median\left[g(x,y), g_{ne}(x,y), g_{se}(m,n)\right]$$

For low resolution images a median filter is used to remove noise, after median filter process is spatial filter used finally the last process is sharpening of an image to increase resolution.

C. Contrast enhancement

Contrast is an important factor in any subjective evaluation of image quality. In visual perception, contrast is determined by

the differences in color and brightness of the object with other objects. Histogram equalization is a method for spreading the histogram of pixel's level more effectively

III. VEHICLE TRACKING

Vehicle tracking is a commonly used technique for vehicle detection. A simple background subtraction [2] followed by background subtraction is used in this project to recognize a moving object, the major reason for using this algorithm is that it is simple and can be implemented of a real-time system. There are many challenges in developing a good background subtraction algorithm :

1. It must be resistant against changes in illumination.
2. It should avoid detecting non-stationary background objects such as moving leaves, rain, snow and shadows cast by moving objects.
3. It should be sensitive to changes made onto static background (background model).

Image subtraction will detect moving regions by subtracting the current image pixel-by-pixel from a reference background image that is created by averaging images over time in an initialization period. First it initializes a background image, then by subtracting current frames (in which moving objects are present) from the background image, the moving object will be distinguished and detected. Ideal results will be achieved when background image and current frame both have the same sizes. Finally two images will be present: one is the current foreground and the other one is background model as shown in Fig 4.

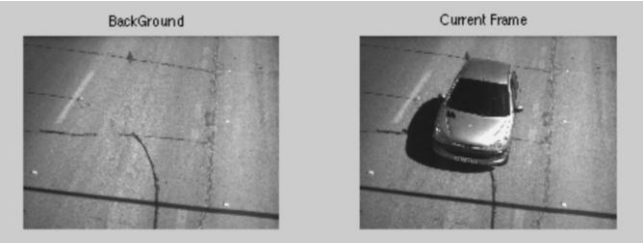


Fig. 4. Background and foreground model

A. *Initialization background frame*

The background frame initializationis very important because it will be referred to as the reference frame. The initial background image will be using median pixel brightness.

B. *Background subtraction*

Background subtraction is a technique in the fields of image processing and computer vision wherein an image's foreground is extracted for further processing, comparing pixel by pixel (x, y) of the both frames where a pixel at location (x, y) in the current image f (x, y) is marked as foreground if

$$| f(x, y) - b(x, y) | > \text{Threshold}$$

Threshold is a predefined parameter. The background image B is updated by Infinite impulse response (IIR) filter. It is marked as the foreground frame :

$$Bt + 1 = aIt + (1+a)Bt$$

C. *Threshoulding*

To subtract the moving object from the current frame we use a certain amount of threshold. To do so, we use the following equation [0, 1].

$$g(x,y) = \begin{cases} 1 & if \quad f(x,y) \geq T \\ 0 & otherwise \end{cases}$$

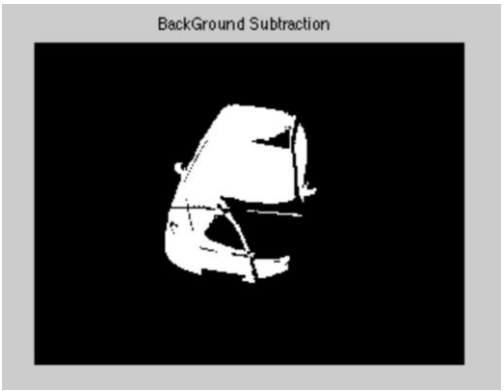


Fig. 5. Image subtraction

IV. LICENSE PLATE LOCATION

The edge detecting an image significantly reduces the amount of data and filters out useless information, while preserving the important structural properties in the image. There are several edge detection methods used, For example, error minimization, maximization object function, fuzzy logic[3], morphological[4], genetic algorithm[5],neural network[6] and Bayesian approach[7]. The canny edge detection is an operator which is a useful algorithm to determine a wide range of edges in a noisy image [8,9].The algorithm runs in 4 separate steps:

1. Use the Gaussian filter G(m,n) to smooth out the image f(m,n). This will reduce noise and texture.

$$g(x,y) = G\sigma(x,y) * f(x,y)$$

G(m,n) is given by :

$$G\sigma(x,y) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left[-\frac{x^2+y^2}{2\sigma^2}\right]$$

2. Compute gradient of g(x,y):

$$M(x,y) = \sqrt{g_x^2(x,y) + g_y^2(x,y)}$$

$$\theta(x,y) = \tan^{-1}\left[\frac{g_y(x,y)}{g_x(x,y)}\right]$$

3. Peak detection (non-maximum suppression along edge normal) removes pixels that are not considered to be part of an edge.

4.Hysteresis threshold along edges, canny does use two thresholds (upper and lower):

If (pixel gradient> upperthreshold)

The pixel is accepted as anedge

Else if (pixel gradient< lowerthreshold)

The pixel is rejected

Elseif(pixel gradient is connected to a pixel that is above the upper threshold)

The pixel is accepted as an edge



Fig. 6. Canny edge detection

V. CHARACTER EXTRACTION

Character segmentation is an important stage in many license plate recognition systems. There are many factors that make the character segmentation task difficult, such as image noise, plate frame, clinch, rotation and illumination variance[10]. Obviously, there are three common segmentation algorithms : vertical projection, connected domain and template matching[11]. The first algorithm is based on binary image and is good for images that are not heavily influenced but its weak point is the recognition between 2 and 3 Persian digits, "۲""۳".Connected domain segmentation is based on the connectivity of character. For letters and numbers, the effects of segmentation are perfect using this way, but for Persian character it always makes mistake (like "ب", "پ" and "ت"). Template matching unlike the algorithms mentioned before does not have any problems detecting Persian letters and digits because it normalizes them. Normalization is to refine the characters into a block containing no extra white spaces (pixels) in all the borders of the characters. Then each character is adjusted to a 38×20 block as shown in Fig 7.

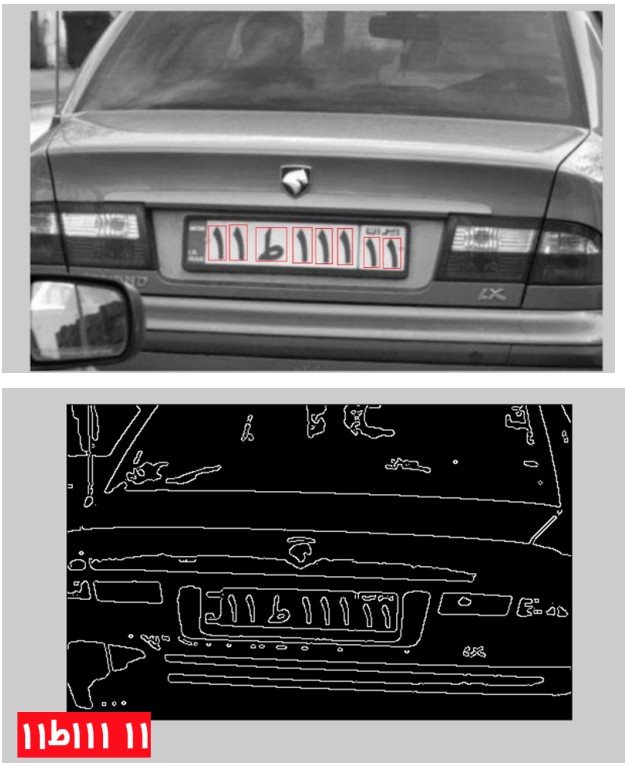


Fig. 7. Character segmentation

Template matching is a method that detects the characters, comparing the extracted characters and the templates built in the database. The similarity between a character and the templates is measured. Template matching is a process of matching the positions of the character with the templates. Template matching is performed after resizing the extracted character into the same size. The different styles of characters and numbers are stored as a templates.

VI. EXPERIMENTS AND RESULTS

We use the background subtraction algorithm for the detection of the moving object in the surveillance area. Alsocanny edge detection is used to localized the license plate location. The experiment is carried out in MATLAB to show the basic process of the image processing. Experiments have been performed to test the proposed system and to measure the accuracy of the system. We used the RGB color images at 640×480 resolution. The Total of 70 vehicle's images were tested. Images are taken in different illumination conditions. Here the reference image is initialized in the code and then the subtraction of the current frame is done. After the subtraction of both frames, the subtracted image is displayed on the screen. The following figure shows the reference image, current image, the subtracted image, extraction of plate region and recognition of characters. The results are presented in Table I.

TABLE I. EXPERIMENTS RESULT

Applied Stage	*Number of correct detection*	*Accuracy(%)*
Extraction of plate region	59	84.28%
Segmentation	54	77.14%
Recognition of characters	50	71.43%

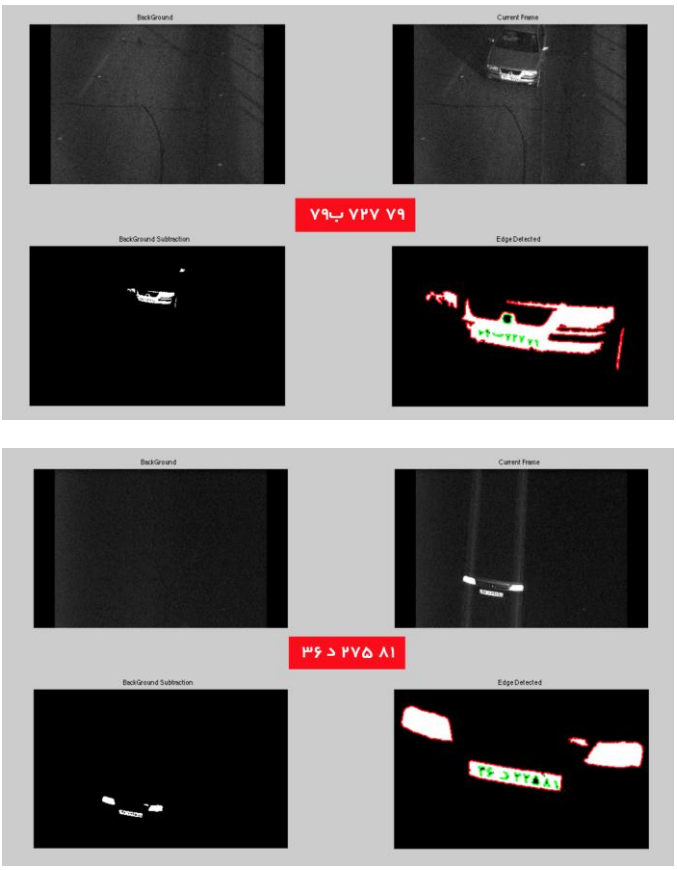


Fig. 8. Experimental result in night and noon

VII . CONCLUSION AND FUTURE WORK

In this paper, we developed an automatic number plate recognition system customized for real-time Iranian vehicles number plate. According to our pilot experiments, our proposed extraction process works well for low resolution, noisy and low contrast images. Thesystemwas tested on a number of vehicles images under different weather and illumination conditions including daytime, night time, sunny, cloudy and rainy days and theaccuracyreportedwas 84.28%. As our future work, we will focus on the extraction of multi-plate multi-vehicle tracking, use of a better template matching algorithm can possibly yield in a better result.

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ارائه یک روش جدید پنهان نگاری متن با حجم بالا با استفاده از تکنیک پیکسل کاندید

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چکیده - علم پنهان سازی اطلاعات، هنر جاسازی داده ها در فایل های صوتی، تصویری، فیلم و یا متن به نحوی است که بتواند نیازهای امنیتی فوق را به شکل آشکار یا پنهان برآورده کند. استگانوگرافی یکی از شاخه های علم پنهان سازی اطلاعات است. رایج ترین تکنیک مورد استفاده در این زمینه، جایگذاری بیت های کم ارزش(LSB) پیکسل های تصویر با بیت های پیام محرمانه می باشد. چندین متد برای بهبود امنیت و ظرفیت روش LSB در گذشته ارائه شده است. دراین مقاله یک روش جدید پنهان نگاری ارائه شده است که دو بیت کم ارزش کانال قرمز، وجود اطلاعات در دو کانال دیگر را نشان می دهد. در الگوریتم پیشنهادی، یک روش جدید با ویژگی عدم تشخیص اطلاعات مخفی شده و حجم بالای اطلاعات قابل ذخیره در تصویر پوششی ارائه شده است. نتایج حاصل از این الگوریتم کارا بودن آن را نسبت به الگوریتم های دیگر نشان می دهد. درالگوریتم پیشنهادی برای تصاویر آزمایشی با ابعاد۵۱۲*۳۸۴ بیشترین ظرفیت ذخیره سازی برابر ۴۵۳۰۸۹ بیت بوده و بیشترین و کمترین مقدار بیشینه نرخ سیگنال به نویز(PSNR) به ترتیب برابر۵۵.۶۱ و ۵۵.۰۳ می باشد.

کلید واژه-استگانوگرافی، امنیت، پنهان سازی اطلاعات، ظرفیت.

۱- مقدمه

پنهان سازی داده ها تکنیکی است که از دیرباز مورد علاقه بسیاری از افراد بوده است. با پیشرفت علوم و دانش بشری روشهای پنهان سازی نیز به نوبه خود با پیشرفت مواجه شده و رسانه های مورد استفاده و تکنیک های پنهان سازی داده ها نیز توسعه یافته اند [۱]. دو هدف اصلی را می توان برای پنهان سازی داده ها در نظر گرفت .هدف اول که از دیرباز مورد توجه بوده و دلیل اصلی پیدایش روشهای مختلف نهان نگاری می باشد پنهان سازی داده های سری و محرمانه درون رسانه ها و حامل های عمومی است. هدف دوم که امروزه رایج شده و به دلیل کثرت استفاده نسبت به هدف اول بیشتر بر روی آن کار شده است، درج امضای صاحب رسانه درون آن می باشد .در حالت اول هدف اصلی گنجاندن حجم قابل قبولی از داده ها، در رسانه به نحوی است که امکان بازیابی آنها توسط افراد دیگر پیچیده و حتی المکان غیر ممکن باشد .وابسته به نوع پیام و نحوه انتقال آن معمولاً حتی امکان کشف وجود داده های نهفته در رسانه نیز غیر قابل قبول بوده و در هر صورت امکان بازیابی داده برای افراد غیر، پذیرفتنی نیست. در این حالت حتی در مواردی خرابی داده ها بر اثر دخل و تصرف در رسانه چندان اهمیتی نداشته و حتی مطلوب است .این در حالی است که در هدف دوم حجم بسیار اندکی از داده می بایست به نحوی در رسانه پنهان شوند که در مقابل انواع تغییرات رسانه از خود مقاومت نشان داده و حداقل خرابی در آنها پیش آید[۲]. عبارت Steganography از کلمه یونانی Steganos(به معنی پوشیده) و Graphy(به معنی نوشتن) به وجود آمده است[۳].

هدف اصلی پنهان نگاری متن در تصویر، ذخیره سازی پیام محرمانه در تصویر پوشش دهنده به گونه ای است که تصویر حاوی پیام از کیفیت بصری بالایی برخوردار بوده و از نظر بیننده شباهت قابل ملاحظه ای به تصویر پوششی اولیه داشته باشد. بدیهی است که چنین تصویری کمتر در معرض حملات واقع خواهد شد[۴]. بطور کلی دو دیدگاه برای پنهان نگاری وجود دارد:

دیدگاه حوزه مکان(Spatial Domain) و دیدگاه حوزه تبدیل(Transform Domain). الگوریتم های پنهان نگاری به صورت عمومی از افزونگی در فضای مکانی یا افزونگی در فضای تبدیل استفاده می کنند. در هر کدام از این فضاها به شیوه های گوناگونی می توان داده را پنهان نمود. در روش حوزه مکان، داده محرمانه و تصویر پوششی در حوزه مکان تغییر داده می شوند. ساده ترین روشها برای پنهان سازی تصویر محرمانه متدهایی هستند که کم ارزش ترین بیت ها در تصویر پوششی تغییر می دهند. در این روش ها بیت های داده درکم ارزش ترین بیت هر پیکسل ذخیره سازی می شوند. رشته بیت داده که داری آنتروپی بالایی است، تغییرات قابل کشفی در برخی ویژگی های آماری تصویر ایجاد می کند. به طوری که جفت مقدار های ایجاد شده در هیستوگرام تصویر حاوی پیغام، سبب ایجاد حملات متعددی به این شیوه از پنهان نگاری شده است. مقاومت روش های ذخیره سازی در حوزه مکان تصویر، در مقابل تغییرات متداول روی تصاویر مانند: نویز،

فشرده سازی و بعلاوه حملات آماری شناخته شده کم است اما می توان با روش های مبتکرانه از استخراج پیام محرمانه جلوگیری کرد[۵].

دیدگاه دوم شامل تبدیل نمودن تصویر پوششی در ضرایب حوزه فرکانس، قبل از ذخیره سازی پیام محرمانه در آن است. تبدیل می تواند، DCT (تبدیل کسینوسی گسسته)، DWT (تبدیل موجک گسسته) و یا IWT (تبدیل موجک صحیح) و غیره باشد. از مزایای این روش ها نسبت به روش های حوزه مکانی این است که از مقاومت بالاتری برخوردار هستند و از مشخصات و ویژگی های سیستم بینایی انسان برای پنهانگاری تصویر استفاده می نمایند، ولی از پیچدگی محاسباتی بالایی برخوردار می باشند[۶].

در روش پنهان نگاری پیشنهادی از پیکسل های تصویر RGB به عنوان رسانه پوششی استفاده شده است. اطلاعات در دو کانال پیکسل رنگی مخفی می شوند. با مقایسه روش پیشنهادی با روش های مرتبط دیده می شود که روش پیشنهادی علاوه بر بالا بردن ظرفیت جاسازی موفق شده کیفیت بصری تصویر را حفظ کند و مقدار PSNR قابل قبولی داشته باشد. در روش پیشنهادی از تکنیک پیکسل کاندید برای بالا بردن امنیت استفاده کرده ایم. در بخش بعدی کارهای مرتبط انجام شده مورد بررسی قرار گرفته می شود. در بخش ۳ ویژگی های مهم در طراحی سیستم پنهان نگاری و توسعه آنها در روش های مختلف بیان شده است. تکنیک پیکسل کاندید در بخش ۴ معرفی شده است. در بخش ۵ روش پیشنهادی با پارامتر های مهم پنهان نگاری مورد بررسی قرار گرفته است. نتایج آزمایشات در بخش ۶ ارائه شده است. نتیجه گیری و ایده های کار آینده در بخش ۷ ارائه شده است.

۲- کارهای مرتبط

در برخی سیستم های پنهان نگاری از ترکیب پنهان نگاری و رمزنگاری برای بالا بردن امنیت استفاده شده است[۷]. در برخی روش ها برای بالا بردن ظرفیت، از فشرده سازی قبل یا بعد از رمزنگاری به منظور کاهش حجم پیام محرمانه استفاده شده است [۸]. دیاگرام کلی سیستم پنهان نگاری در تصویر۱ نشان داده شده است. در روش پیشنهادی فرض بر این است که از رمزنگاری استفاده نمی شود و بدون فشرده سازی پیام محرمانه، حجم جاسازی را افزایش می دهیم.

یک روش پنهان نگاری در تصاویر رنگی با استفاده از تکنیک پیکسل کاندید (Pixel Indicator Technique)، توسط عدنان عبدالعزیز گوتوپ[۹] ارائه شده است. در این روش از تصاویر رنگی بعنوان تصویر پوششی استفاده شده است. اطلاعات محرمانه بصورت پیام متنی می باشد که در بیت های کم ارزش دو کانال رنگی از سه کانال موجود در هر پیکسل جایگزین می شود. عملکرد این الگوریتم به این صورت است که انتخاب کانال کاندید به طول پیام محرمانه بستگی دارد. گوزال[۱۰]مخفی سازی داده ها مبتنی بر زوج بیت در تصاویر رنگی ۲۴ بیتی انجام داده است. عمل جاسازی به تعداد ۰ و ۱ های کانال های هر پیکسل بستگی دارد و مقدار PSNR و ظرفیت ذخیره سازی بدست آمده این الگوریتم در حد قابل قبول می باشد. کو چین چانگ[۱۱] یک رویکرد پنهان نگاری جدید با استفاده از اختلاف مقدار پیکسل سه جهته یا TPVD(Tri-way Pixel-Value Differencing) ارائه کرده است که به منظور افزایش ظرفیت جاسازی روش PVD(Pixel-Value Differencing) که در یک جهت انجام شده است، معرفی شده و در سه جهت مختلف لبه یابی را انجام می دهد. به منظور کاهش اعوجاج کیفیت تصویر پوشانه از طریق تنظیم ظرفیت جاسازی، یک رویکرد بهینه با انتخاب نقطه مرجع و قوانین وفقی ارائه شده است. این رویکرد باعث می شود تصویر پوشانه بدست آمده از نظر کیفیت قابل قبول باشد. این الگوریتم اگرچه از نظر ظرفیت از روش PVD کاراتر می باشد ولی از لحاظ کیفیت و معیار PSNR، این روش ضعیف تر از روش PVD اصلی می باشد. نامیتا تی واری(Namita Tiwari1) و همکارش[۱۲] با استفاده از الگوریتم سه گانه و اصل مشابه LSB، که پیام محرمانه در بیت های کم ارزش جاسازی می شود، از انتخاب تصادفی تعدادی از بیت ها استفاده می کند و کانال های رنگی برای این منظور استفاده می شوند. با انتخاب تصادفی بیت ها انتظار می رود امنیت و ظرفیت جاسازی الگوریتم افزایش یابد. برای اطمینان از ایمن بودن در برابر آنالیز RS، شن وانگ و همکارانش[۱۳] یک روش پنهان نگاری جدید بر مبنای الگوریتم ژنتیک ارائه کرده اند. در این روش هیچ نوآوری در جاسازی داده ها در تصویر میزبان وجود ندارد. اما، ایمن سازی تصویر استگانو بعد از عمل جاسازی داده ها انجام می شود. روش تی سویی و هانگ[۱۴] روی توسعه یک روش پنهان نگاری جدید در حوزه فشرده سازی متمرکز شده است. محبوب ترین تکنیک در این حوزه استفاده از یک الگوریتم بر مبنای مدرج سازی برداری(Vector Quantization)به منظور رمزی کردن تصویر پوششی با داده محرمانه است.

در روش پیشنهادی ظرفیت و کیفیت را نسبت به روش PIT گوتوب[۹] افزایش داده ایم. در ایده پیشنهادی جاسازی در دو کانال از سه کانال رنگی هر پیکسل انجام می شود. انتخاب دو کانال برای جاسازی به مقادیر کانال قرمز بستگی دارد. در روش پیشنهادی فرض بر این است که از هیچ نوع کلیدی برای رمزنگاری پیام محرمانه استفاده نشده است و عمل فشرده سازی روی پیام محرمانه انجام نمی شود.

۳- ویژگی های مهم در سیستم های پنهان نگاری

پارامتر های مهمی در طراحی و توسعه پنهان نگاری موثر هستند. این پارامتر ها شامل امنیت(شفافیت ادراکی)، ظرفیت جاسازی، مقاومت، پیچیدگی و قابلیت شناسایی می باشد[۱۵ و ۱۶ و ۱۷]. ارتباط بین پارامتر های امنیت و ظرفیت از اهمیت بالایی در اکثر تحقیقات انجام شده در این زمینه برخوردار می باشد. در ادامه خصوصیات این پارامتر ها توضیح داده شده است:

ظرفیت: به مقدار داده ای که می تواند در رسانه حامل مخفی شود اشـــاره می کند با این تعریف که " حداکثر اندازه پیام که می تواند در فایل پوشـــشـــی مخفی شـــود طوری که ســـاختار آن تغییر محسوسی نکند"[۱۵].

امنیت یا شـــفافیت ادراکی: فرایند مخفی سازی باید طوری انجام شود که مورد سوء ذن استراق سمع کننده قرار نگیرد. ایمنی "اطلاعات مخفی شـــده در یک روش به این معنی است که سیستم بینایی انسان قادر نباشـــد تشـــخیص دهد که کدام حامل(Carrier) حاوی اطلاعات مخفی شده، است و کدام یک نیست"[۱۸].

اگر ظرفیت مخفی سازی یک رسانه حامل را افزایش دهیم و بیش از اندازه تعیین شـــده در حد آســـتانه مخفی ســـازی کنیم، در شفافیت تصویر اعوجاج زیادی به وجود می آید و سیستم پنهان نگاری قادر به حفظ شفافیت در مقابل استراق سمع کنندگان نخواهد بود[۹]. در این تحقیق دو پارامتر ظرفیت و امنیت ادراکی به منظور مقایسه با کارهای مرتبط در نظر گرفته شـــده است و از این پارامتر ها برای ارزیابی روش پیشنهادی استفاده شده است.

۴- تکنیک پیکسل کاندید

تکنیک پیکسل کاندید برای پنهان نگاری در تصاویر رنگی به کار برده می شـــود. تکنیک استفاده از دو بیت کم ارزش یکی از کانال های رنگی قرمز، سبز یا آبی بعنوان تعیین اینکه در کدام دو کانال باقیمانده داده وجود دارد. بیـــت هـــای کاندید در هر کانال تصـــادفی هســـتند و بستگی به ماهیت تصویر دارد[۹].

جدول ۱: تعیین وجود داده در دو کانال بر مبنای مقادیر کانال قرمز

کانال آبی	کانال سبز	کانال قرمز
داده مخفی وجود دارد	داده مخفی وجود دارد	11
داده مخفی وجود ندارد	داده مخفی وجود دارد	10
داده مخفی وجود دارد	داده مخفی وجود ندارد	01
داده مخفی وجود ندارد	داده مخفی وجود ندارد	00

تفاوت روش PIT پیشنهادی با روش PIT گوتوب[۹] در این است کـــه در روش پیشـــنهادی کانال قرمز بطور ثابت به منظور تعیین وجود داده در دو کانال سبز و آبی در نظر گرفته شده است. در جدول ۱ رابطه بین کانال کاندید و نحوه جاســـازی در ســـایر کانال ها نشان داده شده است.

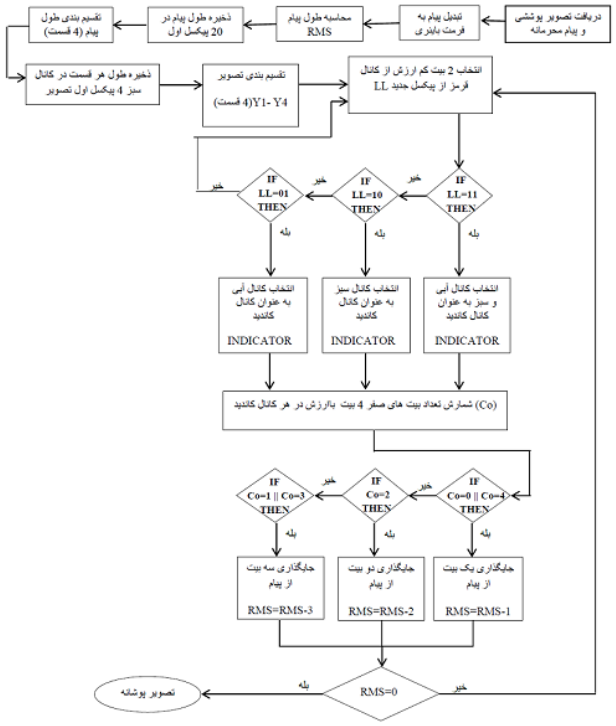
۵- روش پیشنهادی

در روش پیشنهادی با استفاده از تکنیک پیکسل کاندید، برای هرپیکسل باتوجه به ۲ بیت کم ارزش کانال قرمز تعیین می شود که پیکسل مورد نظر قابلیت ذخیره سازی دارد یا خیر. بدین صورت که اگر۲ بیت کم ارزش کانال قرمز دارای مقدار ۱۱ باشند هردو کانال سبز و آبی کاندید ذخیره سازی پیام می شود. درصورتی که ۲ بیت کم ارزش دارای مقدار۰۰ باشد بدین معنا می باشد که هیچکدام ازکانال های سبز و آبی قابلیت ذخیره سازی داده را ندارند و درصورتی که ۲ بیت کم ارزش دارای مقدار ۰۱ باشد فقط کانال آبی و درصورتی که دارای مقدار ۱۰ باشد فقط کانال سبز قابلیت ذخیره سازی داده را دارد. درمرحله بعد درصورتی که کانال مورد نظر جهت ذخیره سازی انتخاب شده باشد، به منظور تعیین تعداد بیت های پیام که باید درون هر کانال جاسازی شود، در کانال رنگی مربوطه مقادیر ۸ بیت مربوط به آن کانال در آن به دو قسمت ۴ بیتی تقسیم می شود. سپس تعداد بیت های با مقدار صفر در ۴ بیت باارزش پیکسل مورد نظر درکانال مربوطه شمارش می شود و باتوجه به تعداد مقادیر بدست آمده ظرفیت ذخیره سازی کانال کاندید در پیکسل مورد نظر مشخص می شود. بدین صورت که اگر در چهار بیت باارزش پیکسل مورد نظر در کانال کاندید، به تعداد صفر یا ۴ عدد بیت صفر وجود داشته باشد ۱ بیت ازپیام مخفی، درکم ارزش ترین بیت کانال ذخیره می شود. درصورتی که تعداد بیت های صفر در۴ بیت باارزش ۲ عدد باشد،۲ بیت ازپیام در۲ بیت کم ارزش درکانال کاندید ذخیره می شود و چنانچه تعداد بیت های صفر در چهار بیت باارزش کانال مورد نظر ،یک یا ۳ عدد باشد، ۳ بیت ازپیام در۳ بیت کم ارزش کانال کاندید پیکسل ذخیره سازی می شود. به طورخلاصه جدول ۲ بیانگر تعداد بیت های ذخیره شده درهرکانال می باشد.

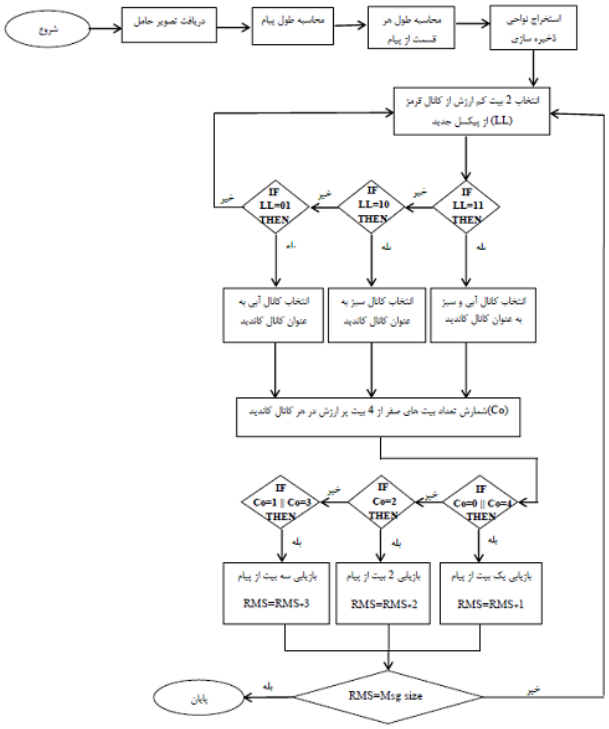
جدول ۲: تعیین ظرفیت جاسازی هر کانال رنگی

تعداد بیت هایی که باید در کانال جاسازی شود	تعداد بیت های صفر در ۴ بیت با ارزش کانال رنگی
یک بیت	صفر یا چهار
دو بیت	دو
سه بیت	یک یا سه

بنابراین در هر کانال کاندید، یک ، دو و یا سه بیت از پیام ذخیره خواهد شد و این مراحل تا زمانی ادامه می یابد که طول کل پیام صفر شود و تمام بیت های پیام ذخیره شوند. به منظور جایگذاری پیام در قسمت های مختلف تصویرطول پیام به ۴ قسمت تقسیم می شود و طول هرقسمت در ۲ بیت کم ارزش کانال سبز پیکسل های ۱ تا ۴ تصویرذخیره می شود. در مرحله بعد تصویر حامل به چهار قسمت مساوی تقسیم می شود و می بایست هر قسمت از پیام در یکی از چهار قسمت تصویر جایگذاری شود.



شکل ۱: فلوچارت فرایند مخفی سازی پیام محرمانه



شکل ۲: فلوچارت فرایند بازیابی پیام محرمانه

با توجه به فلوچارت شکل۲ در الگوریتم بازیابی و استخراج پیام، ابتدا مقدار طول پیام از کانال قرمز ۲۰ پیکسل اول تصویر پوشانه استخراج می شود و طول هر قسمت پیام تقسیم بندی شده درالگوریتم جایگذاری از کانال سبز ۴ پیکسل ابتدایی تصویر پوشانه استخراج می شود و همینطور منطقه ذخیره سازی نیز از کانال آبی ۴ پیکسل ابتدایی تصویر استخراج می شود. سپس با استفاده از دو بیت کم ارزش کانال قرمز هر پیکسل و با توجه به جدول ۱ کانال های کاندید برای عمل بازیابی انتخاب می شوند. سپس تعداد بیت های صفر ۴ بیت باارزش کانال های کاندید محاسبه می شود و با توجه به جدول۲ ظرفیت ذخیره شده در هر کانال کاندید، بیت های پیام محرمانه از تصویر استخراج می شود. این عمل تا زمانی که طول پیام صفر شود انجام می شود.

۶- ارزیابی روش پیشنهادی

برای انجام آزمایش از تصاویر شناخته شده رنگی با فرمت BMP با ابعاد ۵۱۲*۳۸۴ بهره برده شده است.

۶-۱- کیفیت:

پس از مخفی سازی پیام محرمانه در تصویر پوششی علاوه بر تغییرات ظاهری، مشخصه های آماری تصویر نیز دچار تغییرات محسوسی می شود. در این صورت، می بایست تغییرات آماری را توسط استخراج ویژگی های آماری سنجید. محققان بمنظور ارزیابی این معیار، در اکثر مقالات علمی از محاسبه نرخ بیشینه سیگنال به نویزPSNR (Peek Signal Noise Ratio)بهره برده اند[۱۹]. متغیر PSNR مقداری است برحسب دسی بل، که میزان تخریب تصویر حامل پیام را نشان می دهد و با معادله ۱ محاسبه می شود:

$$PSNR = 10 \times \log(\frac{(255)^2}{MSE}) \qquad (۱)$$

که در آن MSE معرف میانگین مربع خطا است و به صورت زیر محاسبه می شود:

$$MSE = \frac{1}{m}\sum_{i=1}^{m}(P_i - P'_i)^2 \qquad (۲)$$

که m سایز مشترک تصویر میزبان P و تصویر مشترک حامل P´ است. مقدار PSNR برای تصاویر آزمایشی با حجم بالای پیام محرمانه، محاسبه و مورد بررسی قرار گرفته است. جدول ۳ نتایج حاصل از محاسبات PSNR را نمایش می دهد.

جدول ۳: مقادیر PSNR محاسبه شده تصاویر آزمایشی با ابعاد 384*512

نام تصویر	PSNR
Flower	۵۷/۲۳
Lion	۵۷/۹۱
Tree	۵۸/۷۷
Parrot	۵۷/۴۸
Pencil	۵۸/۹۳
Lena	۵۷/۹۱
Einstein	۵۷/۹۳

همچنین به منظور ارزیابی روش پیشنهادی با سایر روش های مرتبط، رویکرد پیشنهادی را از لحاظ معیار PSNR با دو روش PIT گوتوب[۹] و روش گوزال[۱۰] مورد بررسی و مقایسه قرار داده شده است. جدول ۴ نتایج حاصل از مقایسه روش پیشنهادی با دو روش معرفی شده را نمایش می دهد. در این آزمایش از تصاویر با ابعاد 384*512 استفاده شده است. پیام محرمانه جاسازی شده در تصاویر یک متن با اندازه ۲۰۰۰ کاراکتر که برابر ۱۶۰۰۰ بیت می باشد استفاده شده است.

جدول ۴: نتایج حاصل از مقایسه روش پیشنهادی با دو روش معرفی شده

نام تصویر	PSNR روش پیشنهادی	PSNR روش گوتوب [9]	PSNR روش گوزال [10]
Animal-1	**۵۸/۸۳**	۵۷/۹۱	۵۵/۸
Animal-2	**۵۷/۹۶**	۵۷/۹۴	۵۶/۳۳
Animal-3	۵۷/۲۷	**۵۸/۱۰**	۵۶/۶۸
Animal-4	**۵۷/۹۲**	۵۷/۸۰	۵۲/۵۴
Animal-5	**۵۸/۵۴**	۵۸/۱۱	۵۶/۱۷
Animal-6	۵۷/۶۳	**۵۷/۸۱**	۵۵/۸۱
Animal-7	**۵۸/۱۸**	۵۷/۹۰	۵۷/۰۲
Animal-8	۵۷/۷۳	**۵۷/۷۷**	۵۰/۱۹
Animal-9	**۵۸/۹۶**	۵۷/۹۰	۵۶/۵۰
Animal-10	**۵۸/۵۱**	۵۷/۷۳	۵۶/۹۲

همانطور که در جدول ۴ مشاهده می شود ، مقادیر PSNR اندازه گیری شده در روش پیشنهادی نسبت به دو روش دیگر بالاتر بوده و نتایج نشان می دهند که روش پیشنهادی نسبت به معیار کیفیت از قابلیت اطمینان بالاتری برخوردار می باشد. ماکزیمم مقدار اندازه گیری شده برای روش پیشنهادی ۵۸/۹۶ دسی بل و مینیمم مقدار اندازه گیری شده ۵۷/۱۸ دسی بل است.

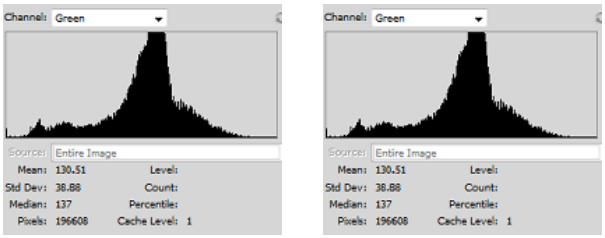
۶-۲- امنیت/شفافیت ادراکی

جهت بررسی امنیت روش پیشنهادی از مقایسه هیستوگرام تصویر قبل و بعد از پنهان نگاری استفاده شده است. مقایسه هیستوگرام تصویر پوششی با هیستوگرام تصویر پنهان نگاری شده معیار خوبی برای بررسی میزان امنیت روش پیشنهادی می باشد. اگر میزان تغییرات در هیستوگرام تصویر قبل و بعد از پنهان نگاری تغییرات محسوسی نداشته باشد ، روش پیشنهادی دارای امنیت مناسبی خواهد بود. به همین منظور هیستوگرام های تصویر پوششی و تصویر پنهان نگاری شده در هر سه کانال RGB برای تمامی تصاویر آزمایشی محاسبه و در شکل ۳ نمایش داده شده است.

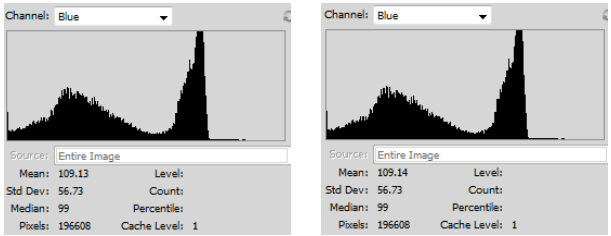


شکل ۳: تصویر پوششی اصلی BMP با ابعاد ۵۱۲*۳۸۴

با میانگین گیری و محاسبه انحراف معیار هیستوگرام هر کانال در هر دو تصویر میتوان میزان اختلاف در هر دو تصویر را محاسبه کرد. جدول ۴-۳ مقادیر اندازه گیری شده میانگین و انحراف معیار در هر کانال از تصاویر قبل و بعد از پنهان نگاری و میزان اختلاف مقادیر دو تصویر را برای هر تصویر آزمایشی به صورت مجزا نمایش می دهد.



شکل ۴: هیستوگرام کانال سبز تصویر پوششی(چپ) و تصویر پوشانه(راست)



شکل ۵: هیستوگرام کانال آبی تصویر پوششی(چپ) و تصویر پوشانه(راست)

همانطور که در شکل۴ و شکل ۵ دیده می شود هیستوگرام های تصویر پوششی و تصویر پوشانه تفاوت محسوسی باهم ندارند. در جدول ۵ با توجه به نتایج میانگین و انحراف معیار محاسبه شده دیده می شود که فقط در میانگین مقادیر کانال آبی به مقدار ۰.۰۱ اختلاف وجود دارد که اختلاف چشمگیری نبوده و می توان از آن چشم پوشی کرد. دلیل وجود این ۰.۰۱ اختلاف در میانگین مقادیر کانال آبی می تواند این باشد

که در این تصویر بیشترین جاسازی در بیت های کم ارزش این کانال رنگی بوده است.

جدول 5 : اندازه گیری میزان شده میانگین و انحراف معیار برای تصویر Lion

مقادیر	میانگین			انحراف معیار		
کانال	تصویر پوششی	تصویر پوشانه	اختلاف	تصویر پوششی	تصویر پوشانه	اختلاف
قرمز	133/56	133/56	0	66/15	66/15	0
سبز	130/51	130/51	0	38/88	38/88	0
آبی	109/13	109/14	0/01	56/73	56/73	0

۶-۳- ظرفیت

ظرفیت پنهان نگاری، حداکثر میزان داده ای است که می تواند در یک پوشانه جاسازی شود. البته نباید فراموش کرد که، حجم داده قابل جاسازی در یک رسانه میزبان به ماهیت رسانه پوششی و میزان داده افزونه و کم اهمیت آن نیز بستگی دارد. بدیهی است که با افزایش ظرفیت جاسازی، تغییرات بوجود آمده در رسانه حامل پیام، افزایش خواهد یافت. در یک سیستم پنهان نگاری، هر قدر بتوان میزان پیام بیشتری را در پوشانه جاسازی کرد بطوریکه امنیت و کیفیت در حد مناسبی باقی بمانند، قابل قبول تر است[۱۹]. جهت بررسی میزان ظرفیت ذخیره سازی روش پیشنهادی، تعداد بیت های قابل ذخیره سازی در هر تصویر آزمایشی اندازه گیری شده است. جدول ۶ نتایج حاصل از اندازه گیری ظرفیت ذخیره سازی را نمایش می دهد.

جدول۶ : نتایج حاصل از اندازه گیری ظرفیت ذخیره سازی

نام تصویر	ظرفیت ذخیره سازی(بیت)
Lena	416397
lion	427487
Parrot	414209
pencil	380207
Peppers	428641
tree	360662
Einstein	453089
Flower	444933

همچنین به منظور ارزیابی ظرفیت ذخیره سازی روش پیشنهادی با سایر روش های مرتبط، رویکرد پیشنهادی را در جدول ۷ با سه روش گوتوب[۹] ، روش گوزال[۱۰] و روش کو چین چانگ[۱۱] مورد بررسی و مقایسه قرار داده ایم.

جدول ۷: ظرفیت ذخیره سازی روش پیشنهادی با سایر روش های مرتبط در تصاویر پوشانه با ابعاد ۱۰۲۴*۱۰۲۴

نام تصویر	ظرفیت ذخیره سازی(بیت)			
	روش پیشنهادی	روش چانگ[۱۱]	روش گوزال[۱۰]	روش گوتوب[۹]
Animal-1	**۲۴۷۷۲۵۱**	۱۲۳۳۶۶۵	۱۵۴۱۲۴۲	۱۵۷۰۰۶۸
Animal-2	**۲۳۳۱۶۷۱**	۱۱۹۷۳۱۵	۱۶۹۲۱۷۸	۱۵۷۲۹۰۰
Animal-3	**۲۲۳۴۸۰۹**	۱۱۸۹۴۱۸	۱۸۶۹۶۱۲	۱۵۷۵۴۰۰
Animal-4	۲۲۸۹۶۳۰	۱۲۰۵۴۹۴	**۲۳۹۷۸۵۴**	۱۵۴۸۵۲۶
Animal-5	**۲۳۳۲۴۱۶**	۱۲۹۲۸۵۵	۱۷۸۲۸۵۰	۱۵۵۹۴۰۸
Animal-6	۲۲۱۱۵۱۵	۱۲۴۰۹۳۰	**۲۷۶۲۳۸۰**	۱۵۸۸۰۴۲
Animal-7	**۲۲۶۶۲۶۷**	۱۲۲۴۰۵۰	۱۴۵۶۳۵۲	۱۵۷۲۳۷۰
Animal-8	**۲۴۹۴۰۵۴**	۱۲۲۴۰۵۵	۲۲۱۱۸۳۸	۱۵۲۸۶۱۶
Animal-9	**۲۴۳۸۶۸۶**	۱۲۶۰۹۱۲	۱۸۱۱۰۲۲	۱۵۲۱۱۸۰
Animal-10	**۲۲۳۲۷۰۳**	۱۲۲۰۶۸۰	۱۴۱۳۳۶۰	۱۵۸۳۴۸۶
میانگین	**۲۳۳۰۹۰۰**	۱۲۲۸۹۳۸	۱۸۹۳۸۶۹	۱۵۶۲۰۰۰

نتایج حاصل از آزمایشات نشان می دهد که تصاویر پوشانه تولیدی توسط رویکرد پیشنهادی، فاقد هرگونه اعوجاج قابل روئیت توسط چشم انسان می باشد. در نتیجه، رویکرد پیشنهادی در مقایسه با رویکردهای مرتبط، کیفیت بصری تصویر پوشانه پیام را بهبود بخشیده است. به منظور بررسی امنیت روش پیشنهادی از مقایسه هیستوگرام تصویر قبل و بعد از پنهان نگاری استفاده شد و با میانگین گیری و محاسبه انحراف معیار هیستوگرام هر کانال در هر دو تصویر قبل و بعد از پنهان نگاری میزان اختلاف در هر دو تصویر محاسبه گردید که میزان درصد اختلاف در هر کانال نسبتا کم و قابل قبول می باشد. همچنین جهت بررسی میزان ظرفیت ذخیره سازی روش پیشنهادی، تعداد بیت های قابل ذخیره سازی در هر تصویر آزمایشی اندازه گیری شد که روش پیشنهادی نسبت به سه روش دیگر دارای ظرفیت ذخیره سازی بالاتری می باشد.

۷- نتیجه گیری و کارهای آتی

در این پژوهش یک روش پنهان نگاری ارائه شد که از تکنیک پیکسل کاندید برای تصاویر رنگی استفاده شده است. در تکنیک پیکسل کاندید از یک کانال برای تعیین وجود داده در دو کانال دیگر استفاده می شود. در این روش کانال قرمز بطور ثابت بعنوان تعیین کانال کاندید برای مخفی سازی در نظر گرفته شده است. به منظور مقایسه روش پیشنهادی با سایر روش های انجام شده در این زمینه از دو روش ارائه شده توسط گوتوب[۹] و گوزال[۱۰] برای مقایسه نتایج آزمایشی استفاده شده است. با توجه به نتایج بدست آمده مشاهده شد که روش پیشنهادی نسبت به دو روش معرفی شده از نظر ظرفیت و کیفیت بهتر بوده است. در روش پیشنهادی پراکندگی مخفی سازی بیت های پیام

محرمانه درون پیکسل های تصویر پوششی، باعث شده امنیت بازیابی پیام محرمانه توسط استراق سمع کنندگان بالا باشد.

به منظور افزایش امنیت؛ برای مثال در کارهای آتی می توانیم انتخاب کانال کاندید را با یک مولد اعداد شبه تصادفی که با توجه به طول پیام محرمانه کنترل می شود، انجام دهیم. با اینکار بدون استفاده از هر نوع کلید و رمزنگاری می توانیم امنیت سیستم پنهان نگاری را افزایش دهیم. با استفاده از کلید و رمزنگاری نیز می توان امنیت بازیابی پیام محرمانه را افزایش دهیم به این صورت که پیام محرمانه را بصورت رمز شده در تصویر پوششی مخفی کنیم تا در صورت شکست پنهان نگاری، پیام محرمانه توسط مهاجمان قابل شناسایی نباشد.

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طراحی و پیاده‌سازی یک سیستم چندعاملی برای کاهش هزینه انرژی در خانهٔ هوشمند با رویکرد Tropos

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چکیده - افزایش تقاضا برای مصرف انرژی و به دنبال آن، افزایش هزینه انرژی، انگیزه‌ای برای ارائه راهکارهای مختلف کاهش هزینه مصرف انرژی ایجاد کرده است. بخشی از اهداف خانه‌های هوشمند نیز کاهش مصرف و هزینهٔ مصرف انرژی است. با استفاده از امکاناتی که سیستم‌های چندعاملی ارائه می‌کنند، می‌تواند پیچیدگی‌های نیازهای متفاوت افراد موجود در منزل را مدیریت کند.

در این مقاله، راه‌حلی مبتنی بر سیستم‌های چندعاملی طراحی و پیاده‌سازی شده است که در آن عامل‌های مختلف سعی می‌کنند ضمن برآورده نمودن انتظارات ساکنین از دمای مورد انتظار خانه، تا حد امکان مصرف انرژی را کمینه کنند. در فاز طراحی از متدلوژی *Tropos* به عنوان روشی که تمام فاز تولید را پوشش میدهد، استفاده شده است. در فاز تولید از چارچوب *JADE* برای پیاده‌سازی تعاملات بین عاملها بهره برده شده‌است. ویژگی بارز این پژوهش نسبت به سایر کارهای مشابه گزارش شده عدم تمرکز تصمیم‌گیری است. عامل‌های مختلف با تقسیم وظایفی که طراح برای آنها در نظر گرفته است، رأساً با توجه به شرایط محیطی و وضعیت سایر عوامل در مورد فعالیت خود تصمیم می‌گیرند. مقایسهٔ تصمیم‌گیری‌های انجام شده از پیاده‌سازی این سیستم با نتایجی که با محاسبات به دست آمده حاکی از دقت بالا و بهینه بودن رفتار کلی سیستم است.

کلید واژه- حداکثر خانه هوشمند، سیستم چندعاملی، شبیه‌سازی، کاهش هزینه مصرف انرژی، JADE، Tropos.

۱- مقدمه

انرژی و بازار تولید و مصرف حامل‌های آن از چالش‌های بزرگ دنیای امروز است. کاربر خانگی از طرفی تمایل دارد برای دستیابی به شرایط مطلوب دمایی، انرژی مصرف کند و از طرفی به منظور کاهش هزینه‌های مترتب، می‌خواهد مصرف را کاهش دهد. ضمناً برای کاربر خانگی مطلوب نیست که مرتباً در مورد انتخاب انرژی مقرون به صرفه تصمیم‌گیری نماید. واگذاری این تصمیم‌گیری به یک سیستم فناوری اطلاعات، بخشی از اهدافی است که در خانه‌های هوشمند دنبال می‌شود. البته اهداف مختلف دیگری نظیر امنیت، سلامت و آسایش نیز در خانه‌های هوشمند مطرح هستند لکن در این پژوهش تمرکز روی کنترل دمای خانه با ارضای تمایلات ساکنان (کاربران) مختلف خانه از نظر دمای محیط و کمینه کردن هزینهٔ مصرف انرژی است.

استفاده از سیستم‌های چندعاملی که در این تحقیق مورد توجه قرار گرفته است، راهکار مناسبی برای غلبه بر چالش مطرح شده می‌باشد؛ زیرا خانه‌های هوشمند از طرفی عموماً دارای حسگرها[۱] و محرک‌هایی[۲] هستند که در ذات سیستم‌های چندعاملی قرار دارد، از طرفی نیز توزیع‌شدگی حسگرها و محرک‌ها در خانه‌های هوشمند با توزیع‌شدگی عامل‌ها در سیستم‌های چندعاملی تناسب دارد.

در ادامهٔ این بخش مروری روی ادبیات موضوع و کارهای انجام شده انجام می‌شود. سپس در بخش ۳ ابعاد مسأله‌ای که در این پژوهش مورد واکاوی قرار گرفته مشخص می‌گردد. برای حل مسأله از متدلوژی Tropos استفاده شده است که مروری بر مراحل آن و مدل‌سازی انجام‌شده، در بخش ۴ انجام می‌گردد. نگاه دقیق‌تری به معماری سیستم چندعاملی که برای حل مسأله طراحی و پیاده‌سازی شده، در بخش ۵ انجام می‌شود و در ادامه، نتایج به‌دست آمده ارائه خواهد شد. در انتها نیز جمع‌بندی و پیشنهاداتی برای ادامهٔ پژوهش به اختصار بیان خواهد گردید.

۲- ادبیات موضوع و کارهای انجام شده

خانهٔ هوشمند خانه‌ای است که در آن با استفاده از خودکارسازی، اهدافی نظیر کاهش مصرف انرژی، افزایش امنیت، سلامت، رفاه، آسایش، کیفیت زندگی و سهولت انجام امور خانه‌داری دنبال می‌شوند. در خانه هوشمند از حسگرهای مختلفی به منظور تشخیص شرایط محیطی استفاده می‌شود و بر اساس اطلاعاتی که از حسگرها دریافت می‌شود، تصمیم‌گیری خودکار توسط سیستم انجام می‌شود. خصوصاً در خانه‌هایی که ساکنین آنها افراد معلول یا ناتوان هستند، خانهٔ هوشمند دارای کاربردهای بسیار متنوع و مفیدی می‌باشد. در خانه هوشمند حسگرهای متفاوتی وجود دارند که عملیات خودکارسازی خانه با استفاده از اطلاعات دریافت شده از آنها انجام می‌گیرند. کنترل‌کننده‌های خانهٔ هوشمند سعی دارند خواسته‌های کاربر را محقق سازند. معمولاً این خواسته‌ها در مقابل هم قرار دارند و باید مصالحه‌ای بین این خواسته‌ها برقرار شود.

در [۱] برخی کاربردهای خانهٔ هوشمند به تفصیل بیان شده‌اند نظیر: قلم هوشمند، میز هوشمند، قفسهٔ هوشمند، تختخواب هوشمند، بالش هوشمند، یخچال هوشمند، مبل هوشمند، پنجرهٔ هوشمند، گلخانهٔ هوشمند و مانند آنها. برخی پروژه‌های مرتبط با حوزهٔ خانهٔ هوشمند در شرکت‌هایی نظیر سیسکو، ماکروسافت، فیلیپس، زیمنس و برخی دانشگاه‌ها در این مقاله مرور شده‌اند.

در جهت استفاده از سیستم‌های چندعاملی در زمینهٔ خانه‌های هوشمند نیز پژوهش‌های مختلفی گزارش شده‌اند. در [۲] از عامل‌های با معماری BDI[۳] استفاده شده که در محیط شبیه‌سازی شدهٔ JADE [3] پیاده‌سازی شده‌اند. در این تحقیق عامل‌های استفاده شده به چهار دستهٔ Sensing، Action، Decision و Database تقسیم شده‌اند. چالشی که در خصوص این مقاله قابل طرح است، وجود یک عامل واحد برای تصمیم‌گیری است. هر یک از دیگر انواع عامل‌ها (sensor، action، database) نقش عمده‌ای در تصمیم‌گیری ندارند.

فعالیت مشابهی در جهت استفاده از سیستم چندعاملی برای خانه هوشمند در [۴] گزارش شده است. در این تحقیق یک عامل خدمتکار با استفاده از مدل‌سازی کاربر، تصمیم‌گیری می‌کند و قابلیت یادگیری نیز دارد. علاوه بر عامل خدمتکار، عامل‌هایی شامل عامل حسگر، عامل اجراکننده، عامل تعامل‌کننده و عامل خانه‌دار نیز تعریف و پیاده‌سازی شده‌اند. عامل حسگر نه تنها وظیفه اندازه‌گیری یک پدیدهٔ فیزیکی نظیر دما، نور یا رطوبت دارد، بلکه استدلالی نیز روی پدیدهٔ فیزیکی اندازه‌گیری شده انجام می‌دهد و اطلاعات را به شکلی که برای سایر عامل‌ها و تصمیم‌گیری‌های آنها مناسب باشد، تبدیل می‌کند. مثلاً اگر دمای هوا از حد مشخصی بیشتر شود، تشخیص می‌دهد که هوا گرم است و "Warm" را به عنوان ویژگی هوای خانه به سایر عامل‌ها اعلام می‌کند. عامل اجراکننده نیز بر اساس تصمیم عامل خدمتکار با توجه به شرایط، نسبت به نحوهٔ انجام تغییر تصمیم می‌گیرد. مثلاً اگر هوا گرم بوده و عامل خدمتکار تصمیم می‌گیرد هوا را خنک(تر) کند و به عامل اجراکننده دستور خنک کردن هوا می‌دهد، عامل اجراکننده باید تصمیم بگیرد که دستگاه تهویه را روشن کند یا پنجره را باز کند (و چقدر باز کند). در این تحقیق نیز عامل خدمتکار یک نقش مرکزی دارد و پیاده‌سازی سیستم پیشنهادی با استفاده از JADE به عنوان فعالیت‌های آتی ذکر شده است.

در [۵] پژوهشی گزارش شده که روی کاهش مصرف انرژی تمرکز داشته و بخشی از این پژوهش که با استفاده از چندعاملی انجام شده است، چهار دسته عامل در چهار لایه شامل عامل‌های بار، کنترل‌کنندهٔ محلی، هماهنگ‌کنندهٔ مرکزی و سوییچ بکار گرفته است.

استفاده از چندعاملی برای بهینه‌سازی مصرف انرژی برای ساختمان‌های تجاری در [۶] مورد توجه قرار گرفته است. در این پژوهش، مدلی مورد مطالعه قرار گرفته که سیستم‌های مختلف ساختمان را تحت کنترل یک سیستم چندعاملی قرار می‌دهد. در این پیشنهاد، دو نوع عامل برای گرمایش/سرمایش و مصرف برق پیشنهاد شده‌اند. ساختار هر عامل شامل هم لایهٔ رفتار واکنشی (مثل واکنش به آتش‌سوزی) و هم لایهٔ رفتار اندیشمندانه است. ضمناً دو لایهٔ دیگر برای ارتباط با سایر عامل‌ها و بررسی تابع بهره‌وری[۴] برای تصمیم‌گیری در مورد تغییر حالت بر طبق یک ماشین حالت طراحی شده است.

در [۷] طراحی و پیاده‌سازی یک سیستم چندعاملی با استفاده از JADE به نام C@sa گزارش شده است که از یک معماری سلسله‌مراتبی سه‌لایه‌ای برای کنترل خانه هوشمند و برقراری ارتباط با کاربر برخوردار است. در یک لایه، عامل عملگر قرار دارد، که کنترل تجهیزات توسط این عامل انجام می‌شود و شامل حسگرها و محرک‌هایی می‌باشد. عامل سرپرست نقش هماهنگی عامل‌های عملگر را به عهده دارد و بر اساس وضعیت موجود محیط و وضعیت مطلوب از نظر کاربر در خصوص رفتار عامل‌های عملگر تصمیم‌گیری می‌کند. در بالاترین لایه نیز عامل تعامل کننده قرار دارد که مهمترین وظیفهٔ آن برقراری ارتباط بین کاربر و سیستم است.

در هر یک از کارهایی که مرور شد، یکی از عامل‌ها نقش مرکزی در کنترل خانهٔ هوشمند دارند. به این ترتیب خودمختاری ضعیف عامل‌ها و عدم رعایت اصول بنیادی سیستم‌های چندعاملی برای چنین سیستم‌هایی را می‌توان به عنوان چالشی برای این دسته از سیستم‌های چندعاملی برای خانهٔ هوشمند مطرح نمود. لکن در پژوهش انجام شده، عاملی به عنوان کنترل‌کنندهٔ مرکزی در نظر گرفته نشده است. عامل‌های مختلف به‌طور خودمختار در مورد عملکرد خود تصمیم‌گیری می‌کنند و با ارتباطات صریح (تبادل پیام) و غیرصریح (از طریق تاثیری که بر روی محیط می‌گذارند) از عملکرد یکدیگر مطلع می‌شوند.

۳- طرح مسأله

مسأله‌ای که در این پژوهش مورد بررسی قرار گرفته، طراحی و پیاده‌سازی یک سیستم چندعاملی برای مصرف بهینهٔ انرژی در خانهٔ هوشمند است. ویژگی‌های مختلفی که مد نظر قرار گرفته‌اند به شرح زیر می‌باشد:

- تعدّد کاربران: منظور از کاربران، ساکنان خانه می‌باشد که به ازای هر یک از آنها، یک عامل ایجاد می‌شود. این عامل به نمایندگی از طرف کاربر واقعی، با سایر عامل‌ها تعامل می‌کند. صرفاً زمانی که کاربر در خانه حضور دارد، تمایلات او در تغییر دمای خانه در نظر گرفته می‌شود. از آنجایی که عامل‌ها نماینده ساکنان منزل هستند، نسبت به هم خیراندیش[5] هستند و تعاملات آنها در راستای منافع یکسان است.
- خواسته‌های هر کاربر: هر کاربر، یک اولویت و سه دما اعلام می‌کند که در کنترل دمای خانه ملاک عمل قرار می‌گیرند. اولویت کاربر به صورت یک طیف عددی در نظر گرفته‌شده‌است، به طوری که برای کاربری که مثلاً به دلیل بیماری یا سن خیلی زیاد/کم نسبت به دما حساس‌تر است این اولویت بیشتر است. دماها شامل موارد زیر هستند:
  - دمای مطلوب: دمایی که بهترین دما برای کاربر است و اگر محدودیتی در هزینهٔ مصرف انرژی وجود نداشته باشد و کاربر دیگری با دمای مطلوب دیگری وجود نداشته باشد، دمای خانه باید در این نقطه قرار گیرد.
  - کمترین دمای قابل تحمل: کمترین دمایی که برای کاربر قابل تحمل است. این دما می‌تواند این گونه تعبیر گردد که دمای کمتر از این دما می‌تواند به کاربر آسیب برساند و نباید تحت هیچ شرایطی (به منظور کاهش هزینه مصرف انرژی) دمای محیط از این دما کمتر شود.
  - بیشترین دمای قابل تحمل: مشابه مورد قبل، بیشترین دمایی است که برای کاربر قابل تحمل است. دمای محیط نباید از این دما بالاتر رود.
- عوامل گرمایشی/سرمایشی: تنوعی از تجهیزات قابل کنترل که روی درجه حرارت خانه تأثیر می‌گذارند را در خانه هوشمند می‌توان در نظر گرفت. تأثیر کار کردن هر یک از عوامل روی درجه حرارت خانه به عوامل مختلفی بستگی دارد و پارامترهای زیادی در مدل کردن دقیق آنها دخیل هستند، که در فیزیک حرارت و مکانیک سیالات بررسی می‌شوند و مدل‌سازی دقیق آنها کار بسیار پیچیده‌ای است. لکن چون تمرکز این مقاله بر روی روش حل مسأله است، یک مدل بسیار ساده در نظر گرفته شده و فرض بر این است که از هر یک از انواع عوامل گرمایشی/سرمایشی زیر یک نمونه در خانه وجود دارد:
  - گرمکن برقی: در هر دقیقه کار کردن، با مصرف برق مشخص دما را به اندازه مشخصی افزایش می‌دهد.
  - گرمکن گازی: در هر دقیقه کار کردن، با مصرف گاز مشخص دما را به اندازه مشخصی افزایش می‌دهد.
  - کولر برقی: در هر دقیقه کار کردن، با مصرف برق مشخص دما را به اندازه مشخصی کاهش می‌دهد.
  - پنجره: در هر دقیقه باز بودن، دمای خانه را به اندازه کسری از اختلاف دمای درون و بیرون خانه به دمای بیرون نزدیک می‌کند.
- انتقال حرارت: در کنار عوامل گرمایشی/سرمایشی که ذکر شدند، انتقال حرارت بین محیط بیرون و درون خانه نیز روی درجه حرارت خانه تأثیرگذار است. تفاوت این عامل با دیگر عوامل تأثیرگذار در کنترل پذیر نبودن این عامل است. انتقال حرارت به مشخصات فیزیکی دیوارها، سقف، ابعاد خانه، و سایر عواملی بستگی دارد که مدل ساده شده‌ای از آن در اینجا در نظر گرفته‌شده‌است. به این صورت که تأثیر تمامی پارامترهای اثرگذار به صورت ضریبی ظاهر می‌شود که به ازای هر دقیقه، اختلاف دمای خانه را متناسب با این ضریب به دمای بیرون خانه نزدیک‌تر می‌کند.
- هزینهٔ مصرف انرژی: اگر نرخ هزینه مصرف انرژی عدد ثابتی باشد، تصمیم‌گیری در مورد اینکه کدام تجهیز

گرمایش/سرمایش روشن یا خاموش شود، نسبتاً آسان است. اما تعرفه‌های مصرف گاز و برق در ایران به صورت پلکانی است و بر اساس میزان مصرف، نرخ مصرف پله‌های بعد بیشتر می‌شود. جدول‌های ۱ و ۲ به ترتیب نرخ هزینه مصرف برق و گاز در ایران را (در زمان نگارش این مقاله) نشان می‌دهد و مسأله برای این نرخ‌ها حل شده‌است.

جدول ۱: نرخ هزینه مصرف برق در ماه

مصرف ماهانه به کیلووات ساعت	هزینه هر کیلووات ساعت به ریال
۰ – ۱۰۰	۳۰۰
۱۰۰ – ۲۰۰	۳۵۰
۲۰۰ – ۳۰۰	۷۵۰
۳۰۰ - ۴۰۰	۱۳۵۰
۴۰۰ – ۵۰۰	۱۵۵۰
۵۰۰ – ۶۰۰	۱۹۵۰
بیش از ۶۰۰	۲۱۵۰

جدول ۲: نرخ هزینه مصرف گاز در ماه

مصرف ماهانه به متر مکعب	هزینه هر متر مکعب به ریال
۰ – ۴۵	۹۴۰
۴۶ - ۹۵	۱۱۴۰
۹۶ – ۱۴۵	۱۴۴۰
۱۴۶ – ۱۹۵	۱۸۴۰
۱۹۶ – ۲۴۵	۲۲۴۰
۲۴۶ – ۲۹۵	۲۴۴۰
۲۹۶ – ۳۴۵	۲۷۴۰
۳۴۶ – ۳۹۵	۳۰۴۰
۳۹۶ – ۴۴۵	۳۲۴۰
۴۴۶ – ۴۹۵	۳۴۴۰
۴۹۶ – ۵۴۵	۳۶۴۰
۵۴۶ به بالا	۳۷۴۰

۴- متدلوژی حل مسأله

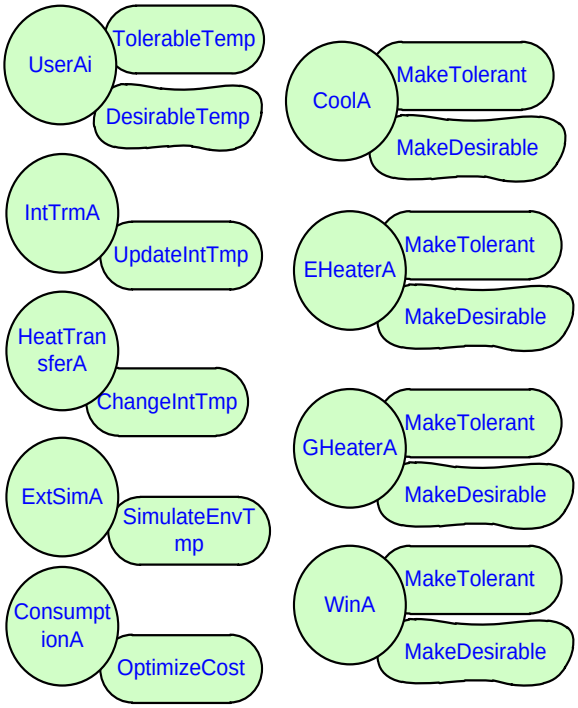
در این پژوهش از متدلوژی Tropos به منظور دستیابی به یک راه حل مبتنی بر چندعاملی برای مسأله مطروحه در بخش قبل استفاده شده است [۸]. متدلوژی Tropos نسبت به سایر گزینه‌ها مراحل بیشتری از چرخهٔ تولید سیستم چندعاملی از تحلیل اولیهٔ نیازمندی‌ها تا پیاده‌سازی را در بر می‌گیرد. این متدلوژی پنج مرحله تا دستیابی به محصول پیاده‌سازی شده، قائل است که شامل (۱) تحلیل اولیه نیازمندی‌ها، (۲) تحلیل ثانویه نیازمندی‌ها، (۳) طراحی معماری، (۴) طراحی جزئیات و (۵) پیاده‌سازی می باشد. در ادامهٔ این بخش مروری اجمالی روی روند طی شدن این مراحل انجام می‌شود.

۱-۱- تحلیل اولیه نیازمندی‌ها

در این مرحله ذی‌نفعان سیستم شناسایی و مدل می‌شوند. بخش مهمی از این مرحله، شناسایی اهداف ذی‌نفعان مختلف سیستم است. عامل‌های درون سیستم که در مراحل بعد شناسایی می‌شوند، نمایندگانی از این ذی‌نفعان را شامل می‌شوند. عامل‌های زیر در این مسأله شناسایی شده‌اند:

- عامل کاربر (userA): به تعداد کاربران واقعی (ساکنان خانه) عامل‌های userA وجود دارد که هر یک از این عامل‌ها به نمایندگی از طرف یک کاربر واقعی، سعی در دستیابی به اهداف (دمای قابل تحمل و مطلوب) دارند. userAi نمایندهٔ کاربر iام می‌باشد.
- عامل‌های CoolA، EHeaterA، GHeaterA و WinA عامل‌های گرمایش/سرمایشی هستند که به ترتیب برای کنترل کولر برقی، کرمگن برقی، گرمکن گازی و پنجره استفاده می‌شوند.
- عامل‌های IntTrmA، HeatTransferA و ExtSimA به منظور ایجاد شرایط شبیه‌سازی، به ترتیب برای محاسبه و ارائهٔ دمای داخل خانه، انتقال حرارت جداره‌های ساختمان و تغییرات دمای محیط بیرون استفاده می‌شوند.
- عامل ConsumptionA انرژی‌های برق و گاز را در اختیار دارد و سایر عامل‌های مصرف کننده در صورتی می‌توانند کار کنند که این عامل، منبع مورد نیاز را در اختیار آنها قرار دهد.

مطابق نمودار بازیگران شکل ۱ هر عامل کاربر یک هدف سخت برای رسیدن به دمای قابل تحمل و یک هدف نرم برای دستیابی به دمای مطلوب دارد. تحقق یا عدم تحقق دستیابی به هدف سخت، به آسانی و بر اساس مقایسهٔ دمای خانه با دماهای کمینه و بیشینهٔ قابل تحمل، قابل محاسبه است. دستیابی به دمای مطلوب، یک هدف نرم در نظر گرفته شده است و البته دماهایی که نزدیک به دمای مطلوب باشند نیز متناسب با نزدیک بودن آنها به دمای مطلوب، تا حدودی مورد قبول تلقی می‌شوند. مشابه عامل‌های کاربر، عامل‌های سرمایشی/گرمایشی نیز همین اهداف را دنبال می‌کنند.



شکل ۱: نمودار بازیگران سیستم

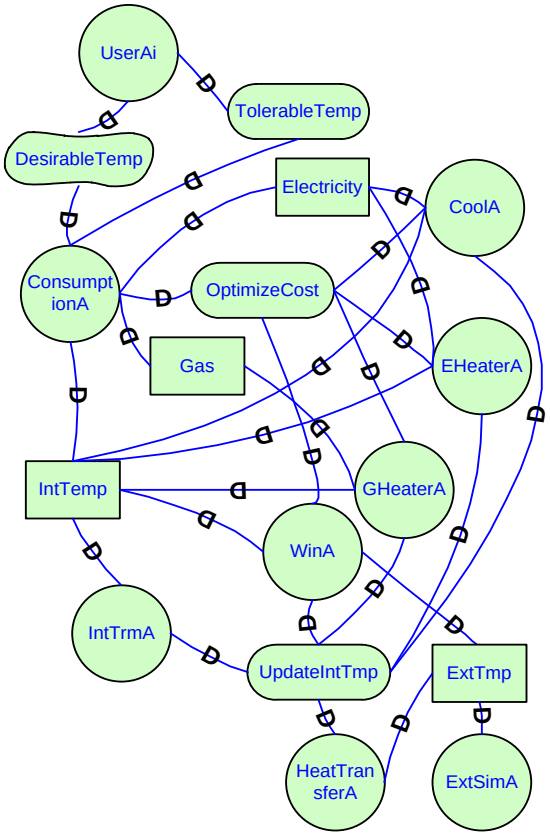
در شکل ۲ نمودار وابستگی نشان می‌دهد که چه وابستگی‌هایی بین عامل‌های مختلف برای دستیابی به منابع مختلف وجود دارد. در این شکل، برق و گاز منابع مصرفی هستند و منابع اطلاعاتی، دمای درون خانه (IntTemp) و شرایط یا دمای بیرون خانه (ExtSimA) می‌باشند.

۱-۲- تحلیل ثانویه نیازمندی‌ها

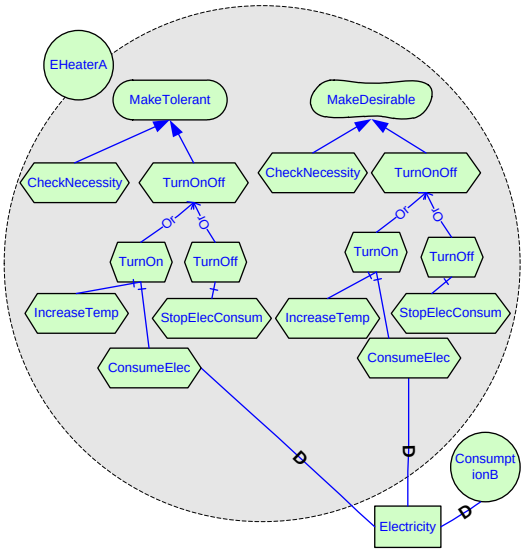
در مرحلهٔ تحلیل ثانویه نیازمندی‌ها جزئیات بیشتری از کارکردها و ویژگی‌های عامل‌ها و چگونگی دستیابی به اهدافشان مشخص می‌شود. در شکل ۳ یکی از نمودارهای این مرحله برای نشان دادن جزئیات بیشتری از عامل گرمکن برقی (EHeaterA) به عنوان نمونه نشان داده شده است. مطابق این شکل، عامل گرمکن برقی برای دستیابی به هر یک از دو هدف سخت و نرم خود، فعالیت‌هایی انجام می‌دهد و منابعی لازم دارد که عامل دیگری باید در اختیار او قرار دهد. شکست فعالیت‌ها به فعالیت‌های خردتر نیز نشان داده شده‌اند.

۱-۳- طراحی معماری

در مرحله طراحی معماری، بازیگران جزئی‌تر سیستم شناسایی می‌شوند و نمودار بازیگر توسعه می‌یابد. همچنین قابلیت‌های بازیگران مشخص می‌شوند. در این مرحله و مراحل بعد، مدل‌سازی با استفاده از زبان مدل‌سازی UML انجام می‌شود.



شکل ۲ : نمودار وابستگی‌های سیستم



شکل ۳: نمودار هدف برای عامل EHeaterA

۱-۴- طراحی جزئیات

در مرحلهٔ طراحی جزئیات، مشخصات درونی هر عامل با جزئیات کافی مدل می‌شود. از نمودارهای مهم این مرحله، نمودار قابلیت است که رفتار درونی عامل را نشان می‌دهد. نمودار قابلیت برای عامل EHeaterA به عنوان نمونه در شکل ۴ نشان داده شده است.

جنبهٔ دیگری از سیستم که در مرحلهٔ طراحی جزئیات باید به دقت مدل شود، تعامل عامل‌های مختلف با یکدیگر است. این تعامل‌ها را می‌توان با استفاده از نمودار ترتیب، نشان داد. شکل ۵ نمونه‌ای از این نوع نمودار است که تعامل بین EHeater و ConsumptionA را نشان می‌دهد.

۵-۱- پیاده‌سازی

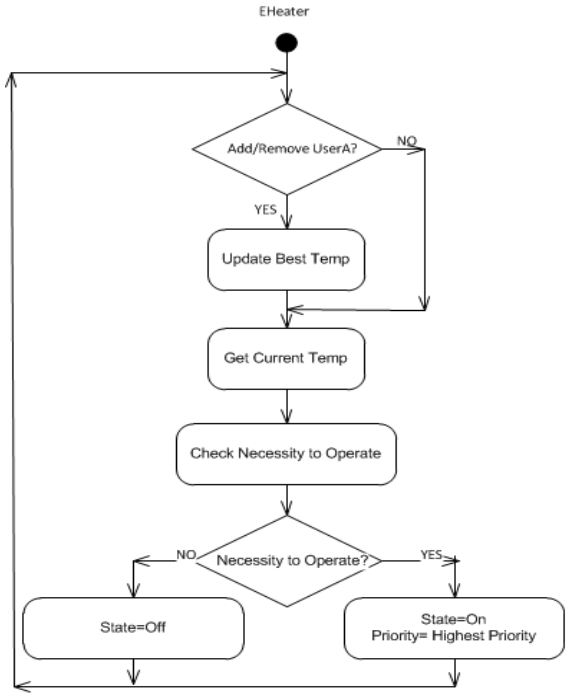
در پیاده‌سازی سیستم از زبان برنامه‌نویسی جاوا و JADE که یک محیط پیاده‌سازی سیستم‌های چندعاملی است، برای پیاده‌سازی عامل‌ها استفاده شده است. برای ارتباط بین عامل‌ها و هماهنگی آنها از FIPA [9] استفاده شده است که JADE به خوبی آن را پشتیبانی می‌نماید.

۵- معماری چندعاملی سیستم

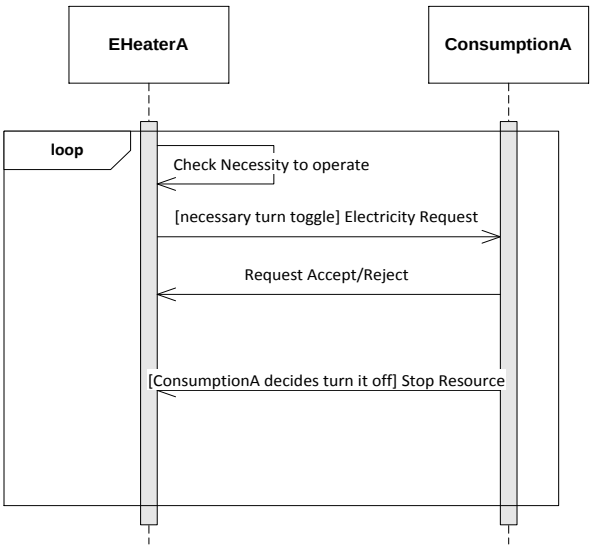
در بخش قبل به عنوان مرحله‌ای از متدلوژی، طراحی معماری مطرح شد. در این بخش، معماری سیستم پیاده‌سازی شده، از نگاه سیستم‌های چندعاملی بررسی می‌شود.

عامل‌ها را در سیستم‌های چندعاملی می‌توان به دو دسته تقسیم کرد: عامل‌های واکنشی[۶] که به تغییرات محیط در زمان مناسب واکنش نشان می‌دهند و عامل‌های اندیشمند[۷] که بر اساس استنتاج و برنامه‌ریزی، تصمیم‌گیری می‌کنند و اقدام به اجرای برنامه می‌نمایند. در سیستم پیشنهادی هر دو نوع رفتار وجود دارد. در شرایطی که دمای محیط، خارج از محدودهٔ دمای قابل تحمل برای حداقل یکی از کاربران باشد، رفتار عامل‌ها از نوع واکنشی است و بدون در نظر گرفتن ملاحظات دیگری حداکثر تلاش خود را صرف می‌کنند که شرایط دمایی به شرایط قابل تحمل برسد. از طرفی نیز رفتار سیستم اندیشمندانه است زیرا در شرایطی که محدودهٔ دما قابل تحمل است، برای رساندن دما به دمای مطلوب کاربران، با توجه به اولویت‌های آنها میزان هزینه برای افزایش تابع بهره‌وری در نظر گرفته می‌شود. به این ترتیب با انجام این تعامل‌هایی، بین گزینه‌های مختلف، انتخاب مناسب انجام می‌شود.

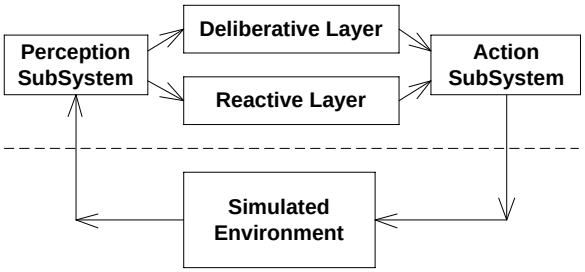
با ترکیب دو رفتار واکنشی و هوشمندانه در عامل‌های سیستم، معماری سیستم، یک معماری لایه‌ای افقی شبیه Subsumption می‌باشد[10]. سیستم را می‌توان به دو زیرسیستم عمده شامل شبیه‌سازی محیط و کنترل تقسیم کرد. هر دو زیرسیستم با رویکرد چندعاملی پیاده‌سازی شده‌اند. شکل ۶ یک نمای کلی از معماری سیستم را نشان می‌دهد.



شکل ۴: نمودار قابلیت برای عامل EHeaterA



شکل ۵: نمودار ترتیب برای عامل EHeater



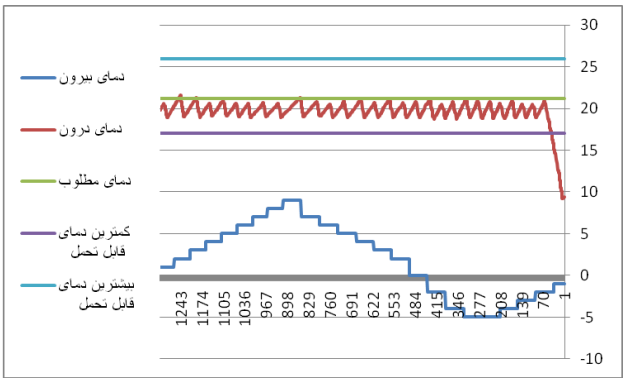
شکل ۶: معماری کلی سیستم

۶- نتایج

سیستم پیاده‌سازی شده با سناریوهای مختلف مورد آزمون قرار گرفته و نتایج آن بررسی شده‌است. در سناریوهای مختلف، هم شرایط دمایی محیط بیرون خانه و هم مشخصات محیط شبیه‌سازی (نظیر میزان انتقال حرارت بین محیط داخل و بیرون خانه) متغیر در نظر گرفته شد.

شکل ۷ یک نمونه از آزمون‌های انجام شده و روند تغییرات دمای درون خانه در یک دوره ۲۴ ساعته این آزمون را نشان می‌دهد. همانطور که در شکل مشخص است، دمای درون خانه به دمای مطلوب رسانده شده و عامل‌های گرمایشی دما را در یک بازهٔ دو درجه‌ای در اطراف این دمای مطلوب نگه می‌دارند.

در این سناریو تغییرات دمای بیرون مشابه تغییرات در طول یک شبانه‌روز در فصل زمستان در نظر گرفته‌شده‌است.



شکل ۶ : تغییرات دمای درون خانه بر حسب زمان(دقیقه)

۷- نتیجه‌گیری و کارهای آتی

یکی از راهکارهای مختلف برای کاهش هزینهٔ مصرف انرژی در خانه‌ها، استفاده از سیستم‌های چندعاملی است. در این پژوهش شرایط محیطی یک خانه شبیه‌سازی شد و سیستم کنترل کنندهٔ چندعاملی، کنترل دما را بر عهده گرفت. سناریوهای مختلف با پارامترهای مختلف برای شرایط محیطی متفاوت و خواسته‌های متفاوت کاربران اجرا شد و رفتار سیستم مطابق با انتظارات کاربران بود.

اگر چه تحقیقات مشابهی قبلاً گزارش شده‌اند، لکن ویژگی بارز این پژوهش، خودمختاری عامل‌ها و کاهش تمرکز در تصمیم‌گیری بود. معماری پیشنهادی برای سیستم کنترل‌کنندهٔ چندعاملی یک معماری لایه‌ای افقی بود. همچنین متدلوژی Tropos مورد استفاده قرار گرفت و مدل استخراج شده با استفاده از JADE و زبان برنامه‌نویسی جاوا پیاده‌سازی شد.

با توجه به نتایج این پژوهش، می‌توان ابعاد مختلف آن را گسترش داد. با تدقیق شبیه‌سازی محیط، شبیه‌سازی محیط به محیط‌های واقعی نزدیک‌تر می‌شود و بستری برای آزمایش‌های مختلف در زمینهٔ اتلاف و کنترل مصرف انرژی خانگی ایجاد می‌گردد. نمونهٔ میدانی با حسگرهای واقعی و بررسی نتایج نیز قدمی به سمت تولید انبوه و مقرون به صرفه خواهد بود.

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پانویس‌ها

[۱] Sensors

[۲] Actuators

[۳] Believe, Desire, Intention

[۴] Utility Function

[۵] Benevolent

[۶] Reactive Agents

[۷] Deliberative Agents

حل مسأله زمان‌بندی دروس دانشگاهی با استفاده از الگوریتم دسته ماهی‌های مصنوعی باقابلیت اولویت‌های انعطاف‌پذیر

محمد صادق پورقربان[۱]، بهروز معصومی[۲]
[۱]دانشگاه آزاد اسلامی، واحد قزوین، دانشکده برق، رایانه و فناوری اطلاعات
[۲]دانشگاه آزاد اسلامی، واحد قزوین، دانشکده برق، رایانه و فناوری اطلاعات

چکیده - مسأله زمان‌بندی دروس به عنوان یکی از مسائل NP-Hard شناخته می شود. هدف این مساله تخصیص یک‌سری منابع مانند اساتید، دروس و دانشجویان به یک‌سری بازه‌های زمانی ثابت و محدود به شرط ارضاء تعداد زیادی محدودیت بوده که در سال‌های اخیر مورد توجه محققین قرار گرفته است. برای حل این مسأله استفاده از روش‌های مختلف فراابتکاری به جای الگوریتم‌های کلاسیک کاربرد زیادی پیدا کرده است. یکی از محدودیت های این مسأله قابلیت در نظر گرفتن اولویت های مختلف برای عوامل مختلفی نظیر اساتید است. در این مقاله روشی برای حل مسأله زمان‌بندی دروس با قابلیت اولویت‌های انعطاف‌پذیر با استفاده از الگوریتم دسته ماهی‌های مصنوعی ارائه شده است که در آن به اساتید و کلاس‌ها این امکان داده می شود که اولویت‌های خود برای تدریس در ساعات موردنظر هفته را در جدولی مخصوص به خود مشخص نمایند. به‌عبارت دیگر قابلیت اولویت‌های انعطاف‌پذیر باعث ایجاد تعاملی خوب بین اساتید و برنامه‌ی زمان‌بند می‌شود که این امر رضایت اساتید را در پی دارد. نتایج به دست آمده از آزمایش های صورت گرفته بر روی روش پیشنهادی حاکی از آن است که الگوریتم دسته ماهی‌های مصنوعی برنامه زمان‌بندی بهتری نسبت به الگوریتم‌های بهینه‌سازی ازدحام ذرات و ژنتیک ارائه می‌دهد.

کلید واژه- الگوریتم دسته ماهی‌های مصنوعی، اولویت‌های انعطاف‌پذیر، زمان‌بندی دروس دانشگاهی، محدودیت.

۱- مقدمه

مسأله زمان‌بندی یکی از مسائلی است که امروزه در بسیاری از مؤسسات آموزشی و خدماتی مثل دانشگاه‌ها، مدارس، خطوط راه‌آهن و ... کاربرد دارد. اکثر این مؤسسات به دنبال دستیابی به جدول زمان‌بندی‌ای هستند که بهینه و خودکار باشد تا از مشکلات و نواقص ایجاد جداول زمان‌بندی به‌صورت سنتی و دستی رهایی یابند. به‌طور کلی مسأله زمان بندی دروس دانشگاهی عبارت است از تخصیص یک‌سری منابع مانند اساتید، دانشجویان و دروس به بازه‌های زمانی ثابت و محدود به‌شرط ارضا تعداد زیادی محدودیت[۱].

از آنجایی‌که مسأله جدول زمانی به‌عنوان یک مسأله NP-Hard شناخته شده است، بنابراین هیچ الگوریتمی وجود ندارد که آن را با پیچیدگی زمانی چندجمله‌ای حل نماید[۲].

در مسأله زمان‌بندی دروس دو نوع محدودیت سخت و نرم وجود دارد. محدودیت‌های سخت آن دسته از محدودیت‌هایی است که حتما باید در زمان‌بندی رعایت شوند و عدم رعایت حتی یکی از آن‌ها موجب عدم اعتبار کل زمان‌بندی می‌شود. اما محدودیت‌های نرم آن‌هایی هستند که در صورت اِعمال در برنامه زمان‌بندی، موجب افزایش کیفیت زمان‌بندی خواهند شد اما عدم رعایت آن‌ها موجب عدم اعتبار برنامه نمی‌شود. یک زمان‌بندی که همه محدودیت‌های سخت را ارضاء کند زمان‌بندی امکان‌پذیر (Feasible Scheduling) نامیده می‌شود. در مسأله زمان‌بندی دروس، هدف اصلی این است که در یک زمان‌بندی امکان‌پذیر، نقض محدودیت‌های نرم به حداقل برسد[۳].

مسأله جدول زمان‌بندی دروس یکی از مسائل زمان‌بندی است که به‌طور وسیع و گسترده در طی ۲۵ سال گذشته مورد مطالعه قرار گرفته و تحقیقات زیادی در این زمینه صورت گرفته است[۴]. از جمله الگوریتم‌های اولیه‌ای که در سال‌های قبل برای حل این مسأله به‌کار برده می‌شد عبارت بودند از: الگوریتم‌های ابتکاری و الگوریتم‌های پس‌گرد[۵]. این الگوریتم‌ها به علت بزرگ بودن فضای حالت مسأله فاقد کارایی لازم بودند.

یکی از پرکاربردترین روش‌های ارائه شده جهت حل مسأله جدول زمان‌بندی، استفاده از روش رنگ‌آمیزی گراف است که نخستین بار در سال ۱۹۶۷، ولچ و پاول با الگوریتمی که ارائه دادند موفق شدند از طرق مسأله رنگ‌آمیزی گراف مسأله جدول زمان‌بندی را حل کنند که این‌کار پایه تحقیقات بعدی در این زمینه شد[۶و۷]. الگوریتم‌های فراابتکاری یکی از انواع الگوریتم‌های بهینه سازی تقریبی هستند که دارای مکانیسم‌های

خروج از بهینه محلی بوده و می‌توانند در طیف وسیعی از مسائل به‌کار برده شوند. به‌همین دلایل در سال‌های اخیر استفاده از الگوریتم‌های فراابتکاری برای حل مسأله زمان‌بندی دروس کاربرد فراوانی پیدا کرده است.

در [۸]چهار متد فراابتکاری معروف برای حل مسأله زمان‌بندی امتحانات باهم مقایسه شده است، این الگوریتم‌ها عبارتند از: بهینه‌سازی کولونی مورچه (Ant Colony Optimization)، الگوریتم ژنتیک (Genetic Algorithm)، الگوریتم تبرید شبیه‌سازی‌شده (Simulated Annealing) و الگوریتم جستجوی ممنوعه (Tabu Search). نتایج نشان داد که ACO کارایی بهتری نسبت به بقیه دارد و به‌دنبال آن به‌ترتیب TS و GA و SA نتایج بهتری از خود نشان داده‌اند.

در گذشته تمرکز اصلی برای حل مسأله زمان‌بندی دروس روی استفاده از تنها یک متد حل خاص بود اما در سال‌های اخیر محققان تلاش کرده‌اند تا با ترکیب چند الگوریتم به نتایج بهتری برسند. یکی از اولین مقاله‌ها در زمینه مسأله زمان‌بندی دروس که ایده‌ی الگوریتم های ترکیبی را به کار برد [۹]بود که یک الگوریتم ژنتیک ترکیبی را پیشنهاد داد.

از جمله الگوریتم های فراابتکاری، الگوریتم بهینه‌سازی اجتماع ذرات (Particle Swarm Optimization) است که در سال‌های اخیر الگوریتم‌های زیادی بر این مبنا برای حل مسأله زمان‌بندی طراحی و به کاربرده شده‌اند. به‌طور مثال در [۱۰]به‌صورت همزمان مسأله زمان‌بندی دروس و امتحانات با استفاده از الگوریتم PSO حل شده که یک مکانیسم جستجوی محلی این کار را مدیریت می‌کند.

مقاله‌ای دیگر یک الگوریتم PSO ترکیبی را برای حل مسأله زمان‌بندی دروس دانشگاه پیشنهاد داده است، از آنجایی‌که فضای جستجو در مسأله زمان‌بندی دروس گسسته است به‌منظور رسیدن به یک حل بهتر از یک مکانیسم جستجوی محلی استفاده می‌کند. الگوریتم با استفاده از داده‌های زمان‌بندی دانشگاهی در تایوان تست شد و نتایج نشان داد که این الگوریتم ترکیبی نتایج بهتری نسبت به الگوریتم ژنتیک دارد[۱۱].

در این مقاله، حل مسأله زمان‌بندی دروس دانشگاهی با قابلیت اولویت‌های انعطاف‌پذیر، با استفاده از الگوریتم دسته ماهی‌های مصنوعی (Artificial Fish Swarm Algorithm) ارائه شده است. بسیاری از روش‌های اشاره شده به موضوع داشتن قابلیتِ اولویت اشاره ای نداشته ولی در روش پیشنهادی این موضوع گنجانده شده است که در آن، اساتید می‌توانند اولویت های خود را برای تدریس در ۴۰ بازه‌ی زمانی هفته مشخص کنند. همچنین برای هر کلاس نیز یک جدول اولویت تدریس دروس وجود دارد که در آن مشخص می‌شود تدریس دروس در چه روزها و ساعاتی از هفته اولویت بالاتری دارد.

در ادامه مقاله چنین سازمان‌دهی شده است: در بخش بعد فرضیات مسأله مورد نظر عنوان شده و پس از آن توضیحاتی در مورد الگوریتم دسته ماهی‌های مصنوعی داده می شود. در ادامه روش پیشنهادی در این مقاله شرح داده می‌شود، پس از آن مقایسه‌ای بین این روش با روش‌های دیگر انجام شده و در آخر نیز نتیجه‌گیری انجام می‌گیرد.

۲- فرضیات مسأله زمان‌بندی دروس دانشگاهی

در این مقاله فرض شده هر هفته شامل پنج روز کاری و هر روز شامل هشت بازه زمانی یک ساعته است. بنابراین یک برنامه زمانی کامل در یک هفته به چهل بازه زمانی تقسیم می‌شود. با توجه به داده‌های دریافتی در ابتدا مشخص است که هر درس در چه کلاس و توسط چه استادی تدریس می شود و بر اساس این داده‌ها، تهیه جدول زمانی آغاز می‌شود. همچنین زمان تدریس هر درس نیز شامل سه بازه زمانی می‌باشد.

محدودیت‌های سخت عنوان‌شده در این مقاله عبارت‌اند از:

۱- زمان تدریس یک درس نباید دوتکه شود، یعنی همه‌ی سه بازه زمانی یک درس باید در یک روز باشد و به‌روز بعد و قبل نیفتد.

۲- یک استاد نباید در یک‌روز و یک‌ساعت دو درس برای تدریس داشته باشد.

۳- دروس یک کلاس نباید با هم تداخل داشته باشند.

محدودیت‌های نرم عنوان‌شده در این مقاله عبارت‌اند از:

۱- اساتید می‌توانند اولویت‌های خود را برای تدریس، در ۴۰ بازه زمانی هفته مشخص کنند.

۲- برای هر کلاس نیز یک جدول اولویت تدریسِ دروس وجود دارد که در این جدول مشخص می‌شود تدریس دروس در چه ساعاتی از هفته و روز، اولویت بالاتری دارد.

۳- اساتید می‌توانند ساعاتی را که ترجیح می‌دهند تدریس نداشته باشند در جدول تعیین اولویت‌ها مشخص کنند.

هر استاد باید اولویت‌های تدریس خود را در یک جدول ۴۰ خانه‌ای که به او تخصیص داده می شود مشخص کند. شکل (۱) مثالی از این موضوع را نمایش می‌دهد که در آن اولویت‌ها از ۰ تا ۵ شماره‌گذاری شده‌اند (محدودیت نرم ۱). شماره ۵ بیشترین اولویت برای آن پریود خاص را نشان می‌دهد، همچنین عدد ۱- نشان می‌دهد که استاد ترجیح می‌دهد در آن بازه زمانی

خاص تدریس نداشته باشد (محدودیت نرم ۳). به‌طور مثال بر اساس مقدار اولویت‌های نشان داده شده در شکل (۱)، اگر به بازه‌های زمانی‌ای که توسط استاد با ۱- نشانه‌گذاری شده است درس تخصیص داده شود محدودیت نرم ۳ نقض شده و این بدین معنی است که تابع هدف یک جریمه برای آن بازه زمانی در نظر می‌گیرد.

همه‌ی این جداولِ تعیین اولویت که برای اساتید در نظر گرفته شده برای هر یک از کلاس‌ها نیز تعیین می‌شود. بعد از تعیین اولویت‌ها برای اساتید و کلاس‌ها نوبت به تخصیص دروس به کلاس‌ها و محاسبه امتیاز برای جداول زمان‌بندی می‌باشد. هدف کلی در اینجا پیدا کردن یک جدول زمان‌بندی است که همه محدودیت‌های سخت را ارضاء کند و مقدار تابع TPV یا (Total Priority Values) را برای هر استاد و کلاس به حداکثر بر ساند. به‌عبارت‌دیگر هدف به دست آوردن رضایت‌مندی بهینه برای همه اساتید و کلاس‌ها بر مبنای مقدار اولویت‌هایشان می‌باشد. برای رسیدن به این مقصود باید سعی در به حداکثر رساندن تابع TPV کنیم، تابع TPV به این صورت محاسبه می‌شود:

$$TPV = \alpha \left[\sum_{t\in T}\sum_{l\in L_t} PV_{lt}\right] + \beta \left[\sum_{k\in C}\sum_{h\in H_k} PV_{hk}\right] \qquad (۱)$$

که در آن PV_{lt} مجموع مقدار اولویت‌های داده شده توسط استاد t به زمان تدریس l درس و PV_{hk} مجموع مقدار اولویت‌های داده شده توسط کلاس k به زمان تدریس h درس هست.

همچنین دو فاکتور α و β در نظر گرفته شده که این دو میزان تمایل تابع هدف به هر یک از پارامترهای اساتید و کلاس‌ها را وزن‌دهی می‌کنند. به‌طور مثال اگر بخواهیم روی میزان رضایت‌مندی اساتید تأکید بیشتری داشته باشیم α را بیشتر از β

		Instructor 1						Instructor m				
		Mon	Tue	Wed	Thu	Fri	...	Mon	Tue	Wed	Thu	Fri
PERIOD	1	0	0	0	-1	5	...	0	5	4	-1	5
	2	1	3	4	-1	5	...	2	5	4	2	5
	3	1	3	4	-1	5	...	2	5	4	2	5
	4	1	3	4	-1	5	...	2	5	4	2	5
	5	3	5	-1	3	4	...	1	3	-1	1	-1
	6	3	5	-1	3	4	...	1	3	-1	1	-1
	7	3	5	-1	3	-1	...	1	2	-1	1	-1
	8	0	0	-1	3	-1	...	0	2	-1	1	-1

شکل ۱. تعیین اولویت‌ها توسط اساتید[۱۱]

در نظر می‌گیریم و بالعکس. مجموع α و β برابر با یک می‌باشد. در اینجا مقدار این متغیرها را مساوی یعنی ۰/۵ در نظر می‌گیریم.

۳- الگوریتم دسته ماهی‌های مصنوعی (AFSA)

الگوریتم دسته ماهی‌های مصنوعی یکی از الگوریتم‌های هوش جمعی است که بر اساس جمعیت و جستجوی تصادفی کار می‌کند. این الگوریتم در سال ۲۰۰۲ توسط دکتر لی و همکارانش ارائه گردید[۱۲]. اساس کار AFSA از روی رفتارهای اجتماعی ماهی‌ها برگرفته شده و برمبنای جستجوی تصادفی، جمعیت و رفتارگرایی کار می‌کند. در جه تراکم غذا در منطقه آبی، تابع هدف الگوریتم هست.

مدل ماهی مصنوعی شامل دو بخش متغیرها و توابع است که متغیرها شامل X (موقعیت فعلی ماهی مصنوعی)، Step (طول گام حرکت)، Visual (میدان دید)، try-number (سقف آزمایش و سعی کردن)، و & (فاکتور شلوغی) می‌باشند (۱>&>۰). همچنین توابع شامل رفتار دنباله‌روی، رفتار گروهی، رفتار جستجوی غذا و رفتار آزادانه می‌باشند[۱۳].

رفتار حرکت آزادانه: در AFSA هنگامی‌که ماهی مصنوعی نتواند به‌سمت موقعیتی با مقدار غذای بیشتر حرکت کند، یک گام به صورت تصادفی با استفاده از رابطه زیر در فضای مسأله حرکت می‌کند.

$$X_i^{(t+1)} = X_i^{(t)} + Step.Rand(-1,1) \qquad (۲)$$

که در آن X_i برابر موقعیت ماهی مصنوعی nام و Rand یک عدد تصادفی در بازه‌ی [۱،۱-] با توزیع یکنواخت تولید می‌کند.

رفتار جستجوی غذا: اگر X_i وضعیت فعلی ماهی مصنوعی با شد، یک وضعیت X_j را به صورت تصادفی در میدان دید ماهی مصنوعی انتخاب می‌کنیم که وضعیت X_j با استفاده از رابطه زیر محاسبه می‌شود.

$$X_j = X_i + Visual.Rand(-1,1) \qquad (۳)$$

تراکم غذایی در X_j را با تراکم غذایی در X_i مقایسه می‌کنیم، اگر $Y_j>Y_i$ باشد (در مسائل بیشینه‌سازی)، ماهی مصنوعی مورد نظر از موقعیت کنونی خود یک گام در جهت X_j حرکت می‌کند که با استفاده از رابطه زیر به دست می‌آید:

$$X_i^{(t+1)} = X_i^{(t)} + \frac{X_j - X_i^{(t)}}{\left\|X_j - X_i^{(t)}\right\|}.Step.Rand(0,1) \qquad (۴)$$

در غیر این‌صورت زمانی که $Y_j<Y_i$، یک موقعیت دیگر برای X_j با استفاده از رابطه (۳) انتخاب می‌کنیم و دوباره تراکم غذایی آن را با موقعیت کنونی ماهی مصنوعی می‌سنجیم تا ببینیم که آیا شرط پیش‌روی ($Y_j>Y_i$) به سمت نقطه X_j ارضا شده است یا خیر، چنانچه پس از try_numbar تکرار موفق به ارضا کردن شرط پیش‌روی نشدیم رفتار حرکت آزادانه برای ماهی مصنوعی اجرا می‌گردد.

رفتار دنباله‌روی: اگر فرض کنیم X_i وضعیت فعلی ماهی مصنوعی با تابع برازش Y_i باشد و آن ماهی همسایگان X_j خود را جستجو کند ($d_{ij}<Visual$)، به‌صورتی‌که برازش بهترین همسایه آن ماهی Y_j باشد. اگر $Y_j>Y_i$ و $(n_f/n)>\&$، به‌معنی این است که وضعیت X_j دارای تراکم غذایی بیشتری نسبت به وضعیت فعلی است و هم‌چنین تراکم جمعیتی در نزدیکی آن زیاد نمی‌باشد، پس یک گام به سمت Xj پیش می‌رویم که با استفاده از رابطه زیر محاسبه می‌شود:

$$X_i^{(t+1)} = X_i^{(t)} + \frac{X_j - X_i^{(t)}}{\left\| X_j - X_i^{(t)} \right\|}.Step.Rand(0,1) \qquad (۵)$$

در غیر این‌صورت رفتار جستجوی غذا اجرا می‌شود.

رفتار حرکت گروهی: فرض کنید X_i موقعیت کنونی AF، X_c موقعیت مرکز دسته که برابر مرکز ثقل بردارهای اعضای دسته هست و n_f تعداد مؤلفه‌های در همسایه‌ی کنونی ($d_{ij}<Visual$) و n تعداد کل ماهی‌ها باشد.

وضعیت $Yc>Y_i$ و $(n_f/n)>\&$، یعنی موقعیت مرکزی دارای تراکم غذایی بالاتری نسبت به وضعیت کنونی است و تراکم جمعیت در آن بالا نیست، پس یک گام به سمت میدان مرکزی پیش می‌رویم که به‌صورت زیر محاسبه می‌شود.

$$X_i^{(t+1)} = X_i^{(t)} + \frac{X_c - X_i^{(t)}}{\left\| X_c - X_i^{(t)} \right\|}.Step.Rand(0,1) \qquad (۶)$$

حال اگر $n_f=0$ یا شرط حرکت به موقعیت مرکزی ارضا نشود، رفتار جستجوی غذا اجرا می‌گردد.

۴- روش پیشنهادی

در این بخش روش پیشنهادی برای حل مساله زمان‌بندی دروس دانشگاهی با استفاده از الگوریتم دسته ماهی‌های مصنوعی ارائه گردیده است.

شیوه کار به این‌صورت است که هر درس به‌عنوان یک ماهی در نظر گرفته می‌شود که با توجه به توضیحات بخش قبل در مورد الگوریتم دسته ماهی‌های مصنوعی این دروس یا ماهی‌ها با جابه‌جا کردن خود، سعی در رفتن از موقعیت فعلی به یک موقعیت بهتر (با امتیاز بیشتر) دارند. در مرحله اول، ابتدا توسط تابع پراکندن دروس مختص هر کلاس را به‌صورت تصادفی به بازه‌های زمانی آن کلاس تخصیص می‌دهیم. روند کار این تابع به این صورت است که ابتدا یک روز و سپس یکی از بازه‌های زمانی آن را برای تخصیص درس مورد نظر انتخاب می‌کند، این کار را چندین بار انجام داده تا به تعداد p زمان‌بندی امکان پذیر برسیم.

بعد از قرار گرفتن هر درس در موقعیت مخصوص به خود در هر زمان‌بندی، روی هر کدام از دروس به‌صورت جداگانه عملیات مربوط به الگوریتم AFSA را اجرا می‌کنیم، به این صورت که دروس یکسان در همه زمان‌بندی‌ها به‌عنوان یک دسته ماهی در نظر گرفته می‌شوند که با اجرای توابع حرکت گروهی، دنباله‌روی، جستجوی غذا و حرکت آزادانه سعی در تغییر موقعیت کنونی خود به یک موقعیت بهتر دارند.

فرض کنیم i یک درس باشد، این درس در هر یک از زمان‌بندی‌ها در موقعیت بخصوصی قرار دارد مثلا ممکن است در یک‌زمان‌بندی در موقعیت ۲ در زمان‌بندی بعد در موقعیت ۴ و یا ۳۹ باشد. در اینجا همه‌ی این دروس را به‌عنوان یک دسته ماهی در نظر می‌گیریم و عملیات چهارگانه‌ی الگویتم دسته ماهی‌های مصنوعی را روی این دسته اجرا می‌کنیم، برای بقیه‌ی دروس نیز همین کار را تکرار می‌کنیم (شکل ۲). قبل از هر چیز ابتدا باید پارامترهای الگوریتم دسته ماهی‌های مصنوعی را مشخص کنیم، در این مقاله میدان دید برابر ۷، فاکتور شلوغی برابر ۰/۶ و حداکثر طول گام حرکت ۵ در نظر گرفته شده است. در شکل زیر درس i در زمان‌بندی‌های ۱ و ۲ در میدان دید هم قرار دارند اما درس i در زمان‌بندی ۳ در میدان دید آن‌ها نیست. بعد از مشخص کردن این پارامترها شروع به اجرای الگوریتم دسته ماهی‌های مصنوعی روی این دروس می‌کنیم.

Period	1	2	3	4	…	39	40
Scheduling 1		Course i			…		
Scheduling 2				Course i	…		
Scheduling 3					…	Course i	

شکل۲: نحوه انتخاب دروس یکسان در هر زمان‌بندی به‌عنوان دسته ماهی

فرض کنیم درس i در زمان t در موقعیت $X_i(t)$ باشد. این درس ابتدا رفتار حرکت گروهی را اجرا می‌کند و باعث تغییر مکان خود از $X_i(t)$ به $X_i(swarm)$ می‌شود. این رفتار به این‌صورت است که درس i مرکز دسته دروس در میدان دید خود را محاسبه کرده و با موقعیت فعلی خود مقایسه می‌کند، اگر موقعیت مرکز دسته دروس بهتر از موقعیت فعلی بود و همچنین تراکم جمعیت در آن بالا نبود یک گام به سمت آن پیش می‌رود (رابطه ۶). یک‌بار دیگر این درس از همان مکانِ $X_i(t)$ رفتار دنباله‌روی را اجرا می‌کند که باعث تغییر مکان خود به $X_i(follow)$ می‌شود. این رفتار موقعیت همه‌ی همسایه‌های درس i را چک می‌کند، بهترین موقعیت را انتخاب کرده و با موقعیت درس i مقایسه می‌کند، در صورت بهتر بودن موقعیت همسایه و عدم تراکم جمعیتی بالا در آن، درس i یک گام به سمت همسایه خود پیش می‌رود (رابطه ۵).

پس از اجرای دو رفتار حرکت جمعی و دنباله‌روی موقعیت بعدی درس i با استفاده از رابطه زیر به دست می‌آید:

$$X_i^{(t+1)} = \begin{cases} X_i^{(follow)} & if \quad f(X_i^{(follow)}) \le f(X_i^{(swarm)}) \\ X_i^{(swarm)} & if \quad f(X_i^{(follow)}) > f(X_i^{(swarm)}) \end{cases} \qquad (۷)$$

درصورتی‌که درس i نتواند با رفتارهای حرکت گروهی و دنباله‌روی به موقعیت بهتر برسد رفتار جستجوی غذا را اجرا می‌کند. به این صورت که یک نقطه تصادفی در میدان دید خود انتخاب کرده (با استفاده از رابطه ۳) و موقعیت آن نقطه را با موقعیت فعلی خود مقایسه می‌کند. در صورتی‌که موقعیت جدید از موقعیت فعلی بهتر باشد و تراکم جمعیت در آن بالا نباشد یک گام به سمت موقعیت جدید پیش می‌رود (رابطه ۴)، در غیر این‌صورت یک موقعیت جدید دیگر را در میدان دید خود تست کرده و مراحل قبل را تکرار می‌کند. اگر تعداد تکرار تعیین شده (Try-number)، نتواند یک موقعیت بهتر پیدا کند رفتار حرکت آزادانه را انجام می‌دهد. مقدار پارامتر Try-number در اینجا ۲۰ در نظر گرفته شده است.

رفتار حرکت آزادانه در صورتی اجرا می‌شود که یک درس با هیچ‌کدام از توابع حرکت گروهی، دنباله‌روی و جستجوی غذا نتواند به سمت موقعیتی با امتیاز بیشتر گام بردارد که در این صورت یک گام تصادفی با استفاده از رابطه (۲) برمی‌دارد.
شبه کد روش پیشنهادی فوق در شکل (۳) آمده است.

```
Algorithm AFS For Scheduling
SchedulingBest=0
for each Generation i ∈ [1 .. G]
   for each Course j ∈ [1 .. C]
      for each Population k ∈ [1 .. P]
         A=False
         perform Swarm Behavior on Coursej,k(t) and
            compute Coursej,k(Swarm)
         perform Follow Behavior on Coursej,k(t) and
            compute Coursej,k(Follow)
         if (f(Coursej,k(Swarm) ≥ f(Coursej,k(Follow))
         then
            Coursej,k(t+1)= Coursej,k(Follow)
            A=True
         else
            Coursej,k(t+1)= Coursej,k(Swarm)
            A=True
         end if
         if (A=False) then
            perform Prey Behavior on Coursej,k(t) and
               compute Coursej,k(Prey)
            Coursej,k(t+1)= Coursej,k(Prey)
         else
            perform Freely Behavior on Coursej,k(t) and
               compute Coursej,k(Freely)
            Coursej,k(t+1)= Coursej,k(Freely)
         end if
      end for
   end for
   Scheduling=Currect(generation(i))
   If (Score(Scheduling) > Score(SchedulingBest)) then
   SchedulingBest = Scheduling
end for
```

شکل ۳: شبه کد روش پیشنهادی

همان گونه که در بالا آمد با اجرای توابع چهارگانه‌ی الگوریتم دسته ماهی‌های مصنوعی روی دروسِ هر زمان‌بندی امکان این وجود دارد که هر یک از محدودیت‌های سخت نقض شوند و زمان‌بندی به‌دست‌آمده امکان‌پذیر نبا شد. در این صورت باید تست شود که کدام محدودیت سخت و برای چه دروسی نقض شده است تا روند اصلاحی برای آن در نظر گرفته شود. در اینجا توضیح مختصری از چگونگی اصلاح زمان‌بندی بعد از نقض هر محدودیت سخت بیان شده است.

نقض محدودیت سخت ۱: در صورت نقض این محدودیت اگر فقط یک بازه زمانی درس به‌روز بعد بیفتد درس را یک واحد به عقب شیفت می‌دهیم تا کل درس در یک روز بیفتد اما اگر دو بازه‌ی زمانی به‌روز بعد بیفتد درس را یک واحد به جلو شیفت می‌دهیم تا کل بازه‌های زمانی آن درس به‌روز بعد انتقال یابد.

نقض محدودیت سخت۲: تابع پراکندن را روی در سی که

امتیاز کمتری در آن موقعیت دارد اعمال می‌کنیم، تا در جای مناسبی قرار بگیرد که هیچ محدودیت سختی نقض نشود.

نقض محدودیت سخت ۳: امتیاز دو درسی که باهم تداخل دارند را محاسبه کرده، هرکدام از دروس که امتیاز کمتری دا شت مانند محدودیت سخت ۲ تابع پراکندن را روی آن اعمال می‌کنیم.

۵- آزمایش‌ها و نتایج

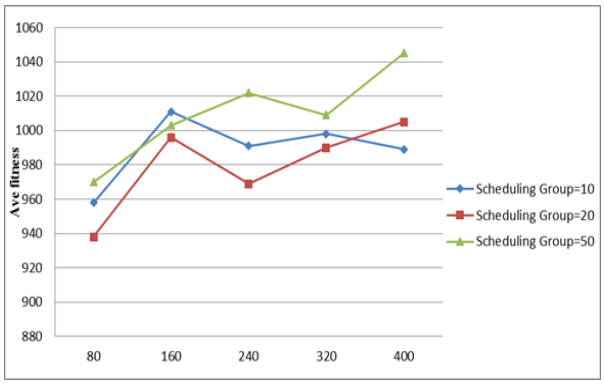
در این بخش، آزمایش ها و نتایج آن ها برای تولید جداول زمانی بهینه ارائه می‌گردد، سپس مقایسه ای بین روش پیشنهادی با روش‌های ارائه شده در [۱۱] و [۱۴] انجام می‌شود. مقایسه به این صورت است که امتیاز جداول زمان‌بندی تولید شده توسط دو الگوریتم با هم مورد ارزیابی قرار می‌گیرند. پارامترهای به کار رفته در آزمایش‌ها برپایه مجموعه داده های استاندارد مطرح در مرجع [۱۱] به‌صورت زیر در نظر گرفته شده‌اند: تعداد اساتید: ۱۷، تعداد کلاس‌ها: ۸، تعداد دروس: ۴۸ و تعداد درس برای هر کلاس: ۶. هر درس در سه بازه‌ی زمانی تدریس می‌شود و دروس هر کلاس نیز از هم مجزا هستند و فقط در همان کلاس برگزار می‌شوند.

در اینجا بالاترین امتیاز یک زمان‌بندی ۷۲۰ می‌باشد (۱۵×۴۸)، یعنی همه‌ی ۴۸ درسِ یک زمان‌بندی امتیاز کاملِ ۱۵ را به دست آورند، البته با توجه به اینکه هم اساتید و هم‌کلاس‌ها اولویت‌های خود را به‌صورت جداگانه مشخص می‌کنند و از آنجا که جداول زمان‌بندی آن‌ها در اینجا به‌صورت جداگانه نمایش داده شده است امتیاز کل در دو ضرب می‌شود و به ۱۴۴۰ می‌رسد.

روند کار به این صورت بوده است که الگوریتم با سه جمعیت مختلفِ ۱۰، ۲۰ و ۵۰ تست شد، این جمعیت‌ها در واقع همان تعداد دسته ماهی‌های ما هستند، به‌طور مثال وقتی اندازه جمعیت برابر ۱۰ در نظر گرفته می‌شود یعنی ۱۰ زمان‌بندی امکان‌پذیر تولید شده و همه دروس یکسانِ آن‌ها تشکیل دسته دروس داده تا عملیات چهارگانه‌ی الگوریتم دسته ماهی‌های مصنوعی روی آن‌ها اعمال شود. همچنین هر کدام از این جمعیت‌ها در پنج نسل مختلف (۸۰،۱۶۰،۲۴۰،۳۲۰،۴۰۰) تست شدند.

بهترین نتیجه وقتی به دست آمد که اندازه جمعیت برابر ۵۰ و تعداد نسل ها برابر ۴۰۰ بود، امتیاز جدول زمان‌بندی در این حالت به ۱۰۴۵ رسید که نسبت به حل مشابه آن با استفاده از الگوریتم های PSO و GA به ترتیب ۹۶ و ۱۳۷ امتیاز بیشتر کسب کرد، به‌عبارت دیگر حل مسئله زمان‌بندی دروس با استفاده از الگوریتم دسته ماهی‌های مصنوعی نسبت به حل مشابه آن با استفاده از الگوریتم PSO، ۱۰/۱ درصد و نسبت به GA، ۱۵ درصد جدول زمان‌بندی بهینه‌تری تولید کرده است.

نتایج حاصل از اجرای الگوریتم دسته ماهی‌های مصنوعی روی مسئله زمان‌بندی دروس با جمعیت های مختلف در نمودارهای شکل (۴) آمده است.



شکل ۴: نتایج حاصل از اجرای روش پیشنهادی با جمعیت‌ها و نسل‌های مختلف

در این نمودارها محور افقی تعداد نسل‌ها و محور عمودی میانگین امتیاز گرفته شده را مشخص می‌کند. نتایج حاصل از روش پیشنهادی برای سه جمعیت ۱۰ و ۲۰ و ۵۰ در نسل‌های مختلف آورده شده است. همان‌طور که از نمودار مشخص است بهترین نتیجه وقتی به دست آمد که تعداد نسل‌ها برابر ۴۰۰ و جمعیت برابر ۵۰ بود.

در یک نگاه کلی حل مسئله زمان‌بندی دروس دانشگاهی با استفاده از AFSA نسبت به الگوریتم هایPSO و GA باعث ایجاد جداول زمان‌بندی بهتری شده است، جدول (۱) در یک مقایسه اجمالی کمترین، بیشترین و میانگین امتیازات جداول زمان‌بندی تولیدشده با استفاده از سه الگوریتم AFSA، PSO و GA را باهم مقایسه کرده است.

جدول۱: مقایسه الگوریتم پیشنهادی با روش‌های ارائه شده در [۱۱] و [۱۴]

	پایین ترین	میانگین	بالاترین
روش [۱۴]	۸۰۷	۸۶۲	۹۰۸
روش [۱۱]	۸۹۸	۹۳۵	۹۴۹
روش پیشنهادی	۹۳۸	۹۹۲	۱۰۴۵

۶- نتیجه‌گیری

در این مقاله، مسئله زمان‌بندی دروس دانشگاهی با استفاده از الگوریتم دسته ماهی‌های مصنوعی به همراه قابلیت اولویت‌های انعطاف‌پذیر حل‌شده است. از این قابلیت برای ایجاد تعامل بیشتر با اساتید استفاده شده است که به اساتید این امکان را می‌دهد اولویت‌های خود را برای تدریس در ساعات مختلف هفته (توسط امتیازی که به آن پریود زمانی می‌دهند) مشخص کنند. نتایج آزمایش‌ها نشان داد که الگوریتم دسته ماهی‌های مصنوعی نسبت به الگوریتم‌های بهینه‌سازی ازدحام ذرات و ژنتیک کارایی بیشتری دارد و جداول زمان‌بندی بهینه‌تری تولید می‌کند. همچنین قابلیت اولویت‌های انعطاف‌پذیر ضمن بالا بردن میزان بهینه بودن جدول زمان‌بندی و ایجاد معیاری مناسب برای مقایسه جداول زمان‌بندی با یکدیگر، باعث رضایت‌مندی بیشتر اساتید از برنامه زمان‌بندی تولید شده می‌شود.

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یک روش مستقل از کاربر برای تشخیص زبان اشاره آمریکایی

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چکیده-شناسائی خودکار علائم اشاره برای افراد ناشنوا یا با استفاده از دستکش به همراه دستگاه های جانبی و یا با استفاده از بینائی ماشین انجام می-شود. در روش دستکش نیاز به دستگاه جانبی و ارتباط آن با دستکش می باشد که این خود مشکلات در نگهداری و استفاده از آن را دشوار می کند. در روش بینائی فرد یا کاربر و همچنین شرایط محیطی از قبیل نور و چرخش از چالش های اساس در این زمینه می باشد. در این مقاله یک روش مبتنی بر لبه و بافت براساس فیلتر گابور در دو فاز پیشنهاد می شود: فاز اول شامل تغییر سایز تصاویر و استخراج ویژگی های مفید توسط فیلتر گابور، در جهت ها و مقیاس های متفاوت می باشد. در فاز دوم از ویژگی های استخراج شده جهت آموزش شبکه عصبی پرسپترون چند لایه استفاده می شود. این روش بر روی مجموعه داده حروف و اعداد آمریکایی که مستقل از کاربر بوده و از پنج شخص متفاوت عکس برداری شده است مورد آزمایش قرار گرفت. نتایج نهائی حاصل برای حروف آمریکایی ۹۵,۷۶٪ و اعداد آمریکایی ۹۷,۲٪ بوده است. نتایج حاکی از دقت و عملکرد مناسب روش ارائه شده در مجموعه داده آمریکایی و در مقایسه با روش های متفاوت روز می باشد.

واژگان کلیدی : استخراج ویژگی ، فیلتر گابور ، لبه های داخلی و خارجی ، شبکه عصبی ، زبان اشاره آمریکایی

۱.مقدمه

حرکت های اشاره کننده ، شامل حالت های فیزیکی دست ها، انگشتان، بازوها، سر، صورت با هدف انتقال اطلاعات معنی دار و تعامل و ارتباط با محیط می باشد. بطورکلی کاربر با استفاده از حرکت های دست می تواند احساسات و افکار خود را بیان کند. که این حرکت ها می‌تواند به صورت ایستا یا پویا باشد. زبان اشاره به شکل اساسی با مشکل واختلال در شنوایی در ارتباط است. برای ارتباط یک فردعادی با یک ناشنوا نیاز به یک مترجم است که زبان اشاره را به زبان طبیعی و برعکس ترجمه کند. تشخیص اتوماتیک زبان اشاره با هدف رونویسی(آوانگاشت[۳]) زبان اشاره به متن، به منظور ایجاد ارتباط بین فرد ناشنوا وجامعه شنوا می باشد. اصولا زبان اشاره دارای چهار رکن اصلی می باشد که عبارتند از : حالت دست ها ، حرکت دست ها ، محل قرار گرفتن دست ها ، موقعیت و یا جهت کف دست ها[۱]، بدیهی است باتغییر هر یک از این حالات ، به هر اشاره، معنی ومفهوم خاص می‌بخشد.

در سال ۲۰۰۷ یک روش در ارتباط با زبان اشاره آمریکایی مطرح گردید [۲] که با استفاده از تبدیل هاف ۲۱۴ ویژگی از تصویر استخراج می کرد که برای بازشناسی ۲۰ حرف انتخابی از زبان اشاره آمریکایی استفاده می شد. در نهایت با استفاده از شبکه های عصبی به عنوان طبقه بند به ۹۶,۳۳ درصد موفقیت دست پیدا کرده است. در سال ۲۰۰۹ سیستم دیگری طراحی شد که از فیلتر گابور برای استخراج ویژگی از تصاویر استفاده می کرد. [۳] این روش برای ۱۱ گروه ژست آمریکایی مطرح شده که در فاز نهائی از SVM به عنوان طبقه بند استفاده کرده و به ۹۵,۲ درصد بازشناسی کل رسیده است. در سال ۲۰۱۱ روشی برای بازشناسی زبان اشاره آمریکایی مطرح گردید [۴] در این روش ۳۰ کلمه از زبان اشاره آمریکایی مورد استفاده قرار گرفت که از روش PCA به عنوان توصیفگر شکل و ویژگی های دیگری برای بیان مکان دست و تشخیص جنبش های دست استفاده شده است. که در فاز نهایی با استفاده از طبقه بند HMM نرخ خطای کلی را تا ۲/۸درصد کاهش داده است.

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[3] Transcribe

در سال ۲۰۱۱ کرمی و کیانی تلاش کردند تا با استفاده از تبدیل ویولت و شبکه عصبی ۳۲ ژست ایستای زبان اشاره فارسی را بازشناسی نمایند [۵] که در نهایت به ۹۴،۰۶ درصد موفقیت دست پیدا کردند.

در ادامه ی این مقاله در بخش ۲ به بررسی روش پیشنهادی خواهیم پرداخت. در بخش ۳ آزمایش ها و نتایج حاصله مورد ارزیابی قرار خواهد گرفت. و در بخش ۴ جمع بندی را خواهیم داشت.

۲. روش پیشنهادی

۲-۱. تبدیل تصاویر به فضای Ycbcr

تصاویر اولیه شامل پس زمینه می باشد که لازم است حذف شوند به عمل حذف پس زمینه از تصویر آشکارسازی می گویند. در اینجا آشکار سازی براساس تفاوت رنگ دست از پس زمینه ایجاد می شود. جهت افزایش حساسیت تشخیص پوست دست و حذف عوامل ناخواسته نظیر تغییرات نوری و سایه اشاره ها در تصاویر از فضای رنگ Ycbcr استفاده می شود. این فضای رنگی خاصیت فشرده سازی تصاویر را دارد و حجم آن تقریبا نصف تصویر مشابه در فضای RGB می باشد. با اعمال یک حد آستانه با توجه به رابطه ۱ و۲ برروی مقدار cb و cr پیکسل های ناحیه دست آشکار سازی می شوند. همان طور که در شکل ۱ مشخص است پیکسل های مرتبط با نواحی دست $Y(X_F, Y_F)$ نسبت به $Cb\ (X_F, Y_F)$ و $Cr\ (X_F, Y_F)$ بیشترین مقدار را به خود اختصاص داده است X_F, Y_F بیانگر پیکسل های مربوط به ناحیه پوست دست می باشند.

$$Min \leq cr \leq Max \qquad ۱$$

$$Min \leq cb \leq Max \qquad ۲$$

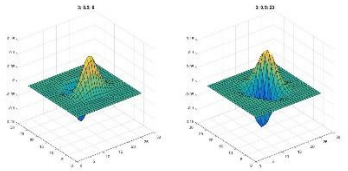


الف)فضای رنگی RGB ب) بعد اول در فضای Ycbcr ج) بعد دوم در فضای Ycbcr د) بعد سوم در فضای Ycbcr

شکل ۱) الف)تصویر اصلی در فضای RGB ب)کانال Y ج)کانال Cb د)کانال Cr

۲-۲. استخراج ویژگی توسط فیلتر گابور

فیلتر گابور مهم ترین ویژگی های بصری نظیر موقعیت مکانی و راستای جهت و مشخصه های فرکانس فضایی را ضبط می کند. [۶] انواع گوناگونی از فیلتر های گابور وجود دارد، که به یک تابع هارمونیک پاسخ می دهند و ماهیتی مختلط دارند، مقادیر فیلتر گابور قسمت حقیقی و قسمت موهومی دارند، دو پارامتر اصلی گابور مقیاس و جهت می باشد با تغییر این پارامترها شکل فیلتر عوض خواهد شد. برای نمونه درشکل۲موجک مادر با ۰و۲۳ درجه و همچنین با مقیاس ۳ نشان داده شده است. بعد از ایجاد فیلترها تصویر اصلی به وسیله این فیلتر های ایجاد شده تغییر می کند و نتیجه، تصاویر متعدد به اندازه ی پارامترها و به صورت مختلط می باشند. در شکل ۳ این تغییر فیلتر برروی اشاره شماره ۷ مشاهده می گردد. مرحله بعد استخراج ویژگی خواهد بود که ویژگی هایی مانند انرژی محلی ، میانگین دامنه ، انحراف معیار و سایر ویژگی ها از تصاویر مورد نظر استخراج می شود.



شکل۲)تغییردرموجک مادربا اعمال مقیاس و جهت مختلف



شکل۳)تغییردرموجک مادربا اعمال مقیاس و جهت مختلف

از آنجایی که استخراج ویژگی برای تشخیص تصاویر اشاره با استفاده از فیلتر گابور نتایج خوبی را می دهد در اینجا از تکنیک استخراج ویژگی براساس فیلتر گابور استفاده می کنیم رابطه ی زیر یک فیلتر گابور را نشان می دهد :

$$g_{\lambda,\theta,\varphi,\sigma,\gamma} = \exp\left(-\frac{x'^2 + \gamma^2 y'^2}{\lambda}\right)\cos\left(2\pi\frac{x'}{\lambda} + \varphi\right) \qquad (۱)$$
$$x' = x\cos\theta + y\sin\theta$$
$$y' = -y\sin\theta + x\cos\theta$$

که X و Y مختصات پیکسل در ناحیه بعدی می باشند.

۲-۳. استخراج لبه های داخلی و خارجی

علاوه بر ویژگی های استخراج شده توسط فیلتر گابور روش پیشنهادی از لبه های داخلی و خارجی اشاره ها نیز استفاده می کند. تا میزان بازشناسی را افزایش دهد این لبه ها پس از برش تصاویر دست توسط عملگر سوبل استخراج می گردد و تعداد این لبه ها بر ماتریس ویژگی ها اضافه می شود آخرین ستون مربوط به بردار ویژگی هر یک از اشاره ها مربوط به تعداد لبه های آن اشاره می باشد چند نمونه از لبه های تصویر که توسط عملگر سوبل استخراج شده است در شکل ۴ مشاهده می شود.



شکل ۴) لبه های مربوط به اعداد ۳ ، ۴ ، ۵

۲-۴. طبقه بندی داده ها

در معماری شبکه عصبی انتخاب یک مدل ساده باعث می شود تا شبکه به خوبی داده های آموزشی را یاد نگیرد و توانایی شناسایی و کلاس بندی آن ها را نداشته باشد. به همین دلیل یک شبکه عصبی با دو لایه را در نظر گرفتیم تعداد نورون های لایه مخفی براساس آزمایش ها و نتایج در بخش ۳ موجود است. یک شبکه عصبی در لایه مخفی با تعداد۱۰۰ نورون و لایه خروجی براساس تعداد کلاس های زبان اشاره آمریکایی در نظر گرفته شده است. که نهایتاً بیشترین کلاس و خروجی در شبکه عصبی ۲۶ نورون می باشد این آزمایش ها در بخش ۳-۲ نشان داده شده است.

۳. آزمایش ها و نتایج

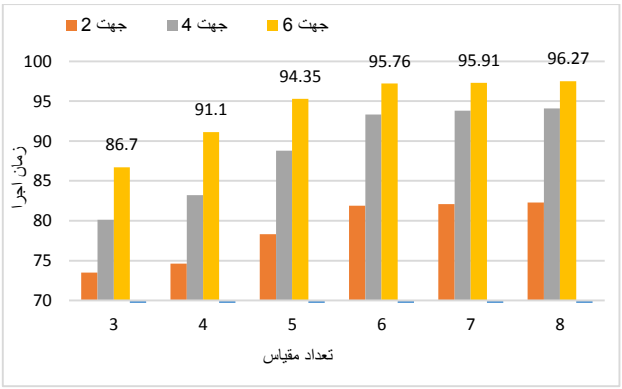
۳-۱.تحلیل پارامتر گابور

از آنجایی که انتخاب بهترین مقادیر برای فیلتر گابور از اهمیت بسیار زیادی برخوردار است. این پارامترها با استفاده از آزمایش هایی که نشان دهنده بهترین پارامتر در بهترین زمان است دست پیدا خواهیم کرد. در این آزمایش میزان تغییر پارامتر جهت دارای سه مقدار و مقادیر اندازه در بازه min و max تعریف شده خواهد بود. همان طور که در شکل ۵ مشاهده می شود با افزایش میزان پارامترهای اندازه و جهت در فیلتر گابور زمان استخراج ویژگی نیز افزایش می یابد و دارای رابطه مستقیمی با زمان است. قابل ذکر است که با افزایش میزان اندازه تصاویر، زمان استخراج ویژگی به نسبت افزایش خواهد یافت .



شکل ۵) ارتباط میان پارامترهای فیلتر گابور و زمان

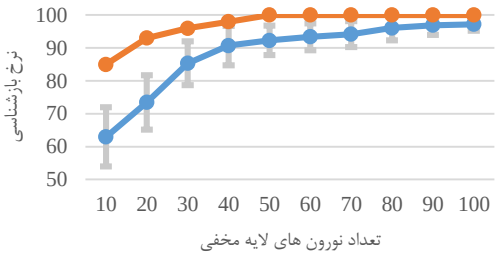
در ادامه به تاثیر پارامترهای فیلتر گابور برروی دقت روش پیشنهادی در مجموعه داده آمریکایی خواهیم پرداخت. همان طور که در شکل ۶ ملاحظه می شود با افزایش میزان مقادیر جهت و اندازه در فیلتر گابور نرخ بازشناسی روش پیشنهادی نیز افزایش پیدا می کند. البته باید توجه کرد که با افزایش میزان این پارامترها و افزایش اندازه تصاویر زمان استخراج ویژگی توسط فیلتر گابور به طور قابل توجهی بالا می رود و سرعت کاهش پیدا می کند و معمولا حافظه بسیاری از سیستم ها پاسخگوی این حجم از اطلاعات نمی باشد. از این رو سعی شده است تا بهترین و سریعترین پارامتر با توجه به آزمایش ها انتخاب گردد در این مقاله یک فیلتر گابور با ۶ جهت و ۶ اندازه گسترش داده شده است با توجه به آزمایش ها برای مقادیر بزرگتر از ۶ در جهت و اندازه ، نرخ بازشناسی تغییر بسیار اندکی داشته ولی زمان محاسبات افزایش چشمگیری دارد.



شکل ۶) ارتباط میان پارامترهای فیلتر گابور و نرخ بازشناسی

۳-۲. تحلیل پارامترهای شبکه عصبی

در آموزش شبکه های پرسپترون چند لایه یکی از موثرترین پارامتر ها انتخاب تعداد نورون های موجود در لایه مخفی می باشد از این رو سعی گردیده تا بهترین و ساده ترین معماری برای شبکه عصبی انتخاب شود. چرا که باید علاوه بر موثر بودن در بازشناسی اشاره ها، در یادگیری و سرعت عمل هم نرخ بالایی از عملکرد را دارا باشد به همین منظور آزمایش های متعددی انجام گرفت و بهترین لایه از نورون های مخفی شبکه عصبی و هم چنین سریعترین آن را انتخاب کرده و برای بازشناسی اشاره ها مورد استفاده قرارداده شد. در شکل ۷ نرخ بازشناسی و انحراف معیار استاندارد روش پیشنهادی ، به ازای تعداد نورون ها مشخص می باشد که با توجه به این شکل ۱۰۰ نورون لایه مخفی نرخ بازشناسی مناسب و پراکندگی داده ی کمتری دارد.

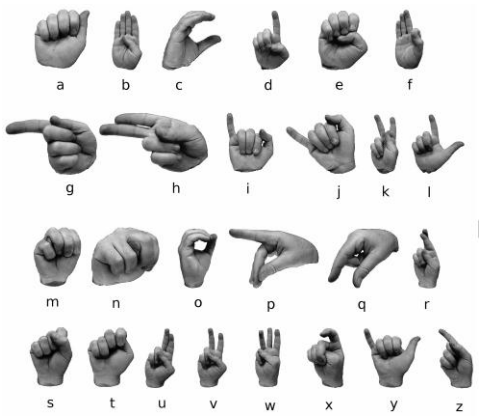


شکل ۷) ارتباط نرون های شبکه عصبی با نرخ بازشناسی

شبکه با الگوریتم "trainscg" مورد تعلیم قرار گرفت و شرط توقف رسیدن به ۵۰۰ دور و یا رسیدن به هدف ۰,۰۰۰۱ می باشد.

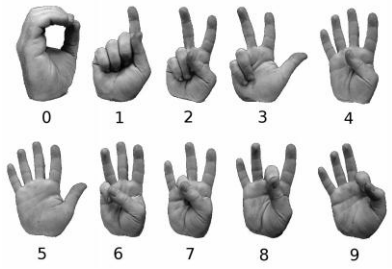
۳-۳. مجموعه داده حروف آمریکایی

مجموعه داده انتخابی یک مجموعه داده ی استاندارد متشکل از ۳۶ اشاره می باشد. این مجموعه داده مربوط به زبان اشاره آمریکایی استاندارد بوده و به تازگی تهیه شده است. [۷] در این مجموعه داده ویژگی های متفاوتی به چشم می خورد. در زبان اشاره آمریکایی ۲۶ حرف اشاره وجود دارد که متشکل از حروف 'A' تا 'Z' می باشد. ۱۰ اشاره دیگر در این زبان اشاره مربوط به اعداد ۰ تا ۹ آمریکایی است. برای هر کدام از این اشاره ها ۲۵ نمونه تصویر وجود دارد. این علائم چرخش کم دست، شرایط نوری متفاوت و اشاره هایی که ساختار مشابه ای دارند را شامل می شوند. برای تهیه این اشاره ها از ۵ شخص متفاوت استفاده شده است. در شکل ۸ اشاره های مربوط به حروف زبان آمریکایی نشان داده شده است.



شکل ۸) مجموعه داده مربوط به حروف زبان آمریکایی[۷]

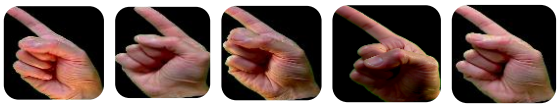
در شکل ۹ اشاره های مربوط به اعداد ۰ تا ۹ زبان آمریکایی نشان داده شده است .



شکل ۹) اشاره های اعداد ۰ تا ۹ آمریکایی[۷]

۳-۳-۱.چالش های موجود در مجموعه داده

اشاره های مربوط به زبان آمریکایی دارای ویژگی های متفاوتی هستند به طور مثال این اشاره ها در شرایط نوری متفاوتی عکس برداری شده است. نمونه هایی از این تغییرات نوری در شکل ۱۰ نمایش داده شده است که مربوط به کلاس حرف A می باشد.



شکل ۱۰) تنوع در نور پردازی حرفZ

این مجموعه داده در زوایای مختلف دست نیز عکس برداری شده است که تنوع درون کلاسی و تغییرات موجود در حرف E را در شکل ۱۱ مشاهده می کنید .



شکل ۱۱) تنوع در زوایای حرف E موجود در مجموعه داده

در شکل۱۲ چند نمونه از حروف زبان اشاره آمریکایی مشاهده می شود که دارای ساختار تقریبا یکسانی هستند و وجود این گونه از اشاره های مشابه در مجموعه داده باعث کاهش دقت و عملکرد روش در بازشناسی حروف می گردد.



A M N E S T

شکل ۱۲) برخی از اشاره ها با ساختار یکسان در زبان اشاره آمریکایی

۳-۳-۲. آزمایش ها و نتایج بر روی مجموعه داده حروف و اعداد زبان اشاره آمریکایی

از آنجایی که نرخ بازشناسی روش پیشنهادی برای تصاویر آموزشی در انجام آزمایش ها همواره برابر با ۱۰۰٪ می باشد از آوردن آن خودداری شده و در همه ی موارد نتایج بازشناسی داده های آزمایشی را گزارش کرده و مورد بررسی قرار می دهیم. در جدول ۱ با مقادیر متفاوتی از k-fold cross validation ، آزمایش ها انجام شده و با افزایش مقدار K میزان آموزش داده ها در شبکه های عصبی افزایش یافته و شاهد افزایش میزان بازشناسی در مجموعه داده مربوطه خواهیم بود. جدول ۱ شامل تصاویر مربوط به حروف و اعداد آمریکایی متشکل از ۶۵۰ تصویر از حروف و همچنین ۲۵۰ تصویر از اعداد آمریکایی است.

جدول۱: نتایج مربوط به حروف و اعداد مجموعه داده آمریکایی

مقدار K	میزان دقت حروف	میزان دقت اعداد
۲	۸۵,۶۹	۹۴,۰۸
۴	۹۵,۷۰	۹۶,۴
۵	۹۵,۷۶	۹۷,۲
۸	۹۶,۱۰	۹۷,۷

از جدول ۱ مشخص است که مقدار 8-fold cross validation بهترین مقدار را دارا بوده و عملکرد بهتری نسبت به سایر مقادیر دارد چرا که از داده های تست کمتری استفاده کرده و مجموعه داده ها را به قسمت های بیشتری تقسیم کرده است. ما مقدار ۵ را برای روش ارائه شده انتخاب می کنیم چرا که داده های تست بیشتری در نظر گرفته می شود و عملکرد روش ارئه شده بیشتر مورد ارزیابی قرار می گیرد. ماتریس آشفتگی مربوط به اعداد آمریکایی در پنج دوره آموزشی در جدول ۲ نشان دهنده ی میزان نرخ بازشناسی و تداخل این اشاره ها با یکدیگر است. بدلیل بزرگی ماتریس آشفتگی مربوط به حروف فقط ماتریس آشفتگی مربوط به اعداد گزارش می شود.

جدول۲)ماتریس آشفتگی اعداد آمریکایی

	0	1	2	3	4	5	6	7	8	9
0	96	4	0	0	0	0	0	0	0	0
1	0	100	0	0	0	0	0	0	0	0
2	0	0	96	0	4	0	0	0	0	0
3	0	0	0	100	0	0	0	0	0	0
4	0	0	0	0	92	8	0	0	0	0
5	0	4	0	4	0	92	0	0	0	0
6	0	0	0	12	0	0	76	12	0	0
7	0	0	0	0	0	0	4	88	8	0
8	0	0	0	0	0	0	0	0	100	0
9	0	0	0	0	0	0	0	0	0	100

با توجه به ماتریس های آشفتگی مربوط به اشاره های آمریکایی نرخ بازشناسی مربوط به بیشترین و کمترین دقت هر یک از اشاره ها در جدول ۳و۴ نشان داده شده است.

جدول۳)نرخ بازشناسی ، خطا ودقت برای اعداد آمریکایی

اشاره ها	طبقه بندی نادرست	طبقه بندی درست	نرخ بازشناسی
۱،۳،۸،۹	۰	۲۵	۱۰۰
۲،۰	۱	۲۴	۹۶
۴،۵	۲	۲۳	۹۲
۷	۳	۲۱	۸۸
۶	۶	۱۹	۷۶

جدول۴)نرخ بازشناسی ، خطا ودقت برای حروف آمریکایی

اشاره ها	تعدادطبقه بندی نادرست	تعدادطبقه بندی درست	نرخ بازشناسی
z,y,x,w,n,k,j,g,d,c,a	۰	۲۵	۱۰۰
p,l,i,f,e	۱	۲۴	۹۶
v,u,t,s,r,q,o,b	۲	۲۳	۹۲
h,m	۵	۲۰	۸۰

با توجه به جداول ۳و۴ ، بیشترین خطا در اشاره هایی دیده می شود که ساختار مشابه ای با یکدیگر دارند.

۳-۳-۴. مقایسه با روش های دیگر

نتایج مربوط به مقایسه روش پیشنهادی با مقاله [۸] که در سال ۲۰۱۴ از حروف و اعداد زبان اشاره آمریکایی استفاده کرده است و روش ویولت[۵] در جدول ۵ قابل مشاهده است. نتایج حاکی از عملکرد مناسب روش پیشنهادی در مقایسه با روش [۸]و روش ویولت [۵] را نشان می دهد. نتایج مربوط به روش پیشنهادی و روش ویولت [۵] میانگین ۱۰ دوره آموزش با 5-fold cross validation و با استفاده از شبکه عصبی می باشد.

جدول ۵ :مقایسه روش پیشنهادی با سایر روش ها در مجموعه حروف

روش استفاده شده	نرخ بازشناسی حروف	نرخ بازشناسی اعداد
روش پیشنهادی	**۹۵،۷۶**	**۹۷،۲**
روش HOG[۸]	۹۳	۹۸
روش ویولت[۵]	۵۳،۹۲	۶۵،۲

۴. نتیجه گیری

در این مقاله یک روش جهت بازشناسی حروف و اعداد ایستای آمریکایی ارائه شده است. در روش معرفی شده نیازی به هر گونه دستکش و یا لوازم جانبی نمی باشد. این روش تنها به تصاویر اشاره دست که توسط دوربین دیجیتال تهیه می شود نیاز دارد. شناسائی علائم در شرایط نوری متفاوت و چرخش این علائم صورت گرفته است. روش ارائه شده در دو فاز مطرح گردید : استخراج ویژگی و طبقه بندی. در فاز استخراج ویژگی از یک فیلتر گابور همراه با لبه های تصاویر دست استفاده شد. در فاز دوم از ویژگی های استخراج شده جهت آموزش شبکه عصبی پرسپترون چند لایه استفاده می شود. نتایج حاصل از بازشناسی حروف و اعداد زبان اشاره آمریکایی نشان دهنده ی عملکرد مناسب روش پیشنهادی در مقایسه با سایر روش ها می باشد که می توان این پژوهش را روی علائم فارسی ادامه داد.

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قطعه‌بندی تصویر مبتنی بر خوشه‌بندی میدان تصادفی مارکوف فازی و اتوماتای یادگیر سلولی

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چکیده - قطعه‌بندی تصویر یک وظیفه مهم در پردازش تصویر و بینایی کامپیوتر است که توجه بسیاری از پژوهشگران را به خود معطوف کرده است. میدان تصادفی مارکوف فازی *(FMRF)* یک مدل میدان تصادفی مارکوف *(MRF)* در فضای فازی است که با فازیت و تصادفی بودن داده‌ها بصورت همزمان مقابله می‌کند. در این مقاله روشی با عنوان *FMRF-CLA*، بر اساس مدل *FMRF* و اتوماتای یادگیر سلولی *(CLA)*، برای بهبود کارایی و دقت روش *MRF* پیشنهاد شده است. تشابه ساختاری دو مدل *CLA* و *FMRF*، دلیل انتخاب خوشه‌بندی *CLA* برای برچسب‌گذاری اولیه *FMRF* می‌باشد. نتایج بدست آمده بیان از کارایی قابل قبول روش پیشنهادی دارد.

کلید واژه- خوشه‌بندی، قطعه‌بندی تصویر، میدان تصادفی مارکوف، میدان تصادفی مارکوف فازی، اتوماتای یادگیر سلولی.

۱- مقدمه

قطعه‌بندی تصویر یکی از گام‌های اساسی در بسیاری از وظایف پردازش تصویر و بینایی کامپیوتر است. قطعه‌بندی تصویر به معنی تقسیم تصویر به دو یا بیش از دو قطعه است، بطوریکه هر قطعه همگن باشد، به این معنی که پیکسل‌های هر قطعه با یکدیگر بیشترین شباهت و با پیکسل‌های قطعه‌های دیگر کمترین شباهت را داشته باشند. این روش بعنوان استخراج ویژگی برای کاربردهای تشخیص الگو، تشخیص شئ، بازیابی تصویر، تطبیق استریو و بسیاری از وظایف دیگر مورد استفاده قرار می‌گیرد. از جمله کارهایی که در این زمینه به خوبی عمل کرده‌اند و نتایج قابل قبولی بدست آورده‌اند می‌توان به قطعه-بندی تصاویر ماموگرافی با استفاده از خوشه‌بندی مبتنی بر میدان تصادفی مارکوف [۱]، قطعه‌بندی سریع و مقاوم با استفاده از خوشه‌بندی c-میانگین فازی با اطلاعات مکانی [۲]، قطعه-بندی با استفاده از خوشه‌بندی k-میانگین و آستانه‌گذاری اتسو [۳]، برش‌های نرمالسازی شده و قطعه‌بندی تصویر [۴] و گام-های تصادفی برای قطعه‌بندی تصویر [۵] اشاره کرد.

خوشه‌بندی یک تکنیک دسته‌بندی بدون نظارت است که در آن مجموعه‌ای از داده‌ها که معمولاً بردارهایی در فضای چند بعدی می‌باشند، بر اساس یک معیار شباهت یا عدم شباهت، به تعداد مشخصی خوشه تقسیم می‌شوند. روش‌های متعددی برای تعریف شباهت بین داده‌ها به صورت کمی وجود دارد که فاصله اقلیدسی و فاصله کسینوسی از مرسوم‌ترین آن‌ها می‌باشد. از جمله کارهایی که در زمینه خوشه‌بندی دادگان انجام شده است می‌توان به خوشه‌بندی k-میانگین [۶]، خوشه‌بندی c-میانگین فازی [۷]، خوشه‌بندی طیفی [۸]، خوشه‌بندی سلسله مراتبی [۹]، خوشه‌بندی مورچگان [۱۰]، خوشه‌بندی شبکه عصبی خودسازمانده [۱۱] و خوشه‌بندی تکاملی [۱۲] اشاره کرد

یکی از مهمترین کاربردهای خوشه‌بندی در بینایی کامپیوتر در زمینه قطعه‌بندی تصویر (رنگی، پزشکی، ماهواره‌ای و غیره) می باشد. در این حالت، مقادیر پیکسل‌ها، داده‌های فضای خوشه‌بندی را تشکیل می‌دهند. تعداد خوشه‌ها به تعداد قطعه-های مطلوب اشاره دارد و همچنین هر خوشه بدست آمده بیانگر یک قطعه است. دقت تصاویر قطعه بندی شده توسط خوشه بندی مرتبط با دقت الگوریتم خوشه بندی است. چنانچه الگوریتم خوشه‌بندی از دقت بالایی برخوردار باشد و نسبت به داده‌های پرت و نویز مقاوم باشد، آنگاه منجر به نتایج قطعه‌بندی مطلوب خواهد شد.

مدل میدان تصادفی مارکوف فازی (FMRF) [۱۳]، یک مدل میدان تصادفی مارکوف در فضای فازی است، که مفهوم متغیرهای تصادفی فازی را در فرآیند مورد نظر اعمال می‌کند. در مدل میدان تصادفی مارکوف یک داده فقط می‌تواند یک مقدار از فضای برچسب $\mathcal{L}$ بگیرد، که به این معنی است که هر داده فقط و فقط باید به یک برچسب تعلق داشته باشد. در حالیکه مدل میدان تصادفی مارکوف فازی اجازه می‌دهد هر داده همزمان به همه برچسب‌های موجود در فضای برچسب $\mathcal{L}$ با متغیرهای مختلف تعلق داشته باشد. تخمین مدل میدان تصادفی مارکوف فازی نیز همانند میدان تصادفی مارکوف تحت چارچوب حداکثر پسین انجام می‌گیرد، بنابراین می‌توان برای حل آن روش‌های کمینه سازی انرژی از قبیل α-گستر [۱۴] و انتشار باور حلقوی [۱۵]را بکار گرفت.

اتوماتای یادگیر سلولی(CLA) [۱۶]، سیستمی با رفتار برآیندی است. در این مدل اجزاء ساده‌ای به نام سلول از طریق ارتباط محلی و بر اساس قانون محلی حاکم، اطلاعات درون خود را پردازش می‌نمایند. هر اتوماتای یادگیر سلولی، از یک اتوماتای سلولی تشکیل شده که هر سلول آن به یک یا چند اتوماتای یادگیر مجهز می‌باشد. وضعیت هر سلول در هر مرحله بر اساس عمل انتخابی اتوماتای یادگیر متناظرش مشخص می‌شود. در این مدل قانون محلی در محیط حاکم بوده و بر اساس این قانون، عمل انتخاب شده سلول، پاداش و یا جریمه دریافت می‌نماید. دریافت پاداش و یا جریمه باعث بروز شدن ساختار اتوماتای یادگیر سلولی به منظور نیل به یک هدف مشخص می‌گردد. از زمان معرفی اتوماتای یادگیر سلولی تاکنون، انواع گوناگونی از این مدل ارائه شده است. از آن جمله می‌توان به انواع اتوماتای یادگیر سلولی ناهمگام [۱۷]، اتوماتای یادگیر سلولی همگام باز [۱۸] و مدل‌های ترکیبی محاسبات تکاملی بر مبنای اتوماتای یادگیر سلولی [۱۹] و بهینه سازی دسته جمعی ذرات با اتوماتای یادگیر سلولی [۱۹] اشاره نمود. این مدل‌ها در کاربردهای وسیعی چون پردازش تصاویر (کاهش نویز، قطعه‌بندی و تشخیص لبه) [۲۰]، تخصیص منابع در شبکه های موبایل (تخصیص کانال و پذیرش کانال) [۲۱, ۲۲]، مدل سازی پدیده‌ها (انتشار شایعه و بازار اقتصادی) [۲۳, ۲۴]و خوشه بندی [۲۵] استفاده شده است.

هدف از این مقاله ارائه یک مدل قطعه‌بندی تصویر مبتنی بر خوشه‌بندی میدان تصادفی مارکوف فازی و اتوماتای یادگیر سلولی، با بهره گیری از خاصیت فازی مدل FMRF می‌باشد. خاصیت فازی FMRF موجب می‌شود، داده‌هایی نظیر داده‌های مرزی، نویزی و پرت بر روی نتیجه بهینه سازی تاثیر نگذارند و برچسب صحیح به داده‌ها (پیکسل‌ها) تعلق یابد، و به نوعی با عدم قطعیت در تصمیم‌گیری مقابله می‌کند. میدان تصادفی مارکوف فازی همانند MRF برای مدلسازی نیاز به برچسب-گذاری اولیه دارد. این مرحله در کارایی و عملکرد مدلسازی از اهمیت ویژه‌ای برخوردار است. برای برچسب‌گذاری اولیه داده‌ها، از روش خوشه‌بندی اتوماتای یادگیر سلولی پیشنهاد شده در [۲۶] استفاده شده است. طی آزمایشات انجام گرفته روش پیشنهادی با الگوریتم‌های قطعه‌بندی مبتنی بر خوشه‌بندی Kmeans [۳]، FCM [۲] و MRF [۱] مقایسه شده و بر اساس نتایج بدست آمده عملکرد بهتری از خود نشان داده است. ادامه این مقاله بدین صورت سازماندهی شده است. در بخش ۲، مدل خوشه‌بندی FMRF-CLA پیشنهادی بیان می‌گردد، که شامل برچسب‌گذاری اولیه، تعریف تابع انرژی و روش کمینه سازی انرژی است. در بخش ۳، آزمایشات بهمراه تجزیه و تحلیل نتایج ارائه می‌شود. در پایان بخش ۴ نتیجه‌گیری مقاله را بیان می‌کند.

۲- مدل خوشه‌بندی میدان تصادفی مارکوف فازی پیشنهادی

در این بخش مدل خوشه‌بندی FMRF پیشنهاد می‌گردد. در مدل خوشه‌بندی MRF، یک داده (پیکسل) تنها می‌تواند یک مقدار از فضای وضعیت (مجموعه برچسب‌ها) بگیرد، که بر تعلق یک داده فقط به یک خوشه دلالت دارد. در حالیکه مدل FMRF اجازه می‌دهد هر داده بصورت همزمان به تمام خوشه‌ها با مقدار عضویت مختلفی تعلق داشته باشد. بنابراین هر داده یک بردار $(u_1,u_2,\ldots,u_k)$، با $u_1+u_2+\ldots+u_k=1$ دارد، و مقدار u_i، $i=1,2,\ldots,K$، بیانگر احتمال عضویت داده به برچسب i است. اگر $u_i=1$، مدل FMRF همانند مدل MRF متداول عمل می‌کند. در این مدل نیز استنتاج همانند مدل MRF انجام می‌پذیرد و روش-های کمینه سازی برای تولید برچسب‌گذاری بهینه اعمال می-شوند. تنها تفاوت مدل FMRF با مدل متداول MRF، نحوه تعریف تابع انرژی می‌باشد. این تابع باید طوری بیان شود، که بتواند بر اساس درجه عضویت هر داده به هر برچسب i از مجموعه برچسب‌های $\mathcal{L}$، انرژی را برای هر گره از میدان تصادفی محاسبه نماید.

۲-۱- برچسب‌گذاری اولیه

کارایی مدل FMRF همانند MRF به برچسب‌گذاری اولیه بستگی دارد. از این رو نقش برچسب‌گذاری اولیه در عملکرد مدل بدیهی است. در این مقاله از روش خوشه‌بندی اتوماتای یادگیر سلولی نامنظم ارائه شده در [۲۶] برای برچسب‌گذاری اولیه FMRF استفاده خواهیم کرد. الگوریتم فوق برای خوشه‌بندی دادگان دیتاست پیشنهاد شده و نتایج آن رضایتبخش بوده است. این الگوریتم در مقایسه با روش‌های K-means [۶]، FCM [۷] و SOM [۱۱] بهتر عمل می‌کند. از خصوصیات قابل توجه آن، استفاده از اطلاعات ساختاری و همسایگی داده‌ها، توانایی تفکیک دقیق داده‌ها و همچنین فرار از کمینه محلی است.

در این مقاله، الگوریتم خوشه‌بندی فوق را برای کاربرد قطعه‌بندی تصویر بکار می‌گیریم. دلیل استفاده از آن خاصیت همسایگی CLA است، که به خوبی اطلاعات همسایگی پیکسل‌ها را مدلسازی می‌کند، و به نوعی با مدل FMRF شباهت دارد. در

مسئله قطعه‌بندی تصویر، هر پیکسل به یک سلول مرتبط می‌شود. تعداد اعمال اتوماتا برابر با تعداد ناحیه‌های مطلوب تنظیم می‌گردد. با استفاده از این روش تصویر را خوشه‌بندی می‌کنیم. آنگاه مقدار عضویت هر داده نسبت به تمام مراکز خوشه در بازه [0,1] از طریق معادله (۱) محاسبه می‌شود. سپس آن را به عنوان بردار عضویت داده به هر یک از برچسب‌ها، به گره متناظر داده در FMRF تخصیص می‌دهیم. در نهایت الگوریتم کمینه‌سازی انرژی، این بردار را بعنوان اطلاعات پیشین برای ادامه روند بهینه‌سازی مورد استفاده قرار می‌دهد.

$$w_{ij} = \frac{1}{\sum_{k=1}^{c}\left(\frac{\|x_i - c_j\|}{\|x_i - c_k\|}\right)^{\frac{2}{m-1}}} \qquad (۱)$$

در معادله فوق $X=\{x_1,x_2,\ldots,x_n\}$ مجموعه داده‌ها، $C=\{c_1,c_2,\ldots,c_n\}$ مجموعه مراکز خوشه، w_{ij} مقدار عضویت داده iام به خوشه jام می‌باشد و m میزان فازیت را مشخص می‌کند، که باید بصورت $m\geq 1$ باشد. مقدار m بزرگ منجر به مقادیر عضویت کوچکتر و در نتیجه تعلق فازی می‌شود، و در مقابل $m=1$ منجر به تولید مقادیر عضویت {0,1} می‌گردد، که بر تعلق کریسپ دلالت دارد. معمولاً در بیشتر مسائل $m=2$ فرض می‌شود

۲-۲- تعریف تابع انرژی

تعریف تابع انرژی مهمترین بخش مسائل مبتنی بر میدان تصادفی مارکوف است. تعریف صحیح این تابع منجر به برچسب-گذاری بهینه با پیچیدگی زمانی پایین خواهد شد، البته این در صورتی میسر خواهد بود که روش استنتاج کارآمدی برای تعیین برچسب‌گذاری بهینه بکار گرفته شود. یکی از مسائل مهم تعریف سیستم همسایگی است. سیستم همسایگی برای هر گره در این روش از نوع ۴-همسایگی می باشد، یعنی هر چهار گره (بالا، پایین، چپ و راست) احاطه کننده گره i، همسایه آن می باشند.

انرژی درستنمایی بصورت مجموع پتانسیل‌های درستنمایی تعریف می شود. در مدل خوشه‌بندی میدان‌های تصادفی مارکوف فازی، انرژی پتانسیل درستنمایی بر اساس مقادیر عضویت داده‌ها به برچسب‌ها تعیین می‌شود، و بصورت معادله (۲) تعریف می گردد.

$$V_F(y_i \mid x_i) = e^{-w_{y_i x_i}} \qquad (۲)$$

که y_i مقدار داده مشاهده شده i ، x_i برچسب گره i و $w_{y_i x_i}$ درجه عضویت داده y_i به برچسب x_i است. با استفاده از منفی نمایی، مقدار عضویت بالا منجر به تولید انرژی کمتر خواهد شد و بالعکس. پتانسیل درستنمایی فوق منجر به تشابه داده مشاهده شده با برچسب تخصیص یافته می‌گردد.

به منظور حذف گسستگی مکانی از برچسب گذاری، پتانسیل دسته مرتبه دو تعریف می شود. این تابع بررسی می‌کند که دو داده (پیکسل) همسایه در یک خوشه قرار دارند یا خیر. معمولاً پتانسیل دسته مرتبه دو از مدل ایزینگ تبعیت می‌کند که بصورت معادله (۳) قابل تعریف است.

$$V_F(x_i, x_{i'}) = \begin{cases} -\beta, (x_i = x_{i'}) \\ \beta, (x_i \neq x_{i'}) \end{cases} \qquad (۳)$$

که β یک جریمه ثابت در بازه [0,1] و x_i ، x_i' برچسب‌های یک جفت گره همسایه در FMRF هستند. اگر برچسب دو گره مشابه باشد، مقدار جریمه β- منظور می‌شود و در غیر اینصورت مقدار جریمه β در نظر گرفته می‌شود. پتانسیل دسته از تخصیص دو برچسب مختلف به داده‌های مشابه همسایه جلوگیری می‌کند.

در نهایت تابع انرژی بصورت حاصلجمع انرژی درستنمایی و انرژی مرتبه دو، که در معادله (۴) بیان شده است، بدست می‌آید.

$$U_F(x \mid y) = \sum_{i \in S} V_F(y_i \mid x_i) + \sum_{i' \in S} \sum_{N_i} V_F(x_i, x_{i'}) \qquad (۴)$$

با توجه به عملکرد مطلوب روش کمینه‌سازی انرژی انتشار باور حلقوی [۱۵] در کاربردهای مبتنی بر میدان تصادفی مارکوف، استنتاج راه حل بهینه از میدان تصادفی مارکوف فازی توسط آن صورت می‌گیرد.

۲-۳- کمینه‌سازی تابع انرژی با انتشار باور حلقوی

روش کمینه‌سازی انتشار باور حلقوی بطور گسترده در کاربردهای مبتنی بر MRF استفاده می‌شود و برچسب‌گذاری با حداقل انرژی بدست می‌آورد. در این مقاله، خوشه‌بندی بهینه بوسیله آن استنتاج می‌شود. در واقع، انتشار باور چیزی بیشتر از یک الگوریتم تکراری نیست، که بوسیله انتشار مستمر پیام‌های محلی بین گره‌های گراف میدان‌های تصادفی مارکوف کار می‌کند. در هر تکرار، هر گره پیام‌هایی را به گره‌های همسایه‌اش ارسال می‌کند، همچنین پیام‌های ارسالی از آن گره‌ها را نیز می‌پذیرد. این فرآیند تکرار می‌شود تا زمانیکه همه پیام‌ها پایدار شوند، یعنی دیگر تغییر نکنند. بصورت خلاصه مراحل این الگوریتم در زیر بیان شده است:

۱. قبل از اینکه یک گره p یک پیام به گره دیگر q ارسال کند، باید ابتدا با بقیه همسایگانش بوسیله دریافت پیام

از آن‌ها، مشورت نماید. در طول انتشار باور، همه گره-های میدان تصادفی مارکوف با یکدیگر همکاری و تعامل می‌کنند تا در مورد برچسب‌هایی که سرانجام باید انتخاب کنند، تصمیم بگیرند. این همکاری بین گره‌ها بوسیله تبادل نظرات (یعنی پیام‌ها)، که در طول الگوریتم انجام می‌شود، منعکس می‌گردد.

۲. بروزرسانی پیام‌ها، تا زمانیکه همه پیام‌ها سرانجام همگرا شوند، ادامه می‌یابد. سپس، بعد از همگرایی، یک مجموعه از باورها برای هر گره p در میدان تصادفی مارکوف محاسبه می‌شود. باور، تقریباً بیان می‌کند، چقدر محتمل است که گره p فکر کند باید برچسب x_p به او اختصاص یابد.

۳. در هر تکرار یک‌مرتبه همه باورها محاسبه می‌شود، سپس هر گره، با برچسبی که دارای بیشترین باور است، اختصاص می‌یابد.

روال فوق تکرار می‌شود تا زمانیکه مقدار انرژی کمینه‌شده پایدار شود و در چند تکرار متوالی بدون تغییر باقی بماند.

۳- نتایج آزمایشات

در این بخش نتایج آزمایشات انجام شده برای بررسی کارایی مدل پیشنهادی در قطعه‌بندی تصویر ارائه می‌گردد. برای این منظور تصاویر متعدد از دسته‌های مختلف دیتاست Berkeley [۲۷] انتخاب شده است. تعداد خوشه‌ها، که بیانگر تعداد ناحیه-های (قطعه‌ها) مورد نظر است، برای تمام تصاویر برابر با ۲ در نظر گرفته شده است، که تصویر را به دو بخش پیش‌زمینه و پس‌زمینه تقسیم می‌کند. به منظور ارزیابی روش پیشنهادی، نتایج قطعه‌بندی با روش‌های K-means [۳]، FCM [۲] و مدل MRF [۱] مقایسه شده است. دلیل اصلی مقایسه مدل پیشنهادی با روش‌های نامبرده، وجه تشابه آن‌ها در استفاده از خوشه‌بندی برای قطعه بندی تصویر می‌باشد.

نتایج حاصل از اعمال الگوریتم‌ها از نظر انرژی کمینه شده، معیار تانیموتو و میانگین مربعات خطا بررسی می‌شود. از این معیارها برای مقایسه عملکرد الگوریتم‌ها استفاده می‌گردد.

برچسب‌گذاری با حداقل انرژی به معنی رعایت محدودیت-های مدل میدان تصادفی مارکوف فازی است. بطوریکه برچسب تخصیص یافته از یک سو باید با داده مشاهده شده مطابقت داشته باشد، و از سوی دیگر باید با همسایگان مشابه خود سازگار باشد. مطمئناً الگوریتمی که انرژی بیشتری را کمینه نماید، مقبول است. معیار تانیموتو برای بیان شباهت بین دو تصویر کاربرد دارد، که مقداری در بازه [0,1] برمی‌گرداند. مقدار بیشتر این معیار به معنی شباهت بیشتر بین تصویر قطعه‌بندی شده با تصویر مرجع است. در نتیجه مقدار بیشتر این معیار به منزله قطعه‌بندی مطلوب‌تر است. میانگین مربعات خطا برای اندازه-گیری خطای بین قطعه‌بندی تصویر بدست آمده با قطعه‌بندی صحیح بکار می‌رود. مقدار آن در بازه [0,1] است. مقدار کمتر این معیار به معنی اختلاف کمتر نتیجه با راه حل صحیح، و تشابه بیشتر نتیجه قطعه‌بندی الگوریتم با قطعه‌بندی صحیح است. شکل ۱ چند نمونه از تصاویر قطعه‌بندی شده را نشان می‌دهد و جداول ۱-۳ به ترتیب مقادیر ارزیابی مربوط به مقدار انرژی کمینه‌شده، معیار تانیموتو و میانگین مربعات خطا را لیست کرده‌اند.

جدول ۱ مقدار انرژی نتایج قطعه‌بندی توسط روش‌های مختلف را نشان می‌دهد. مقدار انرژی کمتر به معنی جریمه و هزینه کمتر برای برچسب‌گذاری بدست آمده است. برچسب-گذاری مطلوب است که کمترین انرژی را داشته باشد. از انرژی کمتر چنین استنتاج می‌شود، که برچسب‌گذاری بدست آمده هر دو اصل تشابه با داده مشاهده شده و هموار درون ناحیه را رعایت کرده است، که اساس کار یک الگوریتم قطعه‌بندی را تشکیل می‌دهد.

جدول ۱: مقدار انرژی نتایج قطعه‌بندی توسط روش‌های خوشه‌بندی مختلف و مدل پیشنهادی

شماره تصویر	Kmeans[3]	FCM[2]	MRF[1]	FMRF-CLA
۱	۶۹۱۴۸	۶۸۵۹۰	۵۸۹۰۴	۴۲۷۵۴
۲	۵۶۶۶۲	۵۵۹۴۹	۵۱۸۹۹	۴۷۴۱۷
۳	۵۴۷۷۰	۵۳۸۴۸	۴۶۳۱۷	۴۲۰۲۴
۴	۴۵۳۹۱	۴۳۹۴۳	۴۰۱۹۳	۳۴۹۱۰
۵	۲۴۸۱۴	۲۳۹۷۷	۲۱۶۸۱	۲۰۵۲۴
۶	۴۳۶۴۱	۴۲۵۸۰	۳۷۳۴۸	۳۲۲۸۰

در میان روش‌های استفاده شده بدترین عملکرد مربوط به روش Kmeans و بهترین عملکرد مربوط به مدل پیشنهادی

FMRF-CLA است. مدل قطعه بندی مبتنی بر خوشه‌بندی MRF که از روش کمینه‌سازی ICM برای حصول برچسب‌گذاری بهینه استفاده می‌کند، با وجود اینکه موفق به کسب بهینه سراسری نمی‌شود و بصورت محلی عمل می‌کند، نسبت به روش-های K-means و FCM عملکرد بهتری از خود نشان داده است. با مشاهده جدول ۱ می‌توان به وجود خاصیت فازی در FMRF پی برد. مقادیر عضویت فازی موجب شده است تا برچسب‌های صحیح به داده‌ها (پیکسل‌ها) تخصیص یابد و در نتیجه برچسب-گذاری با انرژی کمتر حاصل شود. مدل پیشنهادی FMRF-CLA برای تمام تصاویر مورد آزمایش، برچسب‌گذاری با انرژی کمتر از تمام روش‌ها بدست آورده است.

معیار تانیموتو برای بیان شباهت بین دو تصویر بکار استفاده می‌شود، که مقداری در بازه [0,1] برمی‌گرداند. مقدار بیشتر این ضریب به معنی شباهت بیشتر بین تصویر قطعه‌بندی شده با تصویر مرجع است. در نتیجه مقدار بیشتر این ضریب به منزله قطعه‌بندی بهتر است. این معیار از طریق معادله (۵) قابل محاسبه است.

$$coeff = \frac{I^t S}{\|I\|^2 + \|S\|^2 - I^t S} \qquad (۵)$$

که I تصویر مرجع و S تصویر قطعه‌بندی شده است و t بر ترانهادن دلالت دارد. جدول ۲ مقادیر معیار تانیموتو حاصل از اجرای الگوریتم‌های مختلف روی تصاویر دیتاست نشان می‌دهد. همانطور که انتظار می‌رفت، مدل FMRF-CLA پیشنهادی، به ازای تمام تصاویر مورد آزمایش، دارای بیشترین مقدار تانیموتو است. کسب مقدار تانیموتو بیشتر، به منزله قطعه‌بندی بهینه و قابل قبول می‌باشد.

میانگین مربعات خطا (MSE) پیکسل به پیکسل با افزودن تفاضل مربعات تمام پیکسل ها و تقسیم بر تعداد کل پیکسل ها محاسبه می شود. محدوده MSE در بین [0,1] است، که مقدار پایین تر آن به معنای قطعه بندی بهتر است. این معیار بصورت معادله (۶) محاسبه می‌گردد.

$$MSE(I,S) = \frac{\sum_{i=0}\sum_{j=0}(I(i,j),S(i,j))^2}{MN} \qquad (۶)$$

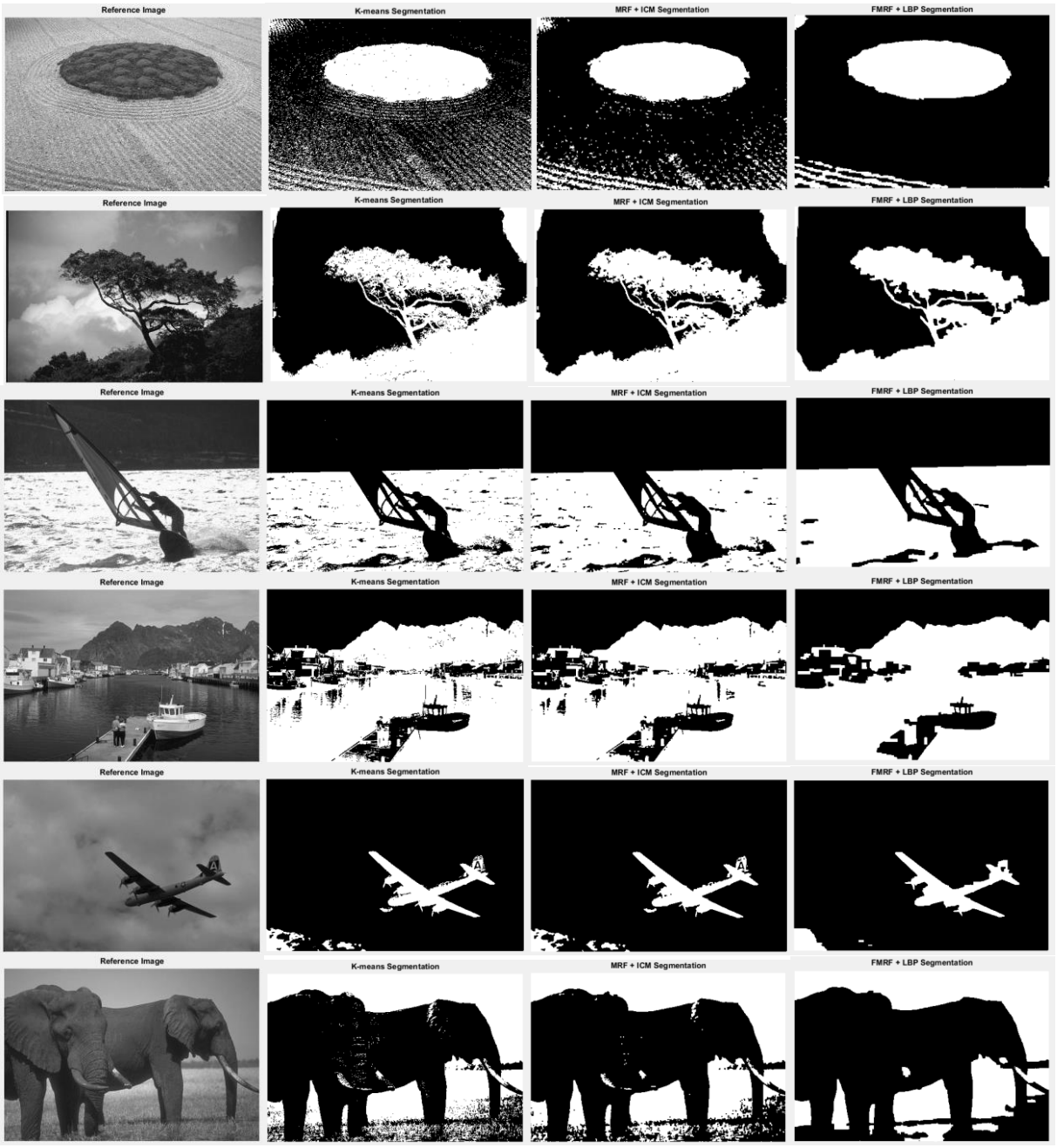
که M و N به ترتیب تعداد سطر و ستون های تصویر ورودی هستند، و همچنین I و S به ترتیب، تصاویر اصلی و قطعه بندی شده هستند. جدول ۳ مقادیر میانگین مربعات خطای حاصل از اجرای الگوریتم‌های مختلف روی تصاویر دیتاست را نشان می-دهد. بر اساس این معیار، کارایی قابل قبول مدل FMRF-CLA در مقابل مدل MRF و دیگر روش‌ها ثابت می‌گردد. مدل پیشنهادی FMRF-CLA برچسب‌گذاری بهینه را برای کل تصاویر دیتاست بدست آورده است. قطعه‌بندی حاصل شده توسط این مدل با قطعه‌بندی صحیح دارای کمترین اختلاف می‌باشد، و به همین دلیل مقدار میانگین مربعات خطای کمتر حاصل شده است.

جدول ۲: مقدار تانیموتو نتایج قطعه‌بندی توسط روش‌های خوشه‌بندی مختلف و مدل پیشنهادی

شماره تصویر	Kmeans[3]	FCM[2]	MRF[1]	FMRF-CLA
۱	۰.۷۷۴۲	۰.۷۸۳۲	۰.۸۵۱۳	۰.۹۱۶۵
۲	۰.۸۶۱۱	۰.۸۷۰۱	۰.۹۱۸۵	۰.۹۵۷۱
۳	۰.۸۸۹۱	۰.۸۹۴۸	۰.۹۲۵۷	۰.۹۶۴۸
۴	۰.۸۳۸۱	۰.۸۵۲۲	۰.۹۱۱۴	۰.۹۴۶۰
۵	۰.۸۱۷۸	۰.۸۳۰۹	۰.۸۷۸۰	۰.۹۱۵۹
۶	۰.۸۳۱۱	۰.۸۳۵۱	۰.۸۸۵۱	۰.۹۳۲۳

جدول ۳: مقدار میانگین مربعات خطای نتایج قطعه‌بندی توسط روش‌های خوشه‌بندی مختلف و مدل پیشنهادی

شماره تصویر	Kmeans[3]	FCM[2]	MRF[1]	FMRF-CLA
۱	۰.۰۹۳۷	۰.۰۹۱۴	۰.۰۷۳۹	۰.۰۴۳۵
۲	۰.۰۶۲۱	۰.۰۶۰۳	۰.۰۵۲۸	۰.۰۳۴۲
۳	۰.۰۶۷۳	۰.۰۵۷۲	۰.۰۴۸۰	۰.۰۳۳۸
۴	۰.۰۵۳۲	۰.۰۴۸۱	۰.۰۳۰۵	۰.۰۱۹۶
۵	۰.۰۴۴۵	۰.۰۳۰۱	۰.۰۲۶۶	۰.۰۱۷۱
۶	۰.۰۶۹۰	۰.۰۵۳۸	۰.۰۳۵۷	۰.۰۲۴۹



شکل ۱: تصاویر بنچ مارک دیتاست برکلی و نتایج قطعه‌بندی [۲۷]. به ترتیب از ستون چپ به راست: تصویر مرجع، نتایج روش‌های K-means[3]، MRF[۱] و روش پیشنهادی FMRF-CLA.

با مشاهده نتایج قطعه‌بندی تصاویر در شکل ۱ به وضوح می‌توان مشاهده کرد که مدل MRF جزئیات ریز تصویر را نیز در قطعه-بندی لحاظ کرده است که خود منجر به افزایش انرژی می‌شود. در حالیکه الگوریتم FMRF-CLA پیشنهادی نواحی همگن و یکنواخت را بدست آورده که موجب تفکیک آسان و سریع پیش-زمینه از پس‌زمینه می‌گردد. از این قطعه‌بندی می‌توان ویژگی-های مطلوب و بهتری را استخراج کرد، که پاسخگوی نیاز کاربردها و وظایف بینایی کامپیوتر و پردازش تصویر است.

۴- نتیجه‌گیری

در این مقاله یک روش خوشه‌بندی مبتنی بر میدان تصادفی مارکوف فازی و اتوماتای یادگیر سلولی با عنوان FMRF-CLA پیشنهاد گردید و برای قطعه‌بندی تصویر استفاده شد.

گام نخست در مدل FMRF برچسب‌گذاری اولیه است. برچسب‌گذاری اولیه نقش مهم و اساسی در عملکرد الگوریتم ایفا می‌کند. به همین منظور برچسب‌گذاری اولیه توسط روش

خوشه‌بندی اتوماتای یادگیر سلولی انجام شد. این روش در برابر نویز و داده‌های پرت مقاوم و پایدار است و ساختار همسایگی دادگان را در تولید نتیجه دخیل می‌کند. با استفاده از این روش داده‌ها (پیکسل‌ها) خوشه‌بندی گردید و با نتیجه حاصل از آن برچسب‌گذاری اولیه مدل میدان تصادفی مارکوف فازی انجام شد، تا در ادامه توسط روش کمینه‌سازی انرژی بهینه شود.

با توجه به مشابهت روش‌های کمینه‌سازی در دو مدل MRF و FMRF، الگوریتم کمینه‌سازی انرژی انتشار باور حلقوی، برای حصول برچسب‌گذاری با حداقل انرژی روی FMRF-CLA استفاده گردید.

روش پیشنهادی بر روی تصاویر دیتاست Berkeley اعمال شد. نتایج بدست آمده بیان از کارآمدی روش پیشنهادی FMRF-CLA نسبت به سایر الگوریتم‌های مطرح در این زمینه دارد. روش پیشنهادی تصاویر قطعه‌بندی با کمترین مقدار انرژی و خطا و با بیشترین مقدار تانیموتو حاصل کرده است. همچنین با مشاهده تصاویر قطعه‌بندی می‌توان به تأثیر ویژگی فازی موجود در مدل FMRF پی برد. این خاصیت مدل FMRF را نسبت به نویز و داده‌های تصادفی در مقایسه با مدل MRF متداول مقاوم ساخته است که نتیجه آن تولید قطعه‌بندی همگن با نواحی یکنواخت می‌باشد.

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ارائه‌ی یک الگوریتم خوشه‌بندی، تحت عنوان خوشه‌بندی قیفی برای زمانبندی استادان مشترک مابین دپارتمان‌ها

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چکیده - جدول زمانبندی دروس دانشگاهی یک مساله در کلاس مسائل سخت می‌باشد و بایستی برای هر نیم سال تحصیلی به طور مکرر انجام شود که این کاری طاقت فرسا می‌باشد. این مقاله ابتدا، بهبود رضایت‌مندی استادان مشترک مابین دپارتمان‌ها و سپس، کمینه‌سازی اتلاف منابع در دپارتمان‌ها را دنبال می‌کند. در این روش، ابتدا کلیه‌ی دپارتمان‌ها فرآیند زمانبندی‌شان را به طور محلی انجام می‌دهند، سپس به ترتیب عامل خوشه‌بند با استفاده‌ی از الگوریتم خوشه‌بندی قیفی پیشنهادی برای خوشه‌بندی استادان مشترک مابین دپارتمان‌ها و عامل پیمایشگر جهت یافتن منابع بلااستفاده مابین دپارتمان‌ها، به کارگرفته می‌شوند. پس از انجام فرآیند خوشه‌بندی و پیمایش، عمل نگاشت بر اساس قیود استادان مشترک در منابع مازاد صورت می‌گیرد، تا اهداف مساله حاصل گردند. مجموعه‌ی داده‌ای استفاده شده بر طبق نیازمندی‌ها در دنیای واقعی مابین دپارتمان‌های مختلف دانشگاه آزاد اسلامی واحد اهر می‌باشد.

کلید واژه- جدول زمانبندی دروس دانشگاهی، زمانبندی استادان مشترک، خوشه‌بندی

۱ - مقدمه

هدف مساله‌ی جدول زمانبندی دروس دانشگاهی (UCTTP) یافتن یک روش برای تخصیص کلیه‌ی رویدادها به برش‌های زمانی و کلاس‌های درسی ثابت می‌باشد، که البته نبایستی قیود موجود در این مساله نیز نقض گردند. رویدادها شامل دانشجویان، استادان، دروس و منابع نیز در برگیرنده‌ی امکانات و تجهیزات کلاس‌های درسی اعم از اتاق‌های تئوری/ عملی و برش‌های زمانی نیز شامل برش‌های زمانی روزانه/ هفتگی می‌باشند، که از یک موسسه به موسسه‌ی دیگر متفاوت هستند. البته هر کلاس درسی نیز دارای اجزاء مخصوص به خود می‌باشد که به صورت، امکانات سمعی و بصری (ویدئو پروژکتور)، تعداد صندلی‌های لازم برای دروس تخصیصی به آن کلاس‌های درسی (ظرفیت اتاق‌های)، تعداد تخته‌های سیاه و سفید مربوط به هر کلاس درسی و... مورد ملاحظه می‌باشند. این مساله بایستی دو قید سخت و نرم را هم در هنگام تخصیص رویدادها به منابع ارضاء نماید، به طوری که جداول زمانبندی امکان‌پذیر پس از ارضاء کامل کلیه‌ی قیود سخت، و ارتقاء درجه‌ی کیفیت جداول زمانبندی امکان‌پذیر تولید شده نیز با ارضاء قیود نرم، تا حد ممکن به دست می‌آیند[۱و۲ و۳ و۴ و۵ و۶].

۱-۱ - فرضیه

این مقاله، زمانبندی استادان مشترک (CLTTP) مابین دپارتمان‌های مختلف را بر مبنای منابع مازاد مابین دپارتمان‌ها، انجام می‌دهد. از الگوریتم خوشه‌بندی قیفی پیشنهادی جهت زمانبندی استادان مشترک استفاده شده است. پس برای رسیدن به اهداف مقاله، به ترتیب دو عامل با نام‌های خوشه‌بند و پیمایشگر در نظر گرفته می‌شوند. عامل خوشه‌بند خوشه‌بندی قیفی پیشنهادی استادان مشترک مابین دپارتمان‌ها را در خوشه‌ها با توجه به اولویت‌ها، قیود و ویژگی‌های مشترک، نیمه‌مشترک و غیر مشترک استادان (مشترک) انجام می‌دهد تا استادانی که از نظر انتخاب اولویت‌ها و قیود، مشابه و نزدیک به یکدیگراند در خوشه‌های با ارزش بیشتر (خوشه‌های اولیه و متراکم‌تر) جهت تخصیص به منابع درخواستی و اولویت‌دارشان قرار گیرند. پس از فرآیند خوشه‌بندی، نگاشت این خوشه‌ها مطابق با خوشه‌های استادان مشترک مابین دپارتمان‌ها به منابع مازاد پیمایش شده‌ی بین دپارتمانی توسط عامل پیمایشگر، صورت می‌پذیرد.

۲ -الگوریتم خوشه‌بندی قیفی پیشنهادی

الگوریتم پیشنهادی شامل چهار عامل: ۱- جدول زمانبندی، ۲- واسط $TA_i; i=1,2,\ldots$ام، i(هر دپارتمان یا عامل (MA))، ۳- (CA)خوشه‌بند و ۴- پیمایشگر $(TraA)$ می‌باشد که در شکل ۱، به همراه ارتباطاتشان در سه فاز نشان داده شده‌اند. فاز اول شامل

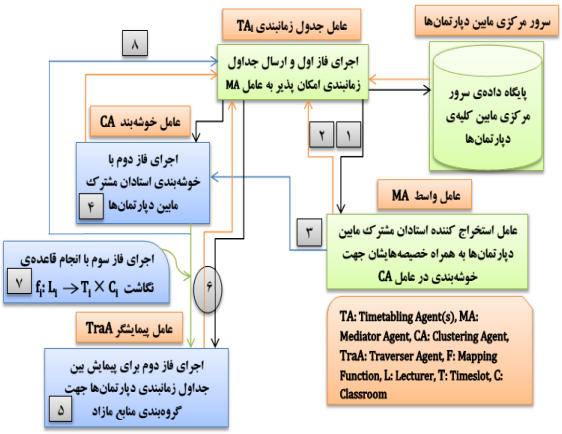
گام‌های ۱ و ۲ است که توسط عامل جدول زمانبندی برای تولید جداول زمانبندی امکان‌پذیر و فاقد برخورد برنامه‌ریزی می‌شوند. البته در این فاز، شناسایی و جمع آوری استادان مشترک مابین دپارتمان‌ها توسط عامل واسط در گام ۳ هم انجام می‌گیرد، فاز دوم شامل گام‌های ۴، ۵ و ۶ است که فرآیند خوشه‌بندی استادان مشترک مابین دپارتمان‌ها را در عامل خوشه‌بند بر روی منابع مازاد پیمایش شده‌ی هر دپارتمان توسط عامل پیمایشگر انجام می‌دهد و فاز سوم نیز در برگیرنده‌ی گام‌های ۷ و ۸ می‌باشد که فرآیند نگاشت خوشه‌های استادان مشترک را در منابع مازاد انجام می‌دهد. در فاز دوم، برای خوشه‌بندی استادان مشترک مابین دپارتمان‌ها در عامل خوشه‌بند خوشه‌بندی پیشنهادی طبق شکل ۲ ارائه شده است.

۲ ۱ -تشریح کامل جزئیات الگوریتم خوشه‌بندی قیفی پیشنهادی

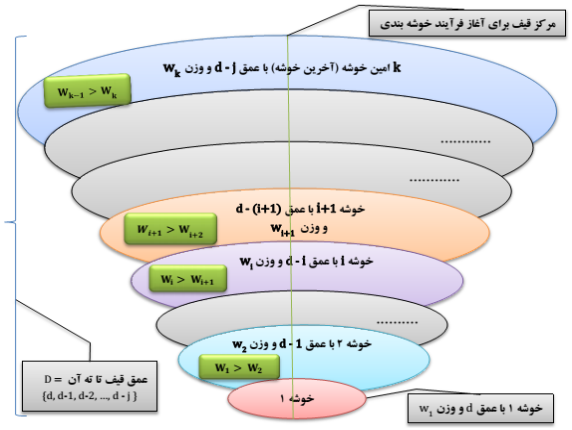
پس از بیان اولویت‌ها و قیود نرم هر یک از استادان مشترک مابین دپارتمان‌ها مطابق رابطه‌ی ۱ حال در این رابطه، L_k استاد مشترک k ام، $WeeklyTimeslots_k$ به منزله‌ی برش‌زمانی هفتگی k ام، $DailyTimeslots_k$ یعنی برش‌زمانی روزانه‌ی k ام، $Departement_k$ نیز دپارتمان k ام و β_k هم میزان درجه‌ی عضویت هر استاد مشترک را نشان می‌دهند.

(۱)

$$WeeklyTimeslot_k \Big/ Departement_k = \left\{ \beta_k \Big/ DailyTimeslot_k \right\}, \beta_k \in [0,1]$$



شکل ۱: نمای کلی از ساختار مساله‌ی CLTTP



شکل ۲: خوشه‌بندی قیفی استادان مشترک مابین دپارتمان‌ها

در رابطه‌ی ۲ طبق مجموعه داده ای الگوی پیش فرض ماتریس‌های اولیه‌ی $U^{(0)}_{Dep/WeeklyTimeslots}$ مربوط به هر ۵ دپارتمان و هر ۷ برش‌زمانی هفتگی و مقادیر میزان درجه‌ی عضویت هر کدام از استادان مشترک با β_k نسبت به هر سطر یا ۷ برش‌های زمانی روزانه به صورت، هر برش‌زمانی روزانه $DailyTimeslots_{(1-7)}$ از ۸-۹:۳۰ تا ۱۹-۲۰:۳۰ هر یک به منزله‌ی یک خوشه که ۷ خوشه خواهد بود، برش‌های زمانی هفتگی $WeeklyTimeslots_{(1-7)}$ از روز شنبه (۱) تا جمعه (۷) هر یک به منزله‌ی یک خوشه که ۷ خوشه می‌باشد و Dep نیز معادل ۵ دپارتمان $Departement_{(1-5)}$ هر یک به منزله‌ی یک خوشه که ۷ خوشه در رابطه‌ی ۲ می‌باشند. در انتها ما به یک ماتریس نهایی از $U^{(0)}$ خواهیم رسید که شامل ۷ سطر (خوشه‌ی اصلی) و ۳۰ ستون (استادان مشترک) می‌باشد. ماتریس نتیجه به صورت رابطه‌ی ۳ نمایش داده می‌شود.

$$U^{(0)}_{Dep_{(1-5)}/WeeklyTimeslots_{(1-7)}} = \begin{matrix} 8-9:30_1 \\ 10-11:30_2 \\ 12-13_3 \\ 13-14:30_4 \\ 15-16:30_5 \\ 17-18:30_6 \\ 19-20:30_7 \end{matrix} \begin{bmatrix} \beta_{11} & \dots & \beta_{1,30} \\ \dots & & \dots \\ & \dots & \\ \dots & & \dots \\ & \dots & \\ \dots & & \dots \\ \beta_{71} & \dots & \beta_{7,30} \end{bmatrix}_{7,30} \quad (۲)$$



(۳)

خوشه‌بندی در سه سطح انجام می‌گیرد که سطح اول توسط برش‌های زمانی روزانه، سطح دوم توسط برش‌های زمانی هفتگی و سطح سوم نیز شامل هر کدام از دپارتمان‌ها برای استادان مشترک مابین دپارتمان‌ها خواهند بود. در نهایت در خوشه‌بندی سطح اول که همان خوشه‌بندی اصلی (برش‌های زمانی روزانه) است، فرآیند زمانبندی استادان مشترک مابین دپارتمان‌ها برای هر استاد مشترک ارائه می‌گردد. انتخاب‌ها، ویژگی‌ها و اولویت‌های استادان مشترک به همراه انتخاب‌های هر دپارتمان (هر دپارتمان برای هر استاد مشترک انتخاب‌هایی را نیز انجام می‌دهد) به صورت مقادیر β_{ik} در ماتریس $U^{(0)}$ مربوطه انجام می‌گیرد.

در خوشه‌ی سطح ۱، برای برش‌های زمانی روزانه‌ی انتخاب شده توسط هر یک از استادان مشترک مابین دپارتمان‌ها، از قاعده‌ی اشتراک در جبر مجموعه‌ها استفاده می‌کنیم، یعنی استادان مشترک مابین دپارتمان‌ها فقط بر اساس برش‌های زمانی روزانه که انتخاب نموده‌اند، بر اساس میزان درجه‌ی اشتراک یا درجه‌ی عضویت‌شان که با m_{ikj_1} نشان داده می‌شود، مورد تحلیل قرار می‌گیرند، یعنی آن استاد مشترکی (استاد مشترک kام) که میزان درجه‌ی اشتراک یا عضویت‌اش (m_{ikj_1}) نسبت به سایر استادان مشترک، نسبت به ویژگی j_1 ام (برش‌زمانی روزانه) بیشترین مقدار را از لحاظ انتخاب‌های برش‌های زمانی روزانه، داشته باشد، محاسبه می‌گردد و آن که بیشترین مقدار را دارد، به عنوان مرکز خوشه‌ی سطح ۱ انتخاب می‌شود و اگر چند استاد به صورت یکسان مقادیر اشتراکشان، همانند باشند باید به سوابق رجوع شود و از روی سوابق‌شان یک استاد مشترک به عنوان مرکز خوشه قرار گیرد و یا اینکه از مابین استادان مشترک یکسان یک استاد مشترک به طور تصادفی به عنوان مرکز خوشه قرار داده شود. باید در اینجا خاطر نشان نمود که در خوشه‌بندی k- میانگین فرآیند انتخاب مرکز خوشه همواره یک فرآیند تصادفی دارد و می‌تواند یک نمونه‌ای به عنوان مرکز خوشه قرار گیرد که هیچ معیار مناسب و منطقی را از لحاظ ارزیابی نسبت به سایر نمونه‌ها نداشته باشد.

در روش خوشه‌بندی قیفی پیشنهادی در بدترین حالت و در آخرین فرآیند انتخاب مرکز خوشه که به عنوان یک استاد مشترک خواهد بود، استاد مشترکی به طور تصادفی در مرکز خوشه، آن هم بر اساس بیشترین میزان درجه‌ی عضویت یا اشتراک آن استاد (یا استادان) مشترک نسبت به سایر استادان مشترک حاضر در آن خوشه‌ی سطح ۱ (برش‌های زمانی روزانه) سنجیده می‌گردد، قرار می‌گیرد. خوشه‌ی سطح ۲، همانند خوشه‌ی سطح ۱، با لحاظ نمودن ویژگی j_2 ام که همان میزان درجه‌ی اشتراک یا عضویت استادان مشترک نسبت به برش‌های زمانی هفتگی است، بیان می‌گردد. در اینجا، m_{ikj_2} یعنی کدام استاد مشترک kام نسبت به ویژگی j_2 ام (برش‌های زمانی هفتگی) در خوشه‌ی iام بیشترین میزان درجه‌ی عضویت یا اشتراک را نسبت به سایر استادان مشترک مابین دپارتمان‌ها دارد، به عنوان مرکز خوشه‌ی سطح ۲ قرار می‌گیرد و خوشه‌ی سطح ۳، مشابه خوشه‌های سطوح ۱ و ۲، با لحاظ نمودن ویژگی j_3 که همان میزان درجه‌ی اشتراک یا عضویت استادان مشترک نسبت به دپارتمان‌های مختلف است را، نشان می‌دهد. در اینجا، m_{ikj_3} یعنی کدام استاد مشترک kام نسبت به ویژگی j_3 (دپارتمان‌هایی که استاد مشترک kام انتخاب کرده است) در خوشه‌ی iام بیشترین میزان درجه‌ی عضویت یا اشتراک را نسبت به سایر استادان مشترک دارد، به عنوان مرکز خوشه‌ی سطح ۳ در نظر گرفته می‌شود.

یک سر خوشه‌ی اصلی، و دو سر خوشه‌ی فرعی معادل و متناظر با ویژگی‌ها، اولویت‌ها و خواسته‌های استادان مشترک مابین دپارتمان‌ها خواهند بود که سر خوشه‌ی اصلی شامل: ۱- برش‌های زمانی روزانه، و بر اساس ویژگی m_{ikj_1}، درجه‌ی عضویت یا میزان درجه‌ی اشتراک استادان مشترک مابین دپارتمان‌ها را محاسبه می‌کند (بر حسب برش‌های زمانی روزانه)، و سر خوشه‌های فرعی نیز در برگیرنده‌ی: ۲- برش‌های زمانی هفتگی، بر اساس ویژگی m_{ikj_2} و ۳- دپارتمان‌ها، بر اساس ویژگی m_{ikj_3} می‌باشند. در ادامه جزئیات سرخوشه‌های اصلی و فرعی و زیر خوشه‌هایشان به این ترتیب ارائه می‌شوند که، ۱- سر خوشه‌ی اصلی اول شامل، برش‌های زمانی روزانه و زیر خوشه‌های سر خوشه‌ی اصلی اول نیز در برگیرنده‌ی، ۹:۳۰ -۸ تا ۲۰:۳۰-۱۹، بر

اساس ویژگی‌های برش‌های زمانی روزانه‌ی j_1 می‌باشند، ۲- سر خوشه‌ی فرعی دوم شامل، برش‌های زمانی هفتگی و زیر خوشه‌های سر خوشه‌ی فرعی دوم نیز در برگیرنده‌ی، روزهای شنبه تا جمعه، و بر اساس ویژگی‌های برش‌های زمانی هفتگی j_2 خواهند بود و ۳- سر خوشه‌ی فرعی سوم شامل، دپارتمان‌ها و زیر خوشه‌های سر خوشه‌ی فرعی سوم نیز در برگیرنده‌ی، دپارتمان‌های مهندسی برق، کامپیوتر، عمران، ریاضی و انسانی، و بر اساس ویژگی‌های دپارتمان‌ها j_3 می‌باشند.

۲ ۴ -روش خوشه‌بندی قیفی پیشنهادی در سر خوشه‌ی اصلی اول (برش‌های زمانی روزانه)

به صورت زیر مراحل خوشه بندی قیفی پیشنهادی انجام می‌گیرد:

۱ -تعیین ماتریس اولیه‌ی $U^{(0)}$ برای استادان مشترک مابین دپارتمان‌ها بر اساس انتخاب‌ها و اولویت‌های هر یک از استادان مشترک و سپس ارائه‌ی ماتریس‌های مربوط به هر دپارتمان (بر اساس برش‌های زمانی هفتگی و سپس برش‌های زمانی روزانه به ازای هر استاد مشترک)، که ما از قبل این مرحله را تهیه نموده‌ایم. در این مرحله ما فقط بر حسب ویژگی j_1 یا همان برش‌های زمانی روزانه فرآیند خوشه‌بندی قیفی پیشنهادی را انجام می‌دهیم.

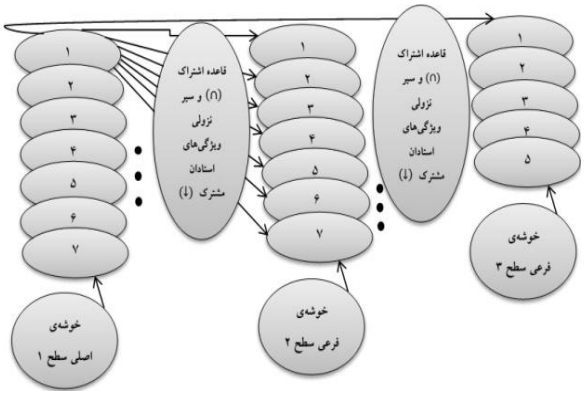
۲ - باید مراکز هر ۷ خوشه تعیین گردد، پس باید از قاعده‌ی اشتراک در جبر مجموعه‌ها جهت قرار دادن هر کدام از استادان مشترک بر اساس ویژگی j_1 (برش‌های زمانی روزانه)، این کار را انجام دهیم، یعنی ابتدا ما باید به ازای هر استاد مشترک میزان درجه‌ی اشتراک یا عضویت مربوطه‌اش را نسبت به همان ویژگی j_1 محاسبه و برابر با متغیر m_{ikj_1} قرار دهیم که این یعنی استاد مشترک k ام در خوشه‌ی i ام، سر خوشه‌ی اصلی نسبت به ویژگی j_1 ام می‌باشد. پس از آنکه ۷ استاد مشترک به ازای این ۷ زیر خوشه‌ی درون سر خوشه‌ی اصلی تعیین شدند حال بایستی از میزان درجه‌ی اشتراک یا عضویت بزرگتر به کوچکتر مرتب‌سازی شوند (سیر نزولی) در اینجا، یا فرآیند قرارگیری هر کدام از این استادان مشترک در خوشه‌ها می‌تواند به طور تصادفی انجام گیرد، و یا بایستی به ترتیب به انتخاب‌ها، اولویت‌ها و... تک تک آن ۷ استاد مشترک نگاه کنیم، و استاد مشترکی که یک برش‌زمانی روزانه‌ی خاص را بیشتر و زیادتر نسبت به سایر برش‌های زمانی روزانه‌ی دیگر انتخاب نموده است، آن استاد مشترک را در خوشه قرار دهیم که این استاد مشترک همان مرکز خوشه باشد و البته راه‌حل دوم منطقی‌تر و مناسب‌تر به نظر می‌رسد، اگر استاد مشترکی باشد که میان این ۷ استاد مشترک همه‌ی برش‌های زمانی روزانه را با یک دید و توزیع نگاه کرده باشد حال قرار دادن آن استاد مشترک را می‌توان پس از اتمام تخصیص سایر آن استادان مشترک در مرکز این خوشه‌ها انجام داد و سپس فرآیند تخصیص این استاد مشترک را صورت داد.

۳ - باید فاصله‌ی هر کدام از استادان مشترک خارج خوشه‌ها (۷ خوشه) را نسبت به تک تک استادان مستقر در مراکز خوشه‌ها، مجددا توسط قاعده‌ی اشتراک به‌دست آوریم و در اینجا هم آن استادان مشترکی که نسبت به هر کدام از استادان داخل مراکز خوشه‌ها، میزان درجه یا اشتراک زیادتری داشته باشند، در آن خوشه قرار می‌گیرند، یعنی آن استادان مشترکی که خارج این ۷ خوشه قرار دارند به نسبت انتخاب‌ها، اولویت‌ها و ....، که انجام داده‌اند میزان درجه‌ی عضویت یا اشتراک‌شان بر حسب ویژگی m_{ikj_1}، نسبت به استادان مشترک مستقر در مراکز این ۷ خوشه مورد محاسبه قرار می‌گیرند. حال پس از محاسبه‌ی میزان فاصله‌ی هر یک از استادان مشترک خارج این ۷ خوشه و قرار گرفتن آن استادان مشترک در خوشه‌ها، در درون هر خوشه بایستی آن استاد مشترکی که از لحاظ انتخاب‌ها، اولویت‌ها و... در حالت کلی از نظر مقدار ویژگی m_{ikj_1} بیشتر است را به عنوان مرکز آن ۷ خوشه انتخاب نماییم، یعنی یک نوع به روز رسانی به ازای هر خوشه بر اساس ویژگی m_{ikj_1} نیز پس از پایان مرحله‌ی ۳، اتفاق می‌افتد. (کارهای گفته شده در ۳ مرحله‌ی قبلی برای خوشه‌ی اصلی سطح ۱ (بر اساس ویژگی‌های m_{ikj_1}) را برای دو خوشه‌ی فرعی دیگر هم؛ ۱- خوشه‌ی سطح ۲، برش‌های زمانی هفتگی (بر اساس ویژگی‌های m_{ikj_2}) و ۲- خوشه‌ی سطح ۳، دپارتمان‌ها (بر اساس ویژگی‌های m_{ikj_3})، تکرار می‌کنیم)

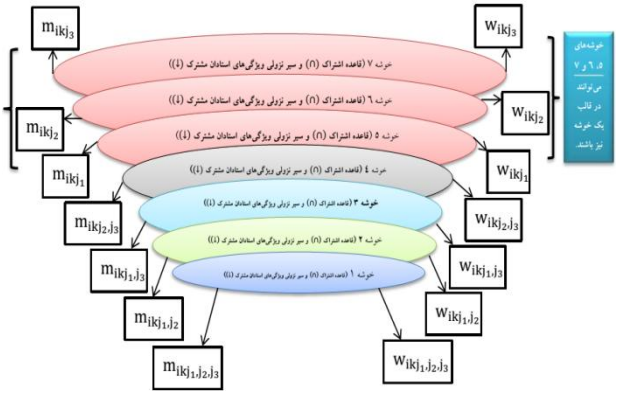
پس از اتمام کار برای هر ۳ سطوح خوشه‌ها و زیر خوشه‌های این ۳ سرخوشه‌ها ما در کل ۲۴۵=۵*۷*۷ (۷ برش‌های زمانی روزانه، ۷ برش‌های زمانی هفتگی و ۵ دپارتمان) خوشه خواهیم داشت و ۳۰ استاد مشترک که به طور مجزا اولویت‌ها، انتخاب‌ها را برای این ۳ سر خوشه و زیر خوشه‌های این سر خوشه‌ها انجام داده‌اند تا اینکه در صورت اعمال الگوریتم خوشه‌بندی قیفی پیشنهادی مابین این ۳ سر خوشه، فرآیند چرخش استادان مشترک بر اساس ویژگی‌ها و اولویت‌های‌شان در خوشه‌بندی قیفی نهایی انجام شود. شکل ۳، نحوه‌ی چگونگی ارتباط سطوح خوشه‌های ۱، ۲ و ۳ توسط قاعده‌ی اشتراک در

جبر مجموعه‌ها را برای آغاز خوشه‌بندی قیفی نهایی استادان مشترک مابین دپارتمان‌ها نشان می‌دهد. علامت ↓ یعنی، استادان مشترک بر اساس ویژگی‌هایشان با یک سیر نزولی و عملگر ∩ نیز، نشان دهنده‌ی قاعده‌ی اشتراک در جبر مجموعه‌ها می‌باشد. L_{j_1,j_2,j_3}، یعنی استاد مشترک L دارای هر ۳ ویژگی مشترک j_1، j_2 و j_3، L_{j_1,j_2}، یعنی استاد مشترک L دارای ۲ ویژگی مشترک j_1 و j_2، L_{j_1,j_3}، یعنی استاد مشترک L دارای ۲ ویژگی مشترک j_1 و j_3، L_{j_2,j_3}، یعنی استاد مشترک L دارای ۲ ویژگی مشترک j_2 و j_3، L_{j_1}، یعنی استاد مشترک L دارای فقط ۱ ویژگی مشترک j_1، L_{j_2}، یعنی استاد مشترک L دارای فقط ۱ ویژگی مشترک j_2 و L_{j_3}، یعنی استاد مشترک L دارای فقط ۱ ویژگی مشترک j_3، می‌باشند. در هر سطح خوشه‌بندی استادان مستقر در درون خوشه‌ها از میزان درجه‌ی اشتراک و عضویت بزرگتر به کوچکتر (از بالاتر به پایین‌تر)، برای مشترک بودن در این ویژگی‌ها بایستی مرتب‌سازی شوند. (یعنی از میزان درجه‌ی اشتراک بالاترین به درجه‌ی اشتراک پایین‌ترین حرکت می‌کنیم)

البته همواره رشد خوشه‌بندی قیفی به صورت پویا و از مرغوب‌ترین به نامرغوب‌ترین میزان درجه‌ی اشتراک‌های استادان مشترک حرکت خواهد نمود. در شکل ۴، چگونگی تجمیع و تراکم ویژگی‌ها به همراه تفرق و پراکندگی ویژگی‌های استادان مشترک مابین دپارتمان‌ها با ویژگی m_{ikj}، و وزن هر کدام از خوشه‌ها توسط w_{ikj} ارائه می‌شود.



شکل ۳: استادان مشترک خوشه‌بندی قیفی در سر خوشه‌ها.



شکل ۴: خوشه‌بندی قیفی نهایی پیشنهادی استادان مشترک.

w_{ikj_1,j_2,j_3}، یعنی وزن استاد مشترک kام در خوشه‌ی iام، دارای هر ۳ ویژگی مشترک j_1، j_2 و j_3 می‌باشد که به صورت میزان درجه‌ی عضویت m_{ikj_1,j_2,j_3} بیان شده (خوشه‌ی ۱)، w_{ikj_1,j_2}، یعنی وزن استاد مشترک kام در خوشه‌ی iام، دارای ۲ ویژگی مشترک j_1 و j_2 می‌باشد که به صورت میزان درجه‌ی عضویت m_{ikj_1,j_2} بیان شده (خوشه‌ی ۲)، w_{ikj_1,j_3}، یعنی وزن استاد مشترک kام در خوشه‌ی iام دارای ۲ ویژگی مشترک j_1، j_3 می‌باشد که به صورت میزان درجه‌ی عضویت m_{ikj_1,j_3} بیان شده (خوشه‌ی ۳)، w_{ikj_2,j_3}، یعنی وزن استاد مشترک kام در خوشه‌ی iام، دارای هر ۲ ویژگی مشترک j_2، j_3 می‌باشد که به صورت میزان درجه‌ی عضویت m_{ikj_2,j_3} بیان شده (خوشه‌ی ۴)، w_{ikj_1}، یعنی وزن استاد مشترک kام در خوشه‌ی iام دارای ۱ ویژگی مشترک j_1 می‌باشد که به صورت میزان درجه‌ی عضویت m_{ikj_1} بیان شده (خوشه‌ی ۵)، w_{ikj_2}، یعنی وزن استاد مشترک kام در خوشه‌ی iام دارای ۱ ویژگی مشترک j_2 می‌باشد که به صورت میزان درجه‌ی عضویت m_{ikj_2} بیان شده (خوشه‌ی ۶) و w_{ikj_3}، یعنی وزن استاد مشترک kام در خوشه‌ی iام دارای ۱ ویژگی مشترک j_3 می‌باشد که به صورت میزان درجه‌ی عضویت m_{ikj_3} بیان شده (خوشه‌ی ۷). در شکل ۴ طبق قاعده‌ی اشتراک در جبر مجموعه‌ها، استادان مشترک در خوشه‌های ۱ تا ۷، حرکت می‌کنند و عملگر، استادان مستقر در درون خوشه‌ها را از میزان درجه‌ی اشتراک و عضویت بزرگتر به کوچکتر مرتب می‌کند. (از بالاتر به پایین‌تر)، مرحله‌ی نهایی پس از فرآیند خوشه‌بندی قیفی استادان مشترک مابین دپارتمان‌ها، آن هم با چرخش یا همان به روز رسانی مکانی استادان مشترک مابین دپارتمان‌ها در مابین خوشه‌های قیفی نهایی انجام می‌گیرد. خوشه‌بندی یا قیف اصلی بر اساس ویژگی برش‌های زمانی روزانه‌ی استادان مشترک مابین دپارتمان‌ها انجام می‌گیرد و فرآیند به روز رسانی و جابه‌جایی استادان مشترک مابین دپارتمان‌ها در قیف نهایی بر اساس دو خوشه‌ی فرعی برش‌های زمانی هفتگی و دپارتمان‌های

استادان مشترک صورت می‌پذیرد. روش به روز رسانی قاعده‌ی اشتراک مابین استادان مشترک مستقر در خوشه‌های قیفی نهایی طبق رابطه‌ی ۴ انجام می‌گیرد. البته باید گفت که روند تکرار به صورتی است که ما به یک ماتریس بهینه‌ی جواب که همان $U^{(*)}$است، برسیم و این روال از قاعده‌ی $U^{(r=0)} \to U^{(r=1)} \to \ldots \to U^{(*)}$ پیروی می کند. استادان مشترک در درون خوشه‌های قیفی نهایی می‌توانند هیچ اشتراکی نسبت به ویژگی‌های j_1 ، j_2 و j_3 با سایر استادان مشترک دیگر نیز نداشته باشند که در آن صورت اشتراک‌شان معادل با تهی ϕ خواهد بود.

$$U^{(*)} = \left\{ \begin{array}{l} \left\{ \begin{array}{l} w_{ikj_1,j_2,j_3} \cap w_{ikj_1,j_2} ; w_{ikj_1,j_2,j_3} \cap w_{ikj_1,j_3} ; w_{ikj_1,j_2,j_3} \cap w_{ikj_2,j_3} \\ w_{ikj_1,j_2,j_3} \cap w_{ikj_1} ; w_{ikj_1,j_2,j_3} \cap w_{ikj_2} ; w_{ikj_1,j_2,j_3} \cap w_{ikj_3} \end{array} \right\} \\ \left\{ \begin{array}{l} w_{ikj_1,j_2} \cap w_{ikj_1,j_3} ; w_{ikj_1,j_2} \cap w_{ikj_1} ; w_{ikj_1,j_2} \cap w_{ikj_2,j_3} \\ w_{ikj_1,j_2} \cap w_{ikj_2} ; w_{ikj_1,j_2} \cap w_{ikj_3} \end{array} \right\} \\ \left\{ w_{ikj_1,j_3} \cap w_{ikj_2,j_3} ; w_{ikj_1,j_3} \cap w_{ikj_2} ; w_{ikj_1,j_3} \cap w_{ikj_1} ; w_{ikj_1,j_3} \cap w_{ikj_3} \right\} \\ \left\{ w_{ikj_2,j_3} \cap w_{ikj_1} ; w_{ikj_2,j_3} \cap w_{ikj_2} ; w_{ikj_2,j_3} \cap w_{ikj_3} \right\} \end{array} \right\} \quad (۴)$$

۳ -نتایج و آزمایش‌ها

برای آزمون ساختار الگوریتم پیشنهادی، مجموعه‌ی داده‌ای شامل: ۳۰ استاد، ۵ دپارتمان (مهندسی کامپیوتر، مهندسی برق، مهندسی عمران، علوم انسانی و علوم ریاضی)، ۷ برش‌زمانی هفتگی (شنبه – یکشنبه – دوشنبه – سه‌شنبه – چهارشنبه – پنج‌شنبه – جمعه)، ۷ برش‌زمانی روزانه (۸:۳۰-۹:۳۰، ۱۰:۳۰-۱۱:۳۰، ۱۲:۳۰-۱۳:۳۰، ۱۴:۳۰-۱۵:۳۰، ۱۶:۳۰-۱۷:۳۰ و ۱۸:۳۰-۱۹:۳۰ و ۲۰:۳۰-۲۱:۳۰) و ۱۳ کلاس درسی به ازای هر دپارتمان (۳ کلاس درس عملی و ۱۰ کلاس درس تئوری) را در نظر می‌گیریم.

۳ ۱ -معیارهای ارزیابی اهداف مساله‌ی CLTTP

پس از به کارگیری الگوریتم خوشه‌بندی قیفی و تخصیص به منابع (مازاد)، روابط ذیل، برای ارزیابی معیارهای مقاله ارائه می‌شوند. رابطه‌ی ۵، $CTDS_1^{(i)}$ درصد ارضاء نزولی خصیصه‌های تک تک استادان مشترک مابین دپارتمان‌ها را در هر خوشه محاسبه می‌کند و رابطه‌ی ۶، $CTDS_2^{(i_j)}$ نیز درصد ارضاء نزولی اولویت‌ها و خصیصه‌های استادان مشترک مابین دپارتمان‌ها را مابین خوشه‌ها و نسبت به هر خوشه به دست می‌آورد.

رابطه‌ی ۵، به ازای تک تک خوشه‌ها و به ازای هر خوشه محاسبه می‌گردد.

$$CTDS_1^{(i)} = \frac{\sum_{k=1}^{n} W_{ik}^{SC} \times X_{ik}}{\sum_{const=1}^{r} \left(Total_{const}^{SC} \right)} \times 100 = \frac{\sum_{Const=1}^{r} \sum_{k=1}^{n} \left(W_{ik}^{Const} \times L_{ik} \right)}{\sum_{Const=1}^{r} \sum_{k=1}^{n} Total_{k}^{Const}} \times 100 \quad (۵)$$

$$L_{ik} = \sum_{k=1}^{n=30} \sum_{j=1}^{m=3} X_{k_j} = \sum_{k=1}^{n} \left(X_{k_1} + X_{k_2} + X_{k_3} \right) = \left(X_{1_1} + X_{1_2} + X_{1_3} \right) + \ldots + \left(X_{30_1} + X_{30_2} + X_{30_3} \right)$$

در رابطه‌ی ۵، خوشه‌ی iام که $i = 1,\ldots,c; c = 7$ ، k تعداد استادان مشترک $k = 1,\ldots,n; n = 30$ و W_{ik}^{SC} قیدی (قیود) که برای استاد مشترک X_{ik} (استاد مشترک kام در خوشه‌ی iام) توسط W_{ik}^{SC} ارضاء شده باشد را نشان می‌دهد. در این رابطه، $Total_{const}^{SC}$ نیز کلیه‌ی قیود استادان مشترک را در هر خوشه به ازای تک تک استادان مشترک بیان می‌کند. مثلا $\left(X_{1_1} + X_{1_2} + X_{1_3} \right)$ یعنی، ویژگی مربوط به استاد مشترک ۱ که کلا در خوشه‌ی ۱ ارضاء شده است. (استاد مشترک هم می‌تواند کاملا ارضاء نشود؟)

رابطه‌ی ۶، نشان دهنده‌ی میزان رقابت مابین خوشه‌ها از لحاظ میزان درصد ارضاء خواسته‌ها، قیود و اولویت‌های استادان مشترک مابین دپارتمان‌های هر یک از خوشه‌ها است،

$$CTDS_2^{(i_j)} = \frac{\sum_{i=1}^{c} \left(W_i^{SC} \times i \right)}{\sum_{j=i+1}^{c} \left(Total_{Const_j}^{SC} \times j \right)} \times 100 = \frac{\sum_{Const=1}^{r} \sum_{k=1}^{n} \sum_{i=1}^{c} W_{ik}^{Const} \times i}{\sum_{Const=1}^{r} \sum_{j=i+1}^{c} Total_{Const_j}^{Const} \times j} \times 100 \quad (۶)$$

در رابطه‌ی ۶، $i = 1,\ldots,c$ تعداد خوشه‌ها، W_i^{SC} درصد ارضاء قیود استادان مشترک خوشه‌ی iام و j نیز تعداد سایر خوشه‌ها را علاوه بر خوشه‌ی iام نشان می‌دهد که $j = i+1,\ldots,c$ و $c = 7$. در این رابطه باید مقدار W_i^{SC} نیز از نسبت تعداد قید (قیود) ارضاء شده

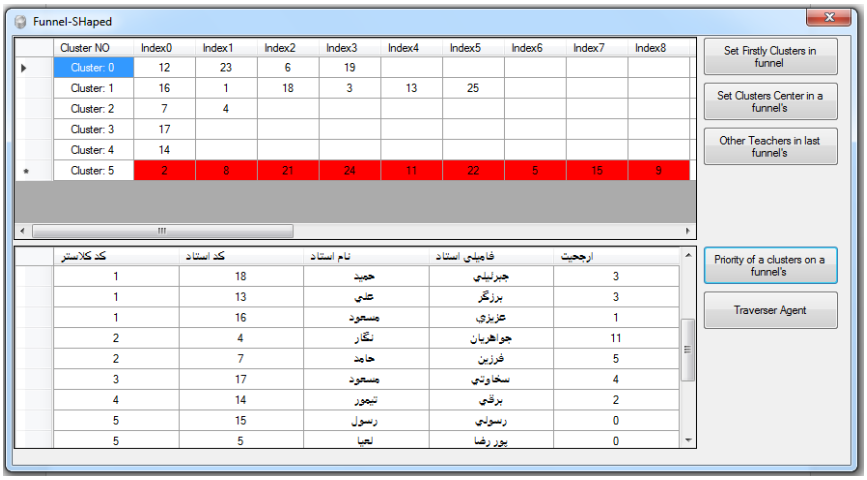
برای استاد مشترک kام در خوشه‌ی iام بر کل قیود خوشه‌ی iام برای استادان مشترک موجود در این خوشه محاسبه گردد. پس از آنکه برای هر خوشه‌ی iام و استادان مشترک هر یک از آن خوشه‌ها عددی بر حسب درصد به دست آمد، می‌توان دید که کدام یک از خوشه‌ها میزان درجه‌ی ارضاءهای حداکثری یا همان میزان تخطی کمینه را دارند، ابتدا آن خوشه اولویت و ارجحیت تخصیص را خواهد داشت. می‌توان میزان درصد اتلاف منابع مازاد مابین دپارتمان‌ها را پس از فرآیند خوشه‌بندی و نگاشت به ازای هر دپارتمان طبق رابطه‌ی ۷ به دست آورد.

$$ERW_A = \frac{a}{b} \times 100 \qquad (۷)$$

در رابطه‌ی ۷، $ERW_A : (Extra\,Re\,sources\,Waste)_{After}$ یعنی اتلاف منابع مازاد پس از فرآیند خوشه‌بندی و نگاشت. در اینجا، a معادل تعداد منابع مازاد باقی مانده‌ی هر دپارتمان پس از تخصیص و b هم متناظر با کل تعداد منابع موجود در هر دپارتمان.

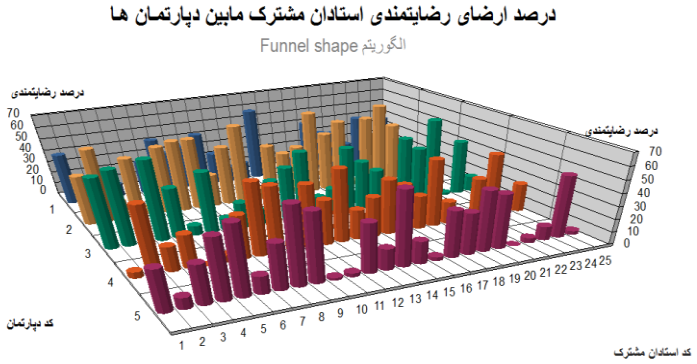
۳ ۲ عملکرد الگوریتم خوشه‌بندی قیفی پیشنهادی بر روی مجموعه‌ی داده‌ای

در شکل ۵، ستون cluster no تعداد خوشه ها ، Index 0…30 تعداد خانه های هر خوشه متناسب با استادان مشترک (مثلاً، اعداد ۱۳، ۳ در cluster1 نشان دهنده ی شماره ی استادان مشترک ۱۳ ام و ۳ ام می‌باشند). دکمه ی set firstly clusters in funnel، در شکل ۵، تعداد خوشه ها را بر اساس تعداد ویژگی های مورد نظر که در این مقاله سه نوع (روزانه ، هفتگی و دپارتمان) است، ایجاد می کند. پنج خوشه که به صورت قیفی از خوشه ی ۱ ام تا ۵ ام ، استادان مشترک مابین دانشکده ها را بر اساس تئوری اشتراک در جبر مجموعه ها طبق روابط بخش ۲- ۱ و ۲-۲، از متمرکز ترین استادان مشترک تا پراکنده ترین شان (طبق اشتراک ویژگی ها) ، تفکیک می کند. دکمه ی set cluster center in a funnel's، مرکز هر پنج خوشه را با توجه به روابط موجود در بخش و ۲-۲ به صورت اشتراک حداکثری در ویژگی های هر یک از استادان مشترک در آن خوشه انجام می دهد، و یکی از استادان مشترک را به عنوان مرکز هر یک از ۵ خوشه انتخاب می کند. دکمه ی other teachers in last funnel's، برای قراردادن استادان مشترک در آخرین خوشه (پنجمین) می باشد که استادان مشترک در این خوشه هیچ اشتراکی از لحاظ اِعمال ویژگی های استادان مشترک با یکدیگر و سایر خوشه های دیگر ندارند و با رنگ قرمز نشان داده می شوند. دکمه ی priority of a cluster on a funnel's در شکل ۵، اولویت خوشه ها را در قیف ایجاد شده به صورت ۵ خوشه ارائه می کند. جدول پایین در شکل ۵، شامل ۵ ستون است که کد خوشه (از ۱ تا ۵) ، کد استاد مشترک ، نام استاد مشترک ، نام خانوادگی استاد مشترک و پارامتر ارجحیت می باشند. منظور از ستون ارجحیت همان اولویت و برتری دادن اینکه کدام استاد مشترک بر اساس ویژگی ها ، خواسته ها و اولویت هایش می تواند در هر خوشه به منابع مازاد مابین دانشکده ها نگاشت یابد. در نهایت دکمه‌ی traverser agent طبق بخش‌های و ۳-۴ نحوه پیمایش منابع مازاد دانشکده‌ها را به همراه نگاشت استادان مشترک به آن منابع مازاد ارائه خواهد داد.



شکل ۵: نتیجه‌ی به کارگیری الگوریتم خوشه‌بندی قیفی.

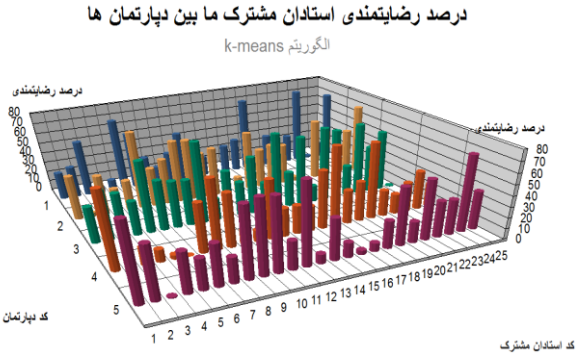
در شکل ۶، نتیجه ی مقایسه رضایت مندی الگوریتم خوشه-بندی قیفی پیشنهادی برای هر یک از ۲۵ استاد مشترک مابین دانشکده ها به صورت 3D (سه بُعدی) نشان داده می شود. در این شکل، ۳ بُعد که بعد طول، کد استادان مشترک، بعد عرض کد دانشکده و بُعد ارتفاع نیز درصد رضایت مندی استادان مشترک را نمایش می دهد.



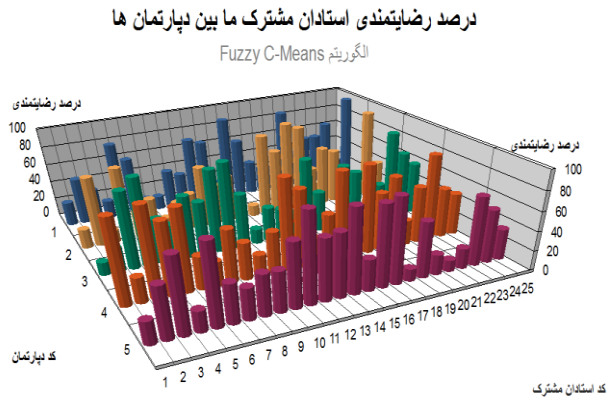
شکل ۶: درصد رضایت مندی استادان مشترک طبق الگوریتم خوشه‌بندی قیفی پیشنهادی.

۳ ۴ مقایسه‌ی الگوریتم خوشه‌بندی k – میانگین سازگار شده با الگوریتم خوشه‌بندی قیفی پیشنهادی و الگوریتم خوشه‌بندی c – میانگین فازی سازگار شده

در شکل های ۷ و ۸ نتیجه ی مقایسه ی رضایت مندی الگوریتم های خوشه‌بندی k- میانگین و c – میانگین فازی برای هر یک از ۲۵ استاد مشترک مابین دانشکده ها به صورت 3D (سه بُعدی) نشان داده می شود. در اینجا، ۳ بُعد که بُعد طول کد استادان مشترک ، بُعد عرض کد دانشکده و بُعد ارتفاع نیز درصد رضایت مندی استادان مشترک را نمایش می دهد.

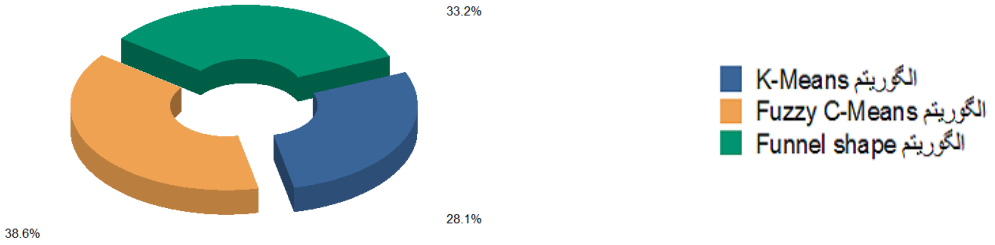


شکل ۷: درصد رضایت مندی استادان مشترک طبق الگوریتم خوشه‌بندی k – میانگین



شکل ۸: درصد رضایت مندی استادان مشترک طبق الگوریتم خوشه‌بندی c- میانگین فازی

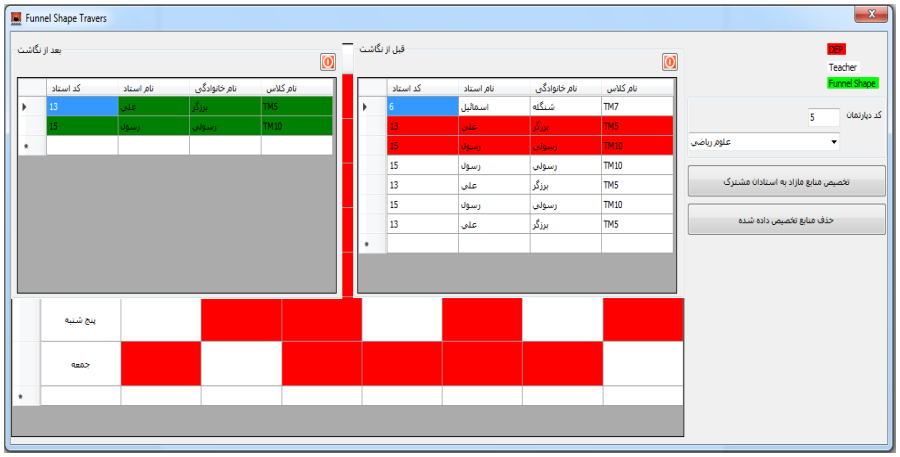
در شکل ۹، خلاصه ی درصد رضایت مندی استادان مشترک مابین دانشکده ها را به صورت مجزا و منطبق با الگوریتم های خوشه بندی نمایش می دهد. درصد رضایت مندی الگوریتم خوشه بندی k- میانگین، c- میانگین فازی و قیفی پیشنهادی، به ترتیب ۱۹. ۲۸ ٪، ۶ . ۳۸ ٪و ۲ . ۳۳ ٪ خواهند بود.



شکل ۹: درصد ارضاء نزولی اولویت‌های استادان مشترک مابین دپارتمان‌ها بر مبنای الگوریتم‌های خوشه‌بندی

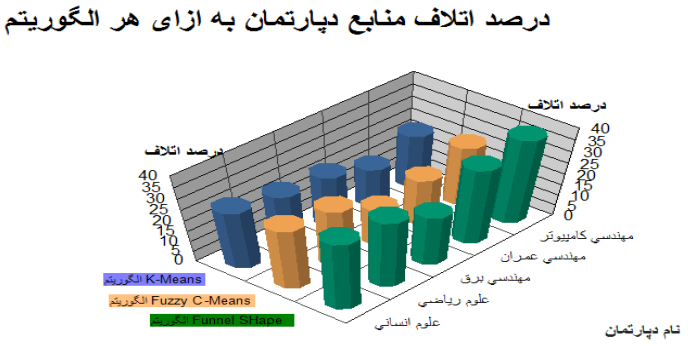
۳ ۴ -پیمایش منابع (مازاد) بین دپارتمانی، و نگاشت خوشه‌های استادان مشترک توسط الگوریتم‌های خوشه‌بندی

شکل ۱۰ نحوه نگاشت خوشه های استادان مشترک به منابع مازاد هر یک از ۵ دانشکده را به واسطه ی استفاده ی از الگوریتم های خوشه بندی قیفی پیشنهادی نشان می دهد. پس بر اساس دو انتخاب که یکی از جانب آموزش (گروه مربوط) هر دانشکده و دیگری هم از جانب استادان مشترک مابین دانشکده ها است کار تخصیص انجام می شود. رنگ قرمز انتخاب های آموزش (گروه) هر دانشکده، رنگ سفید انتخاب های هر یک از استادان مشترک، رنگ سبز نشان دهنده ی تخصیص داده شدن انتخاب های هر کدام از استادان مشترک به قیود و اولویت هایشان در الگوریتم خوشه بندی قیفی پیشنهادی پس از فرآیند نگاشت می باشد.



شکل ۱۰: نگاشت خوشه‌های استادان مشترک در منابع مازاد مابین دپارتمان‌ها با الگوریتم قیفی

نمودار شکل ۱۱ خلاصه ای را برای نمایش درصد اتلاف منابع دانشکده به ازای هر الگوریتم ارائه می کند.



شکل ۱۱: کمینه شدن اتلاف منابع مازاد مابین دپارتمان‌ها، به واسطه‌ی الگوریتم‌های خوشه‌بندی.

۴ -نتیجه‌گیری

در این مقاله، هدف اول ، درصد کمینه سازی اتلاف منابع مازاد دانشکده ها برای الگوریتم های خوشه بندی به ترتیب از بیشترین تا کمترین خوشه بندی c – میانگین فازی (۲۸۸. ۴۱٪) ، خوشه بندی قیفی پیشنهادی (۵۵ . ۳۲٪) و خوشه بندی k- میانگین (۱۶. ۲۶٪) می باشد و هدف دوم ، ارضاء نزولی اولویت های استادان مشترک مابین دانشکده ها است که برای الگوریتم های خوشه بندی به ترتیب از بیشترین تا کمترین ، خوشه بندی c- میانگین فازی (٪۶ . ۳۸) ، خوشه بندی قیفی پیشنهادی (٪ ۲ . ۳۳) و خوشه بندی k- میانگین (٪ ۱ . ۲۸) خواهد بود.

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استفاده از الگوریتم جهش قورباغه ی بهبود یافته در خوشه بندی داده ها

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چکیده - - خوشه بندی یکی از تکنیک های معروف در زمینه ی داده کاوی می باشد که در آن داده های با خواص مشابه درون مجموعه ای از دسته ها قرار می گیرند. . الگوریتم k-means از ساده ترین الگوریتم های خوشه بندی است که دارای معایب حساس شدن به مقادیر اولیه خوشه ها و همگرا شدن به بهینه ی محلی می باشد . در سالهای اخیر الگوریتمهای مختلفی بر پایه الگوریتم های تکاملی برای خوشه بندی ارائه شده است اما متاسفانه رفتارهای ناامیدکننده ای از خود نشان داده اند. در این مقاله نوعی از الگوریتم جهش قورباغه ی بهبود یافته (LSFLA) ، برای خوشه بندی ارائه شده است که در آن از مفهوم ترکیب و آشوب برای بالا بردن دقت عملکرد الگوریتم استفاده شده است. همچنین به دلیل استفاده از مفهوم آنتروپی در تابع برازندگی توانسته ایم کارایی این الگوریتم را برای خوشه بندی بالا ببریم. برای انجام آزمایش از چهار مجموعه داده واقعی استفاده شده است که با الگوریتم های K-menas، GA ،PSO ، CPSO مورد مقایسه قرار گرفته است .نتایج بدست آمده حاکی از عملکرد بهتر این روش در امر خوشه بندی می باشد.

کلید واژه- آشوب ، الگوریتم جهش قورباغه ، آنتروپی ، خوشه بندی

۱ - مقدمه

خوشه بندی یکی از تکنیک های معروف در زمینه داده کاوی میباشد. این فرآیند در واقع نوعی گروه بندی مجموعه ای از اشیا به خوشه های مختلف میباشد که اشیا یک خوشه باهم مشابه هستند. در خوشه‌بندی سعی می‌شود تا داده ها به خوشه‌هایی تقسیم شوند که شباهت بین داده‌های درون هر خوشه حداکثر و شباهت بین داده‌های درون خوشه‌های متفاوت حداقل شود[۱]. زمانی که الگوریتم خوشه بندی را بر روی مجموعه ای از اشیا اعمال میکنیم، خوشه های بدست آمده میتوانند برای ظاهر کردن ساختار ذاتی موجود در داده ها مورد استفاده قرار گیرند.خوشه بندی در زمینه های بسیاری از جمله شناسایی الگو ، یادگیری ماشین ، داده کاوی ، بازیابی اطلاعات و انفورماتیک زیستی کاربرد دارد. در سالهای اخیر نیز الگوریتم های مختلفی برای خوشه بندی ارائه شده است اما متاسفانه تکنیک های خوشه بندی مبتنی بر مدلهای کلاسیک رفتارهای ناامیدکننده ای در خوشه بندی نشان داده اند. . الگوریتم k-means یکی از رایج ترین الگوریتم ها در خوشه بندی است که در سال ۱۹۶۷ توسط Macgueen ارائه شده است. k-means ساده و انعطاف پذیر است و به آسانی قابل درک می باشد اما از معایب این الگوریتم حساس بودن به مقادیر اولیه خوشه ها و همگرا شدن به بهینه ی محلی است[۲] .به منظور غلبه بر کاستی های k-means ، بسیاری از روشهای اکتشافی در دو دهه گذشته استفاده شده است . به عنوان مثال در سال ۲۰۰۰ از قابلیت های الگوریتم ژنتیک برای یافتن مراکز خوشه ها استفاده شده است [۳]. در سال ۲۰۰۷ ترکیبی از الگوریتم تبرید شبیه سازی شده (SA) و k-harmonic means برای خوشه بندی به کار برده شده که مشکلات افتادن در بهینه ی محلی در این روش برطرف شده است [۴]. liu و همکارانش در سال ۲۰۰۸ با استفاده از الگوریتم جستجوی ممنوع روشی برای مقابله با مساله خوشه بندی حداقل مجموع مربعات ارائه دادند[۵]. در سال ۲۰۱۱ روشی برای خوشه بندی داده ها با استفاده از الگوریتم کلونی مورچه(Aco) ارائه شد که توانست به نتایج قابل قبولی نیز دست یابد[۶] .در سال ۲۰۱۱ نیز از الگوریتم زنبور عسل مصنوعی (Bco)برای مسائل طبقه بندی استفاده شد[۷]. از الگوریتم جستجوی گرانشی (GSA) نیز در مسایل خوشه بندی استفاده شده است[۸] ، همچنین ترکیب این الگوریتم با k-means نیز توانست به نتایج خوبی دست یابد[۹] .الگوریتم بهینه سازی ازدحام ذرات (PSO) نیز به صورت موفقیت آمیزی در مسائل خوشه بندی اعمال شده است[۱۰] . همچنین در سال ۲۰۱۱ از

ترکیب الگوریتم بهینه سازی ازدحام ذرات و آشوب برای جلوگیری از افتادن در بهینه ی محلی استفاده شد[۱۱]. الگوریتم های فوق ابتکاری (Metaheuristic) که از طبیعت الهام گرفته شده در حال تبدیل شده به الگوریتم های محبوب و قدرتمند در حل مسائل بهینه سازی می باشند[۱۲, ۱۳] . پس از تحقیقات به عمل آمده، کشف شد که ایده های مورد استفاده در الگوریتم SCE و PSO میتوانند باهم ترکیب شده و یک متاهیوریستیک قویتر جهت حل مسائل گسسته و یا ترکیبی تولید کنند. این متاهیوریستیک جدید به عنوان الگوریتم جهش قورباغه مخلوط شده (SFLA) شناخته میشود. الگوریتم جهش قورباغه (SFLA) یک الگوریتم ممتیک فراابتکاری جدید با تابع ریاضی کارآمد و قابلیت جستجوی سراسری است. این الگوریتم توسط Eusuff و Lansey توسعه داده شده است [۱۴].در این مقاله از نوع بهبود یافته این الگوریتم برای انجام خوشه بندی استفاده شده است. این الگوریتم بهبود یافته مربوط به تحقیقات انجام شده در دانشگاه آزاد اسلامی واحد مشهد می باشد که با کمک آشوب و عملگر ترکیب در جستجوی محلی توانسته در مسایل بهینه سازی به درستی عمل کند[۱۵] .همچنین به دلیل استفاده از مفهوم آنتروپی در تابع هدف توانسته ایم کارایی این الگوریتم را برای خوشه بندی بالا ببریم. برای کارایی الگوریتم پیشنهادی ، از چهار مجموعه داده واقعی استفاده شده است. .در ادامه مبحث در بخش دوم مفهوم آنتروپی را توضیح داده و در بخش سوم به الگوریتم SFLA می پردازیم. در بخش چهارم به تشریح نوع بهبود یافته الگوریتم جهش قورباغه (LSFLA) و کاربرد آن در خوشه بندی می پردازیم و در بخش پنجم نتایج حاصل از اعمال روش پیشنهادی را بر روی چهار مجموعه داده واقعی آورده و به مقایسه ی آن با روش های پیشین می پردازیم. در انتها نیز خلاصه ای از کار انجام شده در این تحقیق را توضیح می دهیم.

۲ -آنتروپی

آنتروپی یکی از روشهای کارآمد برای تحلیل عدم قطعیت محسوب می شود. به دلیل پیچیدگی مفهومی و محاسباتی این تئوری ، تا اوایل قرن بیستم علاقه ی چندانی به استفاده از آن دیده نمی شد، تا اینکه Shannon در سال ۱۹۴۸ تحقیقات گسترده ای را برای استفاده از این تئوری در زمینه های مختلف مهندسی توسعه داد [۱۶] .آنتروپی معیاری برای درجه بی نظمی در هر سیستم می باشد، به این ترتیب که هر چه درجه بی نظمی بالاتر باشد آنتروپی بیشتر است . به طور کلی می توان گفت که آنتروپی معیاری است برای تعداد حالت های داخلی ، که یک سیستم می تواند داشته باشد و از رابطه (۱) قابل محاسبه است.

$$\text{Entropy} = \sum_{i=1}^{c} p_i \log_2 p_i \qquad (۱)$$

که در آن i تعداد دسته بندی ها و p_i احتمال وجود عضو در دسته ی مورد نظر می باشد. در این مقاله از Entropy نوع threshold ، استفاده شده است. ($p\leq 0$). که در آن p حد آستانه ی مجاز است.

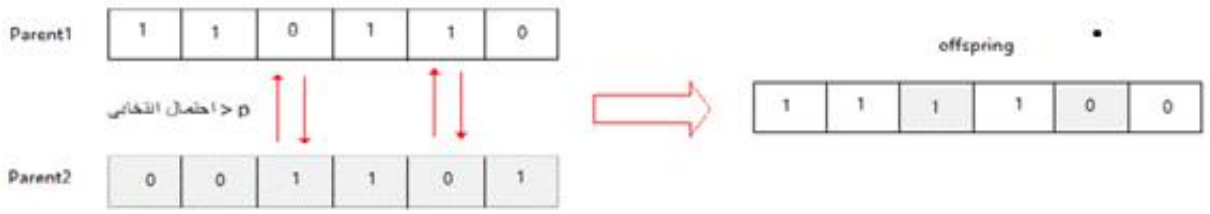
۳ -الگوریتم جهش قورباغه ی مخلوط شده(SFLA)

ترکیبی از EA ها با جستجوی محلی به نام الگوریتم ممتیک نامیده می شود . الگوریتم جهش قورباغه یک الگوریتم فوق ابتکاری ممتیک است که الگوهای رفتاری تکاملی گروهی از قورباغه ها را زمانی که به دنبال محلی با بیشترین مقدار غذا می باشند را تقلید می کند. در SFLA جستجو با انتخاب تصادفی جمعیتی از قورباغه ها که کل مرداب را پوشش داده اند آغاز می شود. جمعیت به m مجتمع (Memeplex) تقسیم میشود که هر مجتمع شامل n قورباغه می باشد . بنابراین کل جمعیت از رابطه $F = m*n$ بدست می آید. قورباغه ها بر طبق مقدار برازندگی شان مرتب می شوند. در هر مجتمع قورباغه با بهترین و بدترین برازندگی به ترتیب با X_b و X_w مشخص می شود. همچنین قورباغه با بهترین برازندگی در جمعیت با X_g مشخص می شود . جستجوی محلی در هر زیر مجتمع اجرا می شود و بدترین قورباغه ها طبق معادله ی (۲) و (۳) بروزرسانی می شوند.

$$D_i = \text{rand}().(X_b - X_w) \qquad (۲)$$

$$X'_w = X_w + D_i,\ D_{min} \leq D_i \leq D_{max} \qquad (۳)$$

که در آن rand() یک عدد تصادفی بین صفر و یک است. D_{min} و D_{max} به ترتیب حد پایین و بالای محدوده ی مجازی است که یک قورباغه فقط در این محدوده می تواند تغییر موقعیت دهد. اگر این فرآیند یک قورباغه بهتر تولید کند جایگزین بدترین قورباغه می شود در غیر این صورت بهترین



شکل ۱- عملکرد عملگر ترکیب در الگوریتم LSFLA

قورباغـه ی سراسـری جـایگزین بـدترین قورباغـه در جمعیـت می شود. اگر بهبودی حاصل نشود یک راه حـل عملـی تصـادفی تولید می شود. در نهایت همه قورباغه ها بـرای تبـادل اطلاعـات سراسری مخلوط می شوند و ایـن مراحـل تـا رسـیدن بـه معیـار همگرایی از پیش تعریف شده موردنظر ادامه می یابد.

۴ -الگوریتم جهش قورباغه بهبود یافته(LSFLA)

در الگـوریتم بهبـود یافتـه (LSFLA) ، بـرای رفـع معایـب SFLA پایه و بهبود توانایی های آن سعی شد کـه تغییراتـی بـر روی الگوریتم انجام گیرد، بـه ایـن صـورت کـه ابتـدا رفتارهـای تصـادفی کـه در الگـوریتم وجـود دارد بـا رفتارهـای آشـوبناک جایگزین می شود، همچنین از عملگر ترکیب برای تولید موقعیت بهتر برای جایگزینی با بدترین موقعیت استفاده شده است.

تابع لجستیک یک نگاشت معکوس پذیر است زیـرا بـه ازای هر X_{n+1} دو مقدار برای X_n بدست می آید که در معادله ی (۴) نشان داده شده است.با اعمال این نگاشت در هر مرحلـه روی پاسخ مرحله ی قبل ، در طول زمان الگوهای مختلفـی در پاسـخ ها مشاهده مـی شـود . ایـن الگوهـا هـم بـه مقـدار پـارامتر α و همچنین به نقطه ی شروع وابسته اند.

$$X_{n+1} = \alpha X_n (1 - X_n) \qquad (۴)$$

با توجه به اینکه در الگوریتم SFLA پایـه ، تولیـد جمعیـت اولیه به صورت تصادفی انجام می شود بنابراین این تولید تصادفی با یک تولید آشوبناک جایگزین شده است . در الگـوریتم SFLA پایه مراحل بهبود موقعیت بدترین عضـو زیـر مجتمـع X_w ، در سه مرحله صورت می گیـرد و درگـام سـوم موقعیـت جدیـد بـه صورت تصادفی در فضای مسئله تولید شده و جـایگزین بـدترین عضو زیر مجتمع می گردد.

ترکیب عملگری اکتشافی است که امکان پرش هـای بـزرگ به ناحیه ی در بین ناحیه مربوط به والدین را فراهم می سازد. در الگوریتم LSFLA بهترین عضو زیر مجتمع و بهترین عضـو کـل جمعیت ، به عنوان والدین در نظر گرفته می شوند. سـپس بـا در نظـر گـرفتن احتمـال p جابجـایی کرومـوزوم هـا بـین والـدین صورت می گیرد که در شـکل ۱ نشـان داده شـده اسـت. فرزنـد بدست آمده در صورت داشتن برازندگی بهتـر جـایگزین بـدترین عضو در زیر جمعیت می گردد.

۴ ۱ - کاربرد LSFLA در خوشه بندی داده

در این تحقیق از قابلیتهای جستجوی الگوریتم LSFLA به منظور یافتن تعداد مشخص k مرکز خوشه بنـدی اسـتفاده شـده است . به طور کلی هدف تحقیق عبـارت اسـت از خوشـه بنـدی صحیح داده هـا بـا متریـک خوشـه بنـدی برگرفتـه از فاصـله ی اقلیدسی میان این نقاط و مراکز خوشه ها. فلوچارت الگـوریتم در شـکل ۲ نشـان داده شـده اسـت. در ادامـه جزئیـات الگـوریتم LSFLA مورد استفاده در خوشه بندی شرح داده میشود.

گـام ۱ : مقـدار دهـی اولیـه. دو متغیـر m , n را انتخـاب می کنیم به طوری که m تعداد مجتمع ها و n تعداد قورباغـه هـا در هر مجتمع باشد.

گام ۲ : تولید جمعیت مجازی با استفاده از تابع لجسـتیک . تعداد F قورباغه مجازی $U(1), U(2), ...U(n)$ را در فضای شدنی $\Omega \subset R^{kd}$ ، جایی که k تعداد خوشه هـا و d تعـداد متغیرهـای تصمیم گیری است نشانه گـذاری مـی کنـیم. . قورباغـه i- ام بـا برداری از مقادیر متغیرهای تصمیم گیـری نمـایش داده میشـود $U(i) = (U_i^1, U_i^2, ..., U_i^{kd})$ که حاوی یک جواب ممکن بـرای k مرکز خوشه میباشد.

گام ۳ : محاسبه ی فاصـله ی اقلیدسـی میـان مراکـز تولیـد شده (قورباغه ها) و داده ها بر اساس معادله ی (۵).

$$d(z_p, m_j) = \sqrt{\sum_{k=1}^{d} (z_{pk} - m_{jk}) \wedge 2} \qquad (۵)$$

کـه در آن z_p نشـان دهنـده ی بـردار داده p- ام ، m_j نشـان دهنده ی بـردار مرکـز خوشـه j-ام ، n_d ابعـاد ورودی ، یعنـی تعـداد پارامترهـای هـر بـردار داده و انـدیس k بعـد را مشـخص میکند.پس از اینکه داده ها بر اساس فاصـله ی اقلیدسـی کـلاس بندی شدند مقدار برازنـدگی بـرای هـر قورباغـه F(i) بـر اسـاس فرمول (۶) محاسبه میشود:

$$Fitness = Max(Entropy(k_i)), \quad i = 1,2,...,n \qquad (۶)$$

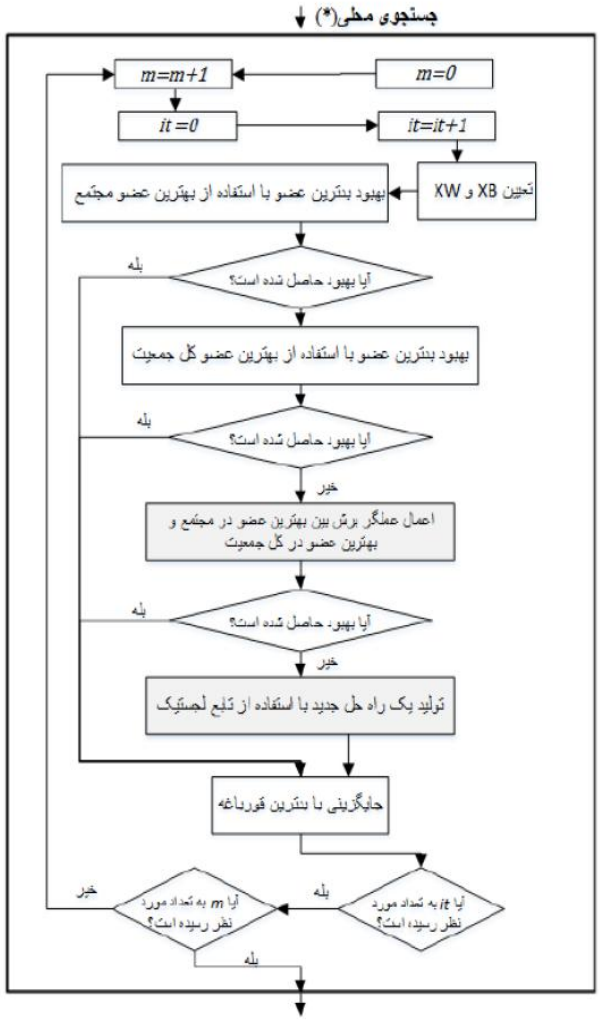
که در آن k_i شماره خوشه می باشـد.در هـر دسـته مقـدار آنتروپی محاسبه می شـود ، بـی نظمـی بیشـتر مقـدار آنتروپـی بیشتری به همراه خواهد داشت در نتیجه حداکثر مقدار آنتروپـی به عنوان تابع برازندگی انتخاب می شود.

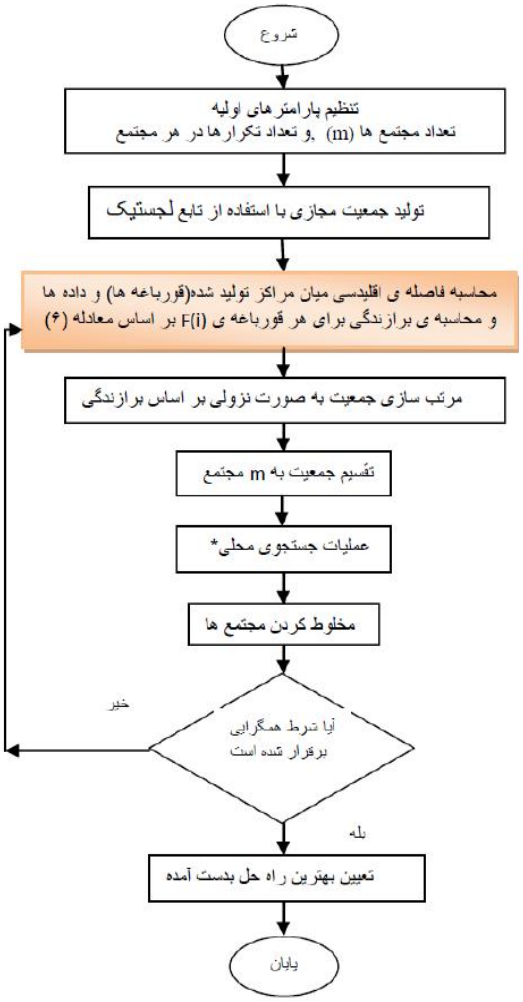
گام ۴ : رتبه بندی قورباغه ها. تعداد F قورباغه را با توجه به مقدار عملکردشان به صـورت نزولـی مرتـب میکنـیم. آنهـا را در آرایه ای نگه می داریم $X = \{U(i), f(i), i = 1,...F\}$. بنابراین i=1 نشان دهنده ی قورباغه با بالاترین میزان عملکرد میباشـد. مکـان بهترین قورباغه در کل جمعیت را در P_X نگه میداریم؛ جایی که $P_X = U(1)$ است.

گام ۵ : دسته بندی قورباغه ها به مجتمع ها. آرایه X را به m مجتمع $Y^1, Y^2, ...Y^m$ تقسیم میکنیم که هرکدام دارای n قورباغه باشد.

گام ۶ : عملیات جستجوی محلی.

گام ۷ : مخلوط شدن مجتمع ها. بعد از انجام تعداد مراحل مشخص از تکامل ممتیک بر روی هر کدام از مجتمع ها





شکل ۲- ساختار الگوریتم LSFLA در خوشه بندی

$Y^1, Y^2, ... Y^m$ را در X جایگذاری میکنیم. آرایه X را به صورت نزولی بر اساس کارایی مرتب کرده و مکان بهترین عضو جمعیت، P_X ، را به روز می کنیم.

گام ۸ : چک کردن همگرایی. اگر حد همگرایی ارضا شد، برنامه تمام میشود. در غیر اینصورت به مرحله ۳ برمیگردیم. تصمیم گرفتن برای اینکه الگوریتم چه زمانی تمام شود با تعداد حداکثر حلقه های زمانی مشخص میشود.

۵ -شبیه سازی و نتایج

در این مقاله برای بررسی کارایی الگوریتم الگوریتم ، روش پیشنهادی بر روی چهار مجموعه داده واقعی اعمال شده است و با الگوریتم های k-means ، GA ، PSO و CPSO مقایسه شده است . داده های مورد نظر در جدول ۱ نشان داده شده است.

۵ ۱ - تنظیم پارامترهای اولیه

برای پیاده سازی الگوریتم از نرم افزار متلب ۲۰۱۳ استفاده شده است و الگوریتم ها بر روی سخت افزار مشابه اجرا می شود. پارامترهای مورد نیاز برای الگوریتم LSFLA به صورت زیر در نظر گرفته شده است. .تعداد مجتمع ها (m) را ۱۰ و تعداد قورباغه ها (n) در هر مجتمع را برابر با مقدار ۲۰ در نظر می گیریم. متغیر (q) که تعداد قورباغه های انتخابی برای زیر مجتمع می باشد برابر با مقدار ۱۸ و جستجوی محلی در هر زیر مجتمع به تعداد ۱۰ بار تکرار می گردد. مقدار پارامتر α برای تابع لجستیک ۴ و مقدار p برای عملیات ترکیب برابر با مقدار ۰/۸ می باشد. پارامتر مقیاس جستجو c در گام جهش برابر با مقدار ۲ و همچنین مقدار حد آستانه در تابع برازندگی مقدار ۰/۱۵ در نظر گرفته شده است.

جدول ۱- داده های مورد استفاده

	تعداد نمونه	تعداد خوشه	تعداد ویژگی
Iris	۱۵۰	۳	۴
Wine	۱۷۸	۳	۱۳
Glass	۲۱۴	۶	۹
Cancer	۶۸۳	۲	۹

۵ ۲ -معیار ارزیابی

ارزیابی روش پیشنهادی بر اساس معیار خطا صورت می گیرد. این معیار بر اساس معادله (۷) محاسبه می شود.

$$\text{error rate} = \left(\frac{\sum_{i=1}^{n} (\text{if } A_i = B_i \text{ then 0 else 1})}{n}\right) * 100 \qquad (۷)$$

در این معادله n تعداد کل داده ها را نشان می دهد . بنابر این رابطه ، اگر داده i -ام به درستی خوشه بندی شده باشد مقدار ۰ و در غیر این صورت مقدار ۱ می شود.بنابراین هر چه میزان اشتباهات خوشه بندی افزایش یابد نرخ خطا بالاتر می رود.

۵ ۳ -نتایج شبیه سازی

جدول ۲ میانگین نرخ خطا و بهترین نرخ خطا برای ۲۰ تکرار را نشان می دهد. همانطور که دیده می شود الگوریتم LSFLA بهترین کارایی را در بین الگوریتم های دیگر دارد. برای هر چهار مجموعه داده ای بدترین کارایی مربوط به الگوریتم الگوریتم ژنتیک می باشد. همچنین الگوریتم k-meams تمایل دارد که در یک بهینه ی محلی بیفتد. روش LSFLA سرعت همگرایی را بالا می برد و در نتیجه قادر می سازد که LSFLA بهتر از سایر روشها باشد. این روش مجموعه داده ها را با مقدار میانگین ۷,۳۳ ، ۲۸,۰۸ ، ۴۰,۵۳ و ۳,۴۲ به ترتیب برای داده های Iris ، Wine ، Glass ، Cancer طبقه بندی می کند. به عبارت دیگر روش معرفی شده در این مقاله دارای نرخ خطای کمتری از دیگر الگوریتم هاست که منجر به روش عملی و کاربردی در خوشه بندی داده ها شده است.

۶ -نتیجه گیری

در این مقاله برای رفع معایبی مانند افتادن در بهینه ی محلی از الگوریتم LSFLA برای انجام خوشه بندی داده ها استفاده شده است . این الگوریتم بهبود یافته با استفاده از عملگرهای آشوب و ترکیب در جستجوی محلی توانسته کارایی الگوریتم را در رسیدن به جواب بهینه بهبود بخشد و به نتایج قابل قبولی دست یابد. همینطور با استفاده از آنتروپی در تابع برازندگی توانستیم کارایی این الگوریتم را برای خوشه بندی افزایش دهیم .نتایج بدست آمده نشان می دهد که این روش در مقایسه با الگوریتم های k-means ، GA، PSO، CPSO دارای خطای کمتری می باشد و می توان از آن به عنوان یک روش کارا در مسائل خوشه بندی استفاده نمود.

جدول۲- مقایسه ی نرخ خطای الگوریتم های خوشه بندی

dataset	Criteria	K-means	GA	PSO	CPSO	LSFLA
Iris	Averegae	17.80	18.2	12.53	10.00	**7.33**
	Best	10.67	10.02	10.00	10.00	**4.00**
Wine	Averegae	31.12	34.52	28.71	28.62	**28.08**
	Best	29.78	31.53	28.09	28.09	**28.08**
Glass	Averegae	39.20	46.89	43.35	40.38	**40.53**
	Best	37.41	41.67	39.48	34.12	**39.28**
Cancer	Averegae	4.39	8.59	5.11	3.51	**3.42**
	Best	4.35	5.27	3.66	3.51	**2.81**

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تشخیص مقاوم اشیاء مبتنی بر استخراج کانتور و با استفاده از گشتاورهای زرنیک

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چکیده - تشخیص اشیاء در تصاویر یکی از موضوعات مهم در مباحث بینایی ماشین و یکی از اصلی‌ترین مراحل درک تصویر است. استخراج خطوط مرزی یا کانتور[a] می تواند یک مرحله ی مفید به منظور تشخیص اشیاء به حساب آید. اغلب روش‌های تشخیص کانتور با چالش‌هایی نظیر نویز، شیفت، تغییر مقیاس و چرخش در تصاویر مواجه هستند که این شرایط موجب عدم استخراج کامل و بهینه ی کانتور می‌شوند. برای استخراج کانتور، لازم است راه‌حلی ارائه گردد که مستقل از نویز، شیفت، تغییر مقیاس و چرخش اشیاء در تصاویر باشد. به همین منظور برای اولین بار در این مقاله استخراج ویژگی به منظور استخراج کانتور با استفاده از گشتاورهای زرنیک و شبه زرنیک انجام گرفته است که این روش مستقل از نویز، شیفت، تغییر مقیاس و چرخش در تصاویر است. روش پیشنهادی شامل سه مرحله ی اصلی، تشخیص ناحیه شیء، استخراج ویژگی و تشخیص الگو می باشد. در مرحله اول خطوط و لبه‌های شیء در تصاویر با استفاده از روش *LDC* شناسایی می‌شود. در مرحله دوم، گشتاور شبه‌زرنیک (زرنیک) به منظور استخراج ویژگی از کانتور شیء مورد استفاده قرار گرفته و در مرحله آخر با استفاده از ماشین بردار پشتیبان کانتور شیء تشخیص داده شده و در نهایت نوع شیء شناسایی می‌شود. نتایج آزمایشات روش پیشنهادی بر روی پایگاه داده‌های *ETHZ* و *Caltech-101* نشان داده است که روش پیشنهادی نرخ تشخیص کانتور را با کاهش پیچیدگی محاسبات، بهبود داده است.

کلید واژه- تشخیص خطوط مرزی، آشکارسازی کانتور، الگوریتم LDC، گشتاور شبه‌زرنیک، گشتاور زرنیک، ماشین بردار پشتیبان.

۱- مقدمه

عملیات تشخیص کانتور شیء یا یافتن مرز نواحی در تصویر، یکی از گام‌های حیاتی در پردازش تصاویر و از مهم‌ترین مراحل کلاس‌بندی و تشخیص اشیاء محسوب می‌شود. اهمیت این مسئله زمانی قابل توجه می‌شود که بدانیم خروجی بسیاری از الگوریتم‌های تحلیل تصویر، به الگوریتم تشخیص صحیح و دقیق کانتور شیء وابسته است. کانتور شیء از روی لبه های تصویر بدست می‌آید. لبه به مناطقی از یک تصویر گفته می‌شود که دارای تغییرات قابل توجهی در روشنایی باشند. لبه های تصویر ممکن است یک نقطه یا یک بخش جدا در اطراف شیء مورد نظر باشند که با اتصال این نقاط به یکدیگر در اطراف شیء مورد نظر، کانتور شیء تشکیل می‌شود. تشخیص کانتور باعث کاهش مقدار اطلاعات موجود در تصویر می‌شود. می‌توان گفت تشخیص کانتور یکی از مهم‌ترین پروسه‌های سطح پایین در پردازش تصاویر است به طوری که کارایی بسیاری از پروسه‌های سطح بالا مستقیما به کارایی آن وابسته می‌باشد [۱]. به عبارت دیگر می‌توان گفت آشکارسازی دقیق کانتور شیء یکی از وظایف اصلی پردازش سطح پایین تصویر محسوب می‌شود که رابطه مستقیمی با قابلیت اجرا، دقت و سرعت اجرای پردازش‌های سطح بالا برای تحلیل تصویر دارد [۲].

الگوهای تشخیص کانتور شامل سه مرحله اصلی فیلترینگ، مشتق‌گیری، تشخیص و اتصال نقاط می‌باشند. در مرحله فیلترینگ، تصویر از یک فیلتر به منظور حذف نویز گذرانده می‌شود. در مرحله مشتق‌گیری، موقعیت‌هایی در تصویر با تغییرات شدت نویز زیاد برجسته می‌گردند. سرانجام، در مرحله تشخیص با آستانه‌گیری از نقاطی که در مرحله مشتق‌گیری برجسته شده‌اند نقاط لبه تعیین می‌گردند. در مرحله آخر با اتصال نقاط لبه تصویر، کانتور تشکیل می گردد. استفاده از الگوریتم تشخیص کانتور در بسیاری از کاربردها از جمله در صنعت، پزشکی، صنایع نظامی، امنیتی و غیره لازم است. به عنوان مثال در حوزه پزشکی می‌توان به محاسبه ی سطح بیماری پسوریازیس که در تشخیص درست بیماری کمک شایانی نموده است و همچنین تشخیص ناحیه تومور یا عارضه در تصاویر

پزشکی اشاره نمود. در تشخیص کانتور شیء در تصویر مشکلاتی مانند وجود نویز در تصاویر گرفته شده توسط دوربین وجود دارد که این امر عمل تشخیص کانتور را با مشکل مواجه می سازد [۳-۴].

در این مقاله روش جدیدی برای تشخیص اشیاء مبتنی بر استخراج کانتور ارائه شده است. برخلاف روش‌های قبلی تشخیص اشیاء، روش پیشنهادی در این مقاله از سه مرحله تشکیل شده است که در مرحله اول، مرز ها و نواحی اشیاء با استفاده از روش LDC تعیین شده، در مرحله دوم عمل استخراج ویژگی از ناحیه مورد نظر با استفاده از گشتاورهای زرنیک [b] و شبه‌زرنیک[c] انجام شده و در مرحله سوم استخراج کانتور شیء (تشخیص شیء) در تصویر با استفاده از الگوریتم یادگیری ماشین تشخیص داده می‌شود. ساختار ادامه ی مقاله به شرح زیر می باشد: بخش (۲) مرور کارهای پیشین، بخش (۳) روش پیشنهادی، بخش (۴) نتایج سیستم پیشنهادی، بخش (۵) تحلیل نتایج سیستم پیشنهادی و در نهایت نتیجه گیری و کارهای آینده ارائه می گردد.

۲- مرور کارهای پیشین

آشکارسازی کانتور تصویر به معنی فرآیند شناسایی و تعیین خطوط تند ناپیوسته در یک تصویر می باشد. این خطوط ناپیوسته محدوده اشیای مختلف در تصویر را مشخص می‌کنند. یکی از ویژگی‌های مفید و موثر در بازشناسی اشیاء، استفاده از اطلاعات شکل و لبه‌های آن‌ها است. بنابراین، استفاده از لبه‌ها در بسیاری از کاربردهای بینایی ماشین و بازشناسی، امری متداول است. با توجه به این موضوع، می‌توان نتیجه گرفت که ضرورت طراحی آشکارسازهای مناسب لبه از اهمیت ویژه‌ای برخوردار است. آشکارسازی لبه‌ها بر اساس عملگرهای مشتق اول و دوم شامل روش‌های Sobel [۵]، prewitt [۶]، Roberts [۷] و لاپلاسین می‌باشد. در سال‌های اخیر تحقیقات بسیاری بر روی لبه‌یابی تصاویر رنگی انجام شده است [۸-۹]. دسته‌ای از این الگوریتم‌ها برای تشخیص لبه از محاسبه بردار مشتق استفاده می‌کنند. این دسته از الگوریتم‌ها در حالت کلی نسبت به نویز حساس می‌باشند. یکی از راه‌های ممکن در جهت کاهش اثر نویز در این نوع الگوریتم‌ها، استفاده از روش‌های میانگین‌گیری در طی فرآیند مشتق‌گیری می‌باشد، مانند الگوریتم لبه‌یاب لاپلاس گوسی [۱۰]. یکی از روش‌های مبتنی بر بردار که اخیرا توسط کنگ و همکارانش [۱۱] ارائه شده، الگوریتمی مبتنی بر درخت پوشای مینیمال[d] است. این الگوریتم در عین ارائه نتایج خوب از زمان اجرای طولانی رنج می برد. در کاربردهای عملی که نیاز به لبه‌یابی تصاویر رنگی با سرعت بالا می‌باشد، زمان اجرای بالای این الگوریتم، استفاده از آن را غیر ممکن می‌سازد. در [۱۲] شناسایی کانتور شیء برجسته بر اساس الگوریتم BSR انجام شده است. این روش با توجه به اُپراتور لبه‌های برجسته عمل می‌کند و مرزهای متوالی از لبه‌های برجسته را ردیابی می‌کند، نواحی مشابه بین مرزها را با کانال مستقیم و فاصله را با الگوریتم BSR محاسبه می‌کند. پس از آن نواحی مرزی مشابه با استفاده از روش درج خطی بمنظور اطمینان از اینکه مرزها متعلق به همان کانتور است، پر می‌شود. روش فوق تا حد زیادی پیچیدگی زمانی را کاهش می‌دهد. در [۱۳] از یک الگوریتم هوش ازدحامی (گروهی) برای شناسایی کانتور در تصاویر استفاده شده است. هوش ازدحامی از مجموعه‌ای از عامل‌ها که قادر به حرکت و جمع‌آوری اطلاعات محلی است، استفاده می‌کند. الگوریتم بر مبنای عامل برای شناسایی کانتور تصاویر بکار می‌رود. عامل قادر به توزیع موقعیت خود روی تصویر ورودی جهت پوشش‌دهی تمام موقعیت‌های مهم تصویر است. برای تولید کانتورهای سراسری، عامل‌ها اطلاعات محلی تصویر را بررسی می‌کنند و بر اساس مجموعه توابع برازندگی و از طریق ارتباطات با یکدیگر، ارتباطات را برقرار می‌کنند. بجای یک الگوی متمرکز، راه حل سراسری، شناسایی هر عامل با قوانین اصلی است. الگوریتم فوق نسبت به مدل‌های شیء و یا مراحل آموزش، مستقل است. اخیرا روش‌های بر مبنای هوش ازدحامی قادر به مدیریت سیستم‌ها و کارهای پیچیده هستند و در کارهای بینایی کامپیوتر و پردازش تصویر اعم از شناسایی لبه [۱۴] و استخراج ویژگی و شناسایی شیء [۱۵] با موفقیت اعمال شده است. الگوریتم شناسایی کانتور LDC بدلیل دقت بیشتر و عدم نیاز به عملکردهای پیچیده و همچنین مقاومت در برابر چرخش و اندازه، در این مقاله مورد استفاده قرار گرفته است.

۳- روش پیشنهادی

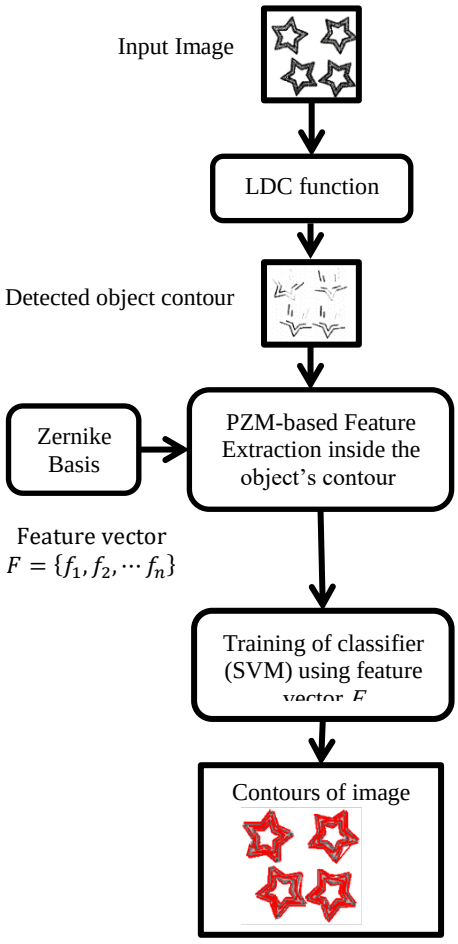
در این مقاله روش جدیدی برای تشخیص کانتور اشیاء ارائه شده است. روش پیشنهادی در این مقاله از سه مرحله تشکیل شده است که در مرحله اول، کانتور اشیاء با استفاده از روش LDC تعیین شده، در مرحله دوم عمل استخراج ویژگی از ناحیه شیء انجام شده و در نهایت شیء توسط الگوریتم ماشین بردار پشتیبان تشخیص داده می‌شود. در روش پیشنهادی به‌منظور

استخراج ویژگی از گشتاورهای زرنیک و شبه‌زرنیک استفاده شده است. به طور کلی روش پیشنهادی شامل مراحل زیر است که در شکل ۱ نیز نمایش داده شده است:

۱) اعمال LDC

۲) اعمال PZM (ZM)

۳) استخراج کانتور شیء (تشخیص شیء) در تصویر با استفاده از الگوریتم یادگیری ماشین



شکل ۱: بلوک دیاگرام روش پیشنهادی

بر اساس شکل ۱، تعدادی از تصاویر پایگاه داده به عنوان مجموعه آموزشی و مابقی به‌عنوان مجموعه تست در نظر گرفته می‌شوند. این تصاویر به‌عنوان ورودی به الگوریتم LDC داده می‌شوند و کانتور اشیاء با استفاده از روش LDC تعیین می‌شود، سپس عمل استخراج ویژگی از کانتور شیء با استفاده از گشتاور زرنیک (شبه‌زرنیک) انجام شده و در نهایت شیء توسط الگوریتم ماشین بردار پشتیبان تشخیص داده می‌شود.

۳-۱- شناسایی کانتور

مرحله اول اعمال الگوریتم LDC بر روی تصاویر ورودی به منظور یافتن کانتور اشیاء است. بنابراین در این مرحله کانتور اشیاء در تصاویر به‌دست می‌آید. از آنجا که LDC مستقل از تبدیلات تصویر است، کانتور اشیاء را حتی با وجود چرخش تصاویر و یا تغییر اندازه‌ی تصویر، به درستی به‌دست می‌آورد.

الگوریتم LDC بر مبنای تشخیص و استخراج پاره خط است. اولین مرحله الگوریتم LDC تبدیل مقیاس خاکستری است که شدت روشنایی تصویر خروجی را نسبت به تصویر اصلی نشان می‌دهد. دومین مرحله نرمال‌سازی تصاویر است. نرمال‌سازی شدت روشنایی را در هرپیکسل از تصویر تغییر می‌دهد. این روند به تشخیص درست لبه کمک زیادی می‌کند. سومین مرحله هموارساز گوسین[e] است. بعد از مرحله نرمال‌سازی، می‌توان کانتور بهتری از تصویر داشت و هموارساز گوسین برای حذف نویز از تصویر و ایجاد کانتورهای اصلی تصویر، استفاده می‌شود. در واقع هموارسازی بر روی تصاویر سطح خاکستری خروجی مرحله نرمال سازی اعمال می‌شود. اگر تصویر نرمال شده نباشد، خروجی مرحله اول یعنی تصویر سطح خاکستری، به‌عنوان ورودی این مرحله در نظر گرفته می‌شود. چهارمین مرحله استفاده از اپراتور لاپلاس است. بررسی نتایج تست الگوریتم‌های مختلف تشخیص لبه مانند Sobel، Canny و Predefined Convolution kernels و همچنین اپراتور لاپلاس در[۱۶] نشان-دهنده بهترین نتیجه برای اپراتور لاپلاس است. پنجمین مرحله استفاده از روش آستانه‌گذاری است. بعد از مراحل نرمال‌سازی، هموارساز گوسین و اپراتور لاپلاس، یک تصویر سطح خاکستری خواهیم داشت که با استفاده از یک حد آستانه، یک تصویر باینری با دو محدوده‌ی رنگ (سفید/سیاه) به‌دست می‌آید. نقاط سفیدرنگ لبه‌های تصویر را نشان می‌دهند و نقاط سیاه‌رنگ پس‌زمینه تصویر را نشان می‌دهند. ششمین مرحله استخراج کانتور تصویر است. تصویر باینری به‌دست آمده از مرحله آستانه-گذاری به عنوان ورودی این مرحله از الگوریتم می باشد. به‌همین منظور اطلاعاتی را از لبه‌ها استخراج می‌کنیم (نواحی سفیدرنگ). کانتورها، لیستی از پیکسل‌ها هستند که هرپیکسل اطلاعاتی را از پیکسل بعدی همسایگی‌اش دارد. کانتورها اجزای مختلف متصل به‌هم در تصویر ورودی را احاطه کرده اند. عملکرد این پارامترها، فیلترکردن کانتورها با حداقل مقدار آستانه برای کل پیکسل‌هاست. آخرین مرحله بخش‌بندی کانتورها است.

۳-۲- استخراج ویژگی

مرحله دوم، استخراج ویژگی روی کانتور اشیاء با استفاده از روش‌های زرنیک و شبه‌زرنیک است. گشتاورهای زرنیکی، تصویر یک تابع دوبعدی به چند جمله‌ای‌های مختلط متعامد[f] هستند. این چند جمله‌ای‌ها داخل دایره واحد $(x^2 + y^2 \leq 1)$ تعریف می‌شوند و یک مجموعه کامل هستند. مجموعه این چند جمله‌ای‌ها با $\{V_{nm}(x,y)\}$ نشان داده می‌شوند.

گشتاورهای زرنیکی، تصویر یک تابع دوبعدی روی این توابع پایه می‌باشند. گشتاورهای زرنیکی از مرتبه n و تکرار m برای تابع گسسته و دوبعدی $f(x,y)$، که فقط در داخل دایره واحد مقدار داشته باشد، به صورت زیر محاسبه می‌شوند:

$$ZM_{nm} = \frac{n+1}{\pi} \sum_x \sum_y f(x,y)\ V^*_{nm}(x,y) \qquad (۱)$$

چون $V_{nm}(x,y) = V^*_{n,-m}(x,y)$ می‌باشد، فقط لازم است که گشتاورهای زرنیکی برای m های مثبت محاسبه شود. تعداد گشتاورهای زرنیکی تا مرتبه n برابر $\frac{(n+1)(n+2)}{2}$ می‌باشد. اگر فقط m های مثبت را در نظر بگیریم، تعداد گشتاورهای زرنیکی تا مرتبه n برای n های فرد برابر $\frac{(n+1)(n+3)}{4}$ و برای n های زوج برابر $\frac{(n+2)^2}{4}$ خواهد بود. برای محاسبه گشتاورهای زرنیکی، دایره محیطی الگوها را به دست آورده و مرکز این دایره را مبدأ مختصات و شعاع آن را برابر واحد فرض می‌کنیم. به این ترتیب تشخیص الگو، از جابجایی و اندازه، مستقل می گردد.

۳-۳- شناسایی اشیاء

آخرین مرحله روش پیشنهادی، آموزش روش تشخیص الگو با توجه به عناصر بردار ویژگی استخراج شده از مراحل قبل است. از آنجا که آموزش یک روش تشخیص الگو (یادگیری) به بردار ویژگی بستگی دارد، استخراج بردارهای ویژگی مفید، تاثیر بسیاری در افزایش سرعت کشف و شناسایی لبه‌های تصویر دارد. هم‌چنین اکثر روش‌های استخراج ویژگی تصویر به هندسه لبه های اشیاء در تصاویر وابسته هستند. بنابراین چرخش و یا تغییرات مقیاس لبه در تصاویر به طور قابل توجهی دقت روش یادگیری را کاهش می‌دهد. اما برخلاف اکثر روش‌ها، روش‌های زرنیک و شبه‌زرنیک حتی با وجود چرخش تصاویر و یا تغییر اندازه تصویر، می‌توانند بردارهای ویژگی تصاویر را استخراج کنند. در روش ارائه شده، استخراج بردار ویژگی توسط دو روش گشتاور زرنیک و شبه زرنیک به منظور تشخیص لبه های اشیا انجام می‌شود و سپس ویژگی‌های استخراج شده به الگوریتم طبقه‌بند ماشین بردار پشتیبان [g] داده می‌شود و نواحی شیء کلاس‌بندی می شود. در این مقاله از ماشین بردار پشتیبان خطی (ماشین بردار پشتیبان با کرنل خطی) برای تشخیص لبه استفاده شده است. شبه کد روش پیشنهادی (LDC-PZM) برای تشخیص شیء در شکل ۲ ارائه شده است.

1. Construction of ZBF.
2. Dividing images dataset into training, validation and testing sets.
3. For *i*=1 to no. of cross validation
4. Object contour recognition using LDC.
5. Feature extraction on the detected contours using PZM based on ZBF.
6. Training of classifier according to the extracted feature vector.
7. Validation of trained classifier using the i^{th} validation set.
8. End For
9. For *j*=1 to no. of testing image
10. Object contour recognition on test images using LDC.
11. Feature extraction from the detected contours of j^{th} testing image based on the ZBF.
12. Test the trained classifier using the extracted feature vector of previous step.
13. End For
14. Calculation of correct estimation rate.

شکل ۲: شبه کد روش پیشنهادی (LDC-PZM) برای تشخیص کانتور

بر طبق این الگوریتم، مرحله اول ساخت تابع پایه زرنیک [h] است که در آن یک دنباله از چند جمله‌ای‌های متعامد ساخته شده است. نکته قابل توجه اینکه چندجمله های متعامد مستقل از تصویر هستند و یک بار تولید شده اما چندین بار استفاده می شوند. بنابراین پیچیدگی زمانی فرآیند تشخیص لبه، کاهش می‌یابد. از آنجا که روش پیشنهادی با استفاده از روش اعتبارسنجی 10-fold ارزیابی می‌شود، مرحله دوم، ارزیابی روش پیشنهادی بر روی مجموعه‌ی تست خواهد بود. بعد از اینکه تابع LDC بر روی تصاویر ورودی اعمال گردید، خطوط مستقیمی به عنوان کانتور شیء استخراج می‌گردد سپس مجموعه‌ای از چندجمله‌ای‌های متعامد تولید شده (و یا ZBF) به منظور استخراج بردار ویژگی از ناحیه کشف‌شده در مرحله قبل به‌دست می‌آید. مرحله بعد تنظیم و آموزش الگوریتم کلاس‌بندی ماشین بردار پشتیبان است که با توجه به بردار ویژگی مبتنی بر گشتاور شبه‌زرنیک ایجاد شده در مرحله قبل انجام می‌گردد. روش پیشنهادی با استفاده از مجموعه داده‌های تست برای استخراج کانتور اشیاء مورد ارزیابی قرار می‌گیرد. در آخرین مرحله آموزش، خطاهای تشخیص کانتور شیء روی مجموعه تست، محاسبه می‌شود. چهار مرحله آموزش برای t بار تکرار می‌شوند. بعد از مراحل

آموزش و اعتبارسنجی داده‌ها، تست روش پیشنهادی بر روی مجموعه تصاویر تست انجام می‌گیرد. در مرحله تست، LDC روی j امین تصویر تست به منظور استخراج ناحیه اشیاء، اعمال می‌گردد. در مرحله بعد، استخراج ویژگی از کانتور شیء انجام می‌شود. سپس بردار ویژگی‌های تولید شده برای تشخیص شیء از j امین تصویر تست مورد استفاده قرار می‌گیرد. مراحل قبل برای تمامی تصاویر تست، تکرار می‌گردد. در نهایت، نرخ خطای طبقه‌بندی محاسبه خواهد شد.

۴- نتایج آزمایشات

به منظور ارزیابی، روش پیشنهادی بر روی پایگاه‌داده‌های Caltech-101 [۱۷] و ETHZ [۱۸] که شامل تصاویر رنگی و خاکستری در پنج گروه اشیاء مختلف است، تست شده است. نمونه‌ای از تصاویر دو پایگاه‌داده در شکل ۳ نمایش داده شده است. لازم به ذکر است که در پایگاه تصاویر ETHZ تعداد ۴۰ تصویر از لوگوی اپل، تعداد ۴۸ تصویر از بطری شیشه‌ای، تعداد ۸۷ تصویر از زرافه، تعداد ۴۸ تصویر از فنجان و تعداد ۳۲ تصویر قو موجود است. لازم به ذکر است که اشیاء موجود در تصاویر تست در شرایط روشنایی و مقیاس‌های مختلفی هستند.



شکل ۳: نمونه هایی از تصاویر موجود در پایگاه داده های مورد استفاده

۴-۱- شرایط شبیه‌سازی

پایگاه داده تصاویر به سه دسته: آموزشی، اعتبارسنجی و تست تقسیم می‌شود. تاثیر ترکیب روش‌های LCD و گشتاور شبه-زرنیک (زرنیک) به عنوان یک سیستم تشخیص شیء (کانتور) به همراه دو الگوریتم کلاس‌بندی ماشین بردار پشتیبان و نزدیک-ترین همسایگی تجزیه و تحلیل شده است. در این راستا، دو معیار درصدخطای کلاس‌بندی[i] و زمان اجرای هر الگوریتم کلاس‌بندی به عنوان معیارهای اندازه‌گیری کارایی در نظر گرفته شده‌اند.

۴-۲- تحلیل نتایج شبیه‌سازی

به منظور ارزیابی روش پیشنهادی، پایگاه داده‌ها به دو بخش اصلی یادگیری و تست تقسیم شده‌اند. برای تحلیل نتایج شبیه-سازی، ۷۰٪ مجموعه‌ی داده‌ها برای آموزش و مابقی تصاویر برای مرحله تست مورد استفاده قرار گرفته‌اند. جدول ۱ نتایج روش-های زرنیک و شبه‌زرنیک را با روش‌های استخراج ویژگی SIFT [۱۹] و SURF [۲۰] به منظور تشخیص کانتور بر روی دو پایگاه تصاویر نشان می‌دهد. نحوه محاسبه CEP در فرمول ۲ آمده است.

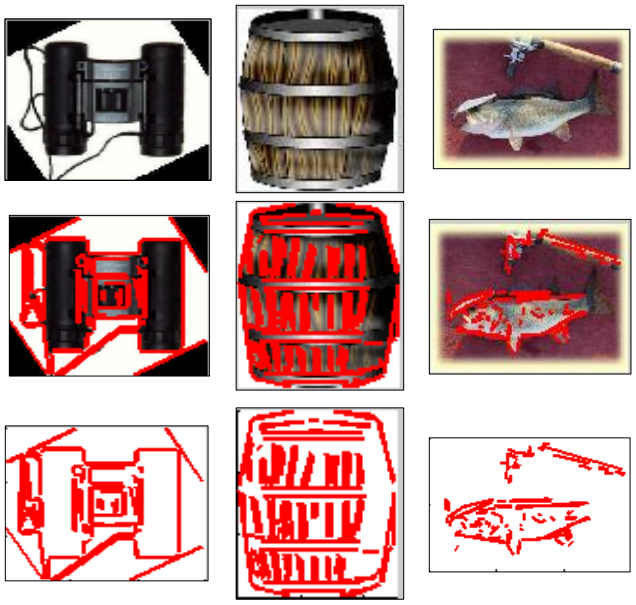
$$CEP = 1 - \left(\frac{number\ of\ misclassified\ samples}{total\ size\ of\ teest\ data\ set}\right) \quad (۲)$$

جدول۱: مقایسه نتایج ZM و PZM و SIFT و SURF برای اندازه‌گیری CEP و CPU بر روی هر دو پایگاه تصاویر

Data set	Measure	Feature extractor							
		SIFT		SURF		ZM		PZM	
		SVM	k-NN	SVM	k-NN	SVM	k-NN	SVM	k-NN
Caltech-101	CEP (%)	82.99	79.88	83.71	80.62	87.62	83.41	97.65	87.22
	CPU (s)	14	12	11	10	5	4	9	7
ETHZ	CEP (%)	82.99	79.88	83.71	80.62	87.62	83.41	97.65	87.22
	CPU (s)	16	11	11	8	6	7	10	9

مطابق جدول فوق، تمامی روش‌ها بر اساس معیارهای اندازه-گیری دقت طبقه‌بندی و معیار اندازه‌گیری زمان اجرا مورد ارزیابی قرار گرفته‌اند. همان طور که نتایج جدول نشان می‌دهند، روش شبه‌زرنیک پیشنهادی به همراه الگوریتم ماشین بردار پشتیبان بهترین نتیجه را برای معیار درصد خطای کلاس‌بندی بر روی هر دو مجموعه تصاویر به‌دست آورده است که دارای بیشترین دقت می‌باشد. برای اندازه‌گیری معیار زمان اجرا روش - استخراج ویژگی زرنیک پیشنهادی رتبه اول را برای تشخیص لبه و روش استخراج ویژگی شبه‌زرنیک رتبه دوم را برای معیار زمان اجرا بر روی هر دو دیتاست به‌دست آورده است. نتایج فوق اثبات می‌کنند که روش پیشنهادی زرنیک و شبه‌زرنیک، قادر به تشخیص بهینه کانتور (حاشیه) اشیاء در کوتاه‌ترین زمان اجرای ممکن است. دلایل این موفقیت به هر دو رویکرد شبه‌زرنیک و LCD برمی‌گردد. از آنجا که LDC مستقل از چرخش و مقیاس پذیری است، تقریبا قادر به کشف خطوط مستقیم در تمام اشکال کانتور اشیاء هستند و به این ترتیب، کانتور دقیق یک

شیء استخراج خواهد شد. علاوه بر این، استخراج بردارهای ویژگی مفید با استفاده از روش شبه‌زرنیک (یا زرنیک) از ناحیه شیء که قبلا تشخیص داده شده بود، می‌تواند مقدار معیار درصد خطای کلاس‌بندی را کاهش دهد. همان‌طور که در جدول نشان داده شده است روش پیشنهادی زرنیک برای معیار زمان اجرا به دو دلیل بهترین نتیجه را به‌دست آورده است: ۱) حداقل پیچیدگی زمانی LDC ۲) روش زرنیک توابع ZBF را که در ابتدا یک بار ساخته شده و چندین بار استفاده می‌شود، را به‌کار می‌گیرد. با مقایسه نتایج ماشین بردار پشتیبان و نزدیک‌ترین همسایگی در روش پیشنهادی، بهترین نتایج با استفاده از ماشین بردار پشتیبان به دست آمده و این اولویت در روش‌های دیگر نیز تکرار می‌شود. مطابق جدول ۱ سومین و آخرین نتایج به‌دست آمده به ترتیب مربوط به روش‌های SURF و SIFT است. عملکرد ضعیف هر دو روش SIFT و SURF حاکی از وابستگی‌شان به هندسه شیء است. شکل ۴ نتایج روش استخراج ویژگی شبه-زرنیک پیشنهادی را برای تشخیص لبه اشیاء نشان می‌دهد.



شکل ۴: نتایج روش پیشنهادی برای تشخیص کانتور که با استفاده از روش استخراج ویژگی شبه‌زرنیک و طبقه‌بند SVM به دست آمده است

همان‌طور که در جدول ۱ ارائه شد یکی از روش‌های تشخیص کانتور تصویر در این مقاله، الگوریتم نزدیک‌ترین همسایگی است. در این الگوریتم پارامتری به منظور تعیین تعداد نزدیک‌ترین همسایگی مورد استفاده قرار می‌گیرد که در عملکرد این الگوریتم تاثیرگذار است. به منظور ارزیابی الگوریتم نزدیک‌ترین همسایگی در مسئله تشخیص کانتور تصویر، این الگوریتم با سه مقدار k=1,3,5 و بر اساس سه روش استخراج ویژگی زرنیک، SIFT و SURF مورد تست قرار گرفته است. بر اساس این آزمایش، در تمامی روش‌های استخراج ویژگی بیشترین خطا در زمانی بدست آمده است که k=1 تعیین شده است. در این حالت به منظور کلاس‌بندی هر نمونه تست، از برچسب تنها یک نمونه‌ی آموزشی استفاده می‌شود که این عمل موجب کلاس‌بندی تصادفی نمونه-ی تست شده و در نتیجه دقت کلاس‌بندی کاهش می‌یابد. در تمامی روش‌های استخراج ویژگی کمترین میزان خطا مربوط به k=5 است که در این حالت دقت کلاس‌بندی افزایش خواهد یافت. در ارزیابی بعدی دو روش استخراج ویژگی گشتاورهای زرنیک و شبه‌زرنیک در عمل تشخیص کانتور تصویر به ازای مرتبه‌های (N) متفاوت از گشتاور مورد مقایسه قرار گرفته‌اند. بر اساس جدول ۲ گشتاور زرنیک به ازای مرتبه‌های مختلف، بردارهای ویژگی با طول‌های ۲۱، ۱۵ و ۱۱ المان و گشتاور شبه-زرنیک بردارهای ویژگی با طول‌های ۲۷، ۲۴ و ۲۱ المان تولید می‌نمایند. لازم به ذکر است که الگوریتم کلاس‌بندی که در این تست مورد استفاده قرار گرفته است ماشین بردار پشتیبان است. بر اساس این جدول، گشتاور شبه‌زرنیک بیشترین دقت را در تشخیص کانتور تصویر نسبت به روش زرنیک بدست آورده است. مهمترین دلیل این موفقیت تعداد المان‌های بیشتر بردار ویژگی روش شبه‌زرنیک نسبت به روش زرنیک برای یک مرتبه ثابت است. این موفقیت نشان‌دهنده آن است که روش شبه‌زرنیک تعداد ویژگی‌های بیشتر و موثرتری را نسبت به روش زرنیک از تصویر استخراج می‌نماید.

جدول ۲: مقایسه گشتاور زرنیک و شبه‌زرنیک به ازای مرتبه‌های (N) متفاوت. (FE تعداد المان‌های بردار ویژگی است)

الف) دیتاست Caltech-101

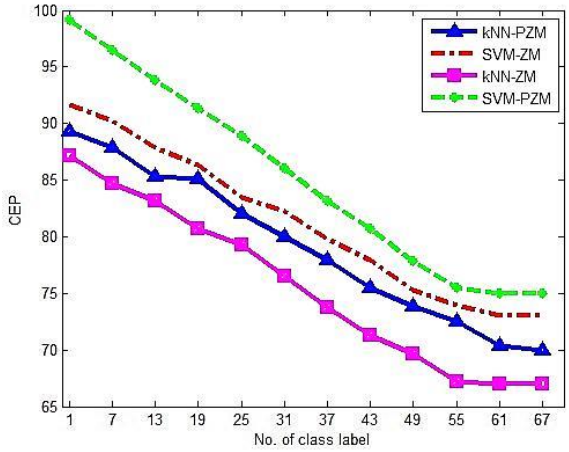
Different Orders	Feature Selector			
	ZM		PZM	
	No. FE	Accuracy (%)	No. FE	Accuracy (%)
n=1,…,6	21	82.69	27	89.62
n=6,7,8	15	84.81	24	94.43
n=9,10	11	87.62	21	97.65

ب) دیتاست ETHZ

Different Orders	Feature Selector			
	ZM		PZM	
	No. FE	Accuracy (%)	No. FE	Accuracy (%)
n=1,…,6	21	85.03	27	93.26
n=6,7,8	15	88.42	24	96.79
n=9,10	11	89.97	21	98.14

بر اساس نتایج ارائه‌شده، گشتاور شبه‌زرنیک به همراه الگوریتم کلاس‌بندی ماشین بردار پشتیبان بهترین نتایج را بر روی هر دو پایگاه تصاویر ارائه نموده‌اند که دلیل آن استخراج ویژگی‌های اصلی و موثر از تصویر است که مستقل از چرخش، مقیاس‌پذیری و انتقال تصویر می باشند. به بیان دیگر در صورتی که شیء در یک تصویر با هر مقیاس و یا زاویه ای ظاهر شود روش شبه-زرنیک (زرنیک) قادر است بهترین نتایج را استخراج نماید که دلیل این امر این است که در گشتاور شبه‌زرنیک کل تصویر به یک ناحیه دایره‌ای با شعاع واحد نگاشت پیدا کرده و در نتیجه مفهوم مقیاس در زمان استخراج ویژگی از بین خواهد رفت. لازم به ذکر است که گشتاور زرنیک به دلیل تعداد المان‌های کمتر در بردار ویژگی دقت تشخیص کمتری را نسبت به گشتاور شبه زرنیک بدست آورده است.

در شکل ۵ میزان robustness روش پیشنهادی به منظور تشخیص شیء به ازای روش‌های بهینه‌سازی مختلف ارائه شده است. در این نمودار محور افقی تعداد کلاس‌ها (انواع مختلف اشیاء) و محور عمودی نرخ CEP را نشان می‌دهد. بر اساس این نمودار با افزایش تعداد کلاس‌ها مقدار CEP کاهش یافته و از یک تعداد کلاس به بعد، نرخ CEP ثابت می‌شود.



شکل ۵: نمودار دقت کلاس‌بندی به ازای افزایش تعداد کلاس‌ها

بر اساس این نمودار این کاهش یک روال منطقی است اما در صورتی که این نرخ در نقطه‌ای تثبیت نشود، نشان‌دهنده ضعف آن روش است. این تثبیت به معنای آن است که با افزایش تعداد کلاس‌ها، نرخ خطای کلاس‌بندی کاهش نمی‌یابد که این نشان‌دهنده robustness روش پیشنهادی است. بر اساس نمودار شکل ۵ در تمامی تعداد کلاس‌ها، روش ترکیبی SVM-PZM بالاترین نرخ CEP را بدست آورده است و در حدود ۵۵ کلاس به بعد نرخ CEP برای این روش ثابت می‌شود.

۵- نتیجه‌گیری

در این مقاله یک روش جدید به منظور تشخیص کانتور اشیاء ارائه شده است. در این سیستم LDC، به عنوان مرحله تشخیص کانتور و گشتاور زرنیک و شبه‌زرنیک به‌عنوان استخراج‌کننده ویژگی استفاده شده است. هر دو روش LDC و شبه‌زرنیک (زرنیک) نسبت به چرخش و مقیاس‌پذیری در لبه‌یابی تصاویر، مقاوم هستند. LDC یک روش جدید است که برای تشخیص خطوط مستقیمی که در مرحله تشخیص کانتورهای تصویر به کار می‌رود. هم‌چنین هر دو گشتاور زرنیک و شبه‌زرنیک مبتنی بر مجموعه‌ای از گشتاورهای عمود هستند. در روش پیشنهادی، ویژگی‌های استخراج شده از هر ناحیه شیء به الگوریتم طبقه بند ماشین بردار پشتیبان برای عمل تشخیص کانتور، داده می‌شود.

روش پیشنهادی بر روی پایگاه داده ETHZ و Caltech-101 تست شده است. نتایج آزمایشات روش پیشنهادی بر روی این پایگاه داده‌ها نشان داده است که روش پیشنهادی قادر است نرخ تشخیص کانتور تصاویر را با کاهش پیچیدگی محاسبات، بهبود بخشد. در واقع در روش پیشنهادی بدلیل استفاده از گشتاورهای زرنیک و شبه‌زرنیک و همچنین روش LDC کارایی سیستم بالا رفته است.

۶- کارهای آینده

به عنوان کارهای آینده ی این مقاله می توان به موارد زیر اشاره نمود:

- استفاده از دیگر طبقه‌بندها به منظور شناسایی
- کار بر روی پایگاه‌های داده‌های دیگر
- و استفاده از سایر گشتاورهای هندسی به‌عنوان استخراج‌کننده ویژگی

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[a] Contour
[b] Zernike Moment (ZM)
[c] Psodo Zernike Moment (PZM)
[d] Minimal Spanning Tree
[e] Gaussian Smooth
[f] Complex Orthogonal Polynomials
[g] Support Vector Machine (SVM)
[h] Zernike Basis Function (ZBF)
[i] Classification Error Percentage (CEP)

حل مسأله پوشش در شبکه‌های حسگر دوربین با کمک الگوریتم دسته ماهی مصنوعی

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چکیده – در این مقاله پیشنهادی برای حداکثر کردن پوشش با استفاده از الگوریتم دسته ماهی مصنوعی در شبکه‌های حسگر دوربین ارائه شده است. بدین منظور در ابتدا ویژگی‌های حسگر دوربین و مفهوم «میدان دید» بیان شده است و تفاوت مسأله پوشش در شبکه‌های سنتی و دوربین مورد بررسی قرار گرفته است. در ادامه مفهوم ماهی و همچنین الگوریتم دسته ماهی مصنوعی و رفتارهای حرکت گروهی، دنباله روی، جستجوی غذا و حرکت آزاد برای رسیدن به غذای بیشتر تعریف شده است و در پایان از این الگوریتم به عنوان راهکاری برای حداکثر نمودن پوشش با تعیین جهت حسگرهای دوربین در شبکه‌ای که موقعیت و تعداد دوربین‌های آن مشخص می‌باشد استفاده شده است.

کلید واژه- الگوریتم دسته ماهی مصنوعی، پوشش، شبکه حسگر دوربین، حداکثرسازی

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۱- مقدمه

شبکه‌های حسگر دوربین به عنوان کلاس مهمی از شبکه‌های حسگر می‌باشد که گره‌های آن ترکیبی از حسگر تصویری، پردازنده توکار و انتقال دهنده بی‌سیم است. یکی از چالش‌های مهم در این نوع از شبکه‌ها پوشش می‌باشد که با توجه به ویژگی‌های منحصر به فرد دوربین مانند زاویه و میدان دید، راه‌حل‌های آن را نسبت به شبکه‌های حسگر سنتی متفاوت نموده است. در یکی از راه حل‌های ارائه شده برای حداکثر کردن پوشش در شبکه‌های حسگر دوربین از الگوریتم ژنتیک برای تعیین زاویه حسگرها با محور x در شبکه‌ای که موقعیت و تعداد حسگرهای آن مشخص می باشد استفاده شده است [۱]. در این راه حل، جواب مسأله در الگوریتم ژنتیک آرایه‌ای از زاویه حسگرها می‌باشد که در کروموزوم‌ها قرار داده شده است و تابع ارزیابی هر کروموزوم نیز برابر میزان پوشش بدست آمده بوسیله هر کروموزوم می باشد.

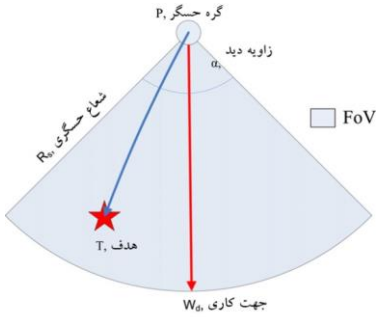
با توجه به کاربرد الگوریتم دسته ماهی مصنوعی در حل مسائل پیچیده و ویژگی‌های آن، این الگوریتم به عنوان یک راه‌حل برای حل مسأله پوشش بوسیله تعیین جهت مناسب برای حسگرهای دوربین در این مقاله مورد توجه قرار گرفته است و روش پیشنهادی با روش حل مسأله بوسیله الگوریتم ژنتیک مقایسه شده است.

این الگوریتم گونه‌ای از الگوریتم‌های برگرفته شده از طبیعت و نوعی از الگوریتم‌های هوش جمعی می‌باشد که توسط دکتر Li Xiao Lei در سال ۲۰۰۲ ارائه شده است و اساس کار آن بر حسب توابعی است که از رفتارهای اجتماعی ماهی‌ها در طبیعت الهام گرفته شده است. بدین صورت که با جستجوی فردی یا گروهی مناطق دارای غذای بیشتر را پیدا می‌کنند. مطابق با این ویژگی فضایی که ماهی‌های مصنوعی در آن زندگی می‌کنند فضای راه حل و میزان تراکم غذا در منطقه، تابع هدف دسته ماهی‌های مصنوعی است و در نهایت ماهی‌ها به فضایی می‌رسند که درجه غلظت غذا در آن بیشترین است. در این مقاله فضای راه حل، زوایای حسگرهای دوربین با محور x و تراکم غذا میزان منطقه پوشش داده شده توسط حسگرهای دوربین در نظر گرفته شده است.

۲- شبکه‌های حسگر دوربین

در این شبکه‌ها حداکثر حجم قابل دید از یک دوربین تحت عنوان *میدان دید* تعریف شده است. این منطقه قابل دید، قطاع مانند است که از یک دوربین ناشی می‌شود و یک جهت دید را از دوربین تعریف می‌کند. *عمق ناحیه*، مقدار فاصله بین نزدیک‌ترین و دورترین اشیاء است که می‌تواند به درستی به وسیله یک دوربین دیده شود. همچنین زاویه دید نیز یک نمای منحصر به فردی از منطقه تحت نظارت ایجاد می‌نماید. شکل ۱ نمایش دو

بعدی ساده‌ای از یک میدان دید دوربین را نشان می‌دهد که در آن زاویه دید 2α و شعاع حسگرایی r می‌باشد. جهت دوربین‌ها یک پارامتر اساسی برای پوشش شبکه است [۲].



شکل ۱: نمایش ساده از میدان دید دوربین [۳].

شبکه های حسگر دورین در مقایسه با انواع دیگر شبکه های حسگر بی سیم دارای ویژگی‌های منحصر به فرد بیشتری از جمله نیازمندی های منابع، پردازش محلی، اجرای بلادنگ، موقعیت دقیق و اطلاعات جهت یابی است.

۳- مسأله پوشش

شبکه‌های حسگر دوربین با چالش‌های بسیاری روبرو است که از جمله آن مسئله پوشش است. پوشش شبکه‌های حسگر دوربین مشخص می‌نماید محیط تحت نظارت تا چه میزان تحت کنترل می‌باشد. از آنجائی که مدل پوشش در گره حسگر دوربین مانند شبکه‌های حسگر سنتی همه جهته نیست، راه‌حل‌های پوشش در شبکه‌های حسگر سنتی برای شبکه‌های دوربین مناسب نمی‌باشد.

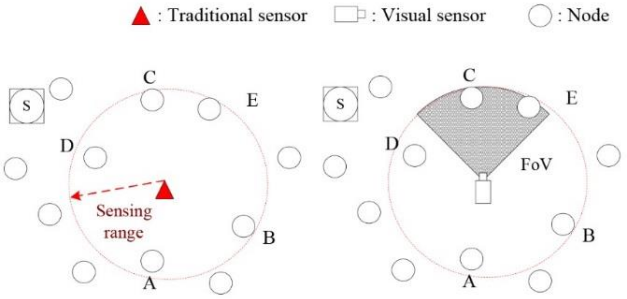
یک گره حسگر جهت‌دار خصوصیات منحصر به فردی دارد که در راه‌حل‌های مسئله پوشش اثر می‌گذارد، که در ادامه مورد بررسی قرار می‌گیرد [۴].

الف) زاویه دید: حسگرهای جهت‌دار، یک زاویه محدودی از پوشش حسگرایی بخاطر محدودیت‌های تکنیکی و ملاحظات هزینه‌ای دارند (شکل ۲). زاویه دید ممکن است از لحاظ تئوری از یک تا ۳۶۰ تغییر نماید. شبکه‌های شامل گره‌هایی با زاویه کوچکتر نیاز به گره‌های بیشتری برای یک نرخ پوشش معین دارند.

ب) جهت کاری: جهتی است که یک حسگر جهت‌دار قرار گرفته است. در شبکه‌های جهت‌دار حسگرها ممکن است جهت‌های کاری متفاوتی بعد از یک قرارگیری تصادفی داشته باشند. در این حالت جهت‌یابی حسگرها مورد نیاز است تا پوشش حداکثر شود.

ج) مسیر مستقیم: در پوشش چند رسانه‌ای ممکن است بوسیله هر مانعی در محیط انسداد ایجاد شود. میدان دید حسگرهای ویدئویی تا حد زیادی وابسته به فاصله و سایز موانع است. تنها زمانی تصاویری که حسگرهای ویدئویی می‌گیرند سودمند است که یک خط مستقیم بین اتفاق و حسگر وجود داشته باشد. از این رو مدل‌های پوشش توسعه یافته در شبکه‌های بی‌سیم سنتی برای شبکه‌های چند رسانه‌ای کافی نیست.

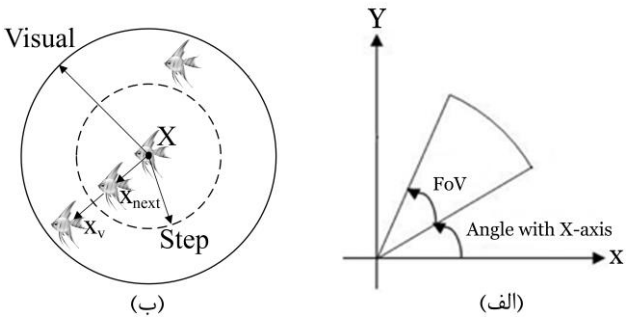
د)حرکت: در برخی از دوربین‌ها عملکردهایی وجود دارند که اثر مهمی بر پوشش دارند به ویژه زمانی که با یکدیگر ترکیب شوند. این عملکردها عبارتند از Tilt, Pan و Zoom که حرکاتی هستند که حول سه محور x، y و z انجام می‌گیرد. به مجموع این حرکت‌ها Motility می‌گویند.



شکل ۲: مقایسه حسگر سنتی و دوربین [۵]

۴- مدل سیستم

در الگوریتم دسته ماهی مصنوعی دو پارامتر مسافتی به نامهای *میدان دید* (Visual) و *طول گام* (Step) وجود دارد که در شکل ۳ نشان داده شده است. x_v موقعیتی در میدان دید است که ماهی مصنوعی می‌خواهد به آنجا برود.



شکل ۳: (الف) میدان دید و زاویه با محور X (ب) ماهی مصنوعی و محیط پیرامون آن [۴].

وضعیت فعلی ماهی مصنوعی توسط بردار $X=(\alpha_1,\alpha_2,\ldots,\alpha_n)$ نشان داده می‌شود که $\alpha_i(i=1,2,\ldots,n)$ همانطور که در شکل ۳-الف نمایش داده شده است زاویه حسگرهای دوربین با محور x است که برای مقدار بهینه جستجو می‌شود.

حال اگر وضعیت $X_V = (x_1^V, x_2^V, ..., x_n^V)$ از نظر تراکم

غذایی بهتر از وضعیت فعلی باشد، یک گام به جلو در جهت آن پیش می‌رویم که باعث تغییر وضعیت ماهی مصنوعی از X به X_{next} می‌شود ولی اگر وضعیت فعلی بهتر از X_v باشد، به گشت-زنی در محدوده میدان دید ادامه می‌دهیم. در رفتارهای ماهی مصنوعی از یک تابع به نام تابع Rand() استفاده می‌شود. تابع Rand() تابعی است که یک عدد تصادفی با توزیع یکنواخت بین صفر و یک تولید می‌کند.

۴-۱- الگوریتم دسته ماهی مصنوعی (AFSA)

مدل ماهی مصنوعی شامل دو بخش متغیرها و توابع است که متغیرها شامل X (موقعیت فعلی ماهی مصنوعی)، Step (حداکثر طول گام حرکت)، Visual (میدان دید)، try_number (سقف تعداد آزمایش و سعی کردن) و فاکتور شلوغی δ ($0<\delta<1$) می‌باشد. همچنین توابع شامل رفتار جستجوی غذا، رفتار حرکت گروهی و رفتار دنباله‌روی (پیروی) می‌باشد. نحوهٔ اجرای این توابع در هر تکرار الگوریتم به این صورت است که در هر تکرار دو رفتار حرکت گروهی و دنباله‌روی اجرا می‌شوند و در صورتی که هر کدام از این دو رفتار به نتیجهٔ مورد نظر نرسد رفتار جستجوی غذا در ادامهٔ آنها اجرا می‌گردد.

۴-۲- رفتار جستجوی غذا

اگر X_i وضعیت فعلی ماهی مصنوعی باشد، یک وضعیت X_j را به طور تصادفی در میدان دید ماهی مصنوعی انتخاب کنیم. حال اگر تراکم غذایی در X_j را بیشتر از تراکم غذایی در وضعیت فعلی باشد، ماهی مصنوعی مورد نظر از وضعیت فعلی‌اش یک گام به جلو در جهت X_j حرکت می‌کند که با استفاده از معادله (۱) محاسبه می‌شود.

$$X_i^{(t+1)}=X_i^{(t)}+\frac{X_j-X_i^{(t)}}{\left\|Xj-X_i^{(t)}\right\|}.\text{Step.Rand()} \qquad (۱)$$

در صورتی که تراکم غذایی در X_j بیشتر نباشد به میزان try_number در محیط تلاش می کند تا نقطه‌ای بهتر را برای حرکت بیابد در غیر اینصورت یک حرکت تصادفی طبق معادله (۲) در محیط انجام می‌دهد.

$$X_i^{(t+1)}=X_i^{(t)}+\text{Step.Rand()} \qquad (۲)$$

۴-۳- رفتار حرکت گروهی ماهی‌ها

در AFSA برای آنکه دسته ماهی‌های مصنوعی به صورت یک دسته واحد حرکت کنند و دستهٔ ماهی‌های مصنوعی تکه تکه نشود، در هر تکرار سعی می‌شود تا ماهی‌های مصنوعی، به سمت یک موقعیت مرکزی حرکت کنند. حال اگر تراکم غذا در موقعیت مرکزی بیشتر از موقعیت فعلی باشد یک گام به سمت میدان مرکزی پیش می‌رویم که از معادله (۳) محاسبه می‌گردد.

$$X_i^{(t+1)}=X_i^{(t)}+\frac{X_C-X_i^{(t)}}{\left\|XC-X_i^{(t)}\right\|}.\text{Step.Rand()} \qquad (۳)$$

۴-۴- رفتار دنباله‌روی

در فرآیند حرکت دسته‌ای ماهی‌ها هنگامی که یک ماهی یا تعدادی از آنها غذا پیدا کنند همسایگان و ماهی‌های نزدیک به آنها به دنبال آنها می‌روند و به سرعت به غذا می‌رسند. اگر X_i وضعیت فعلی ماهی مصنوعی باشد، همسایه X_j را کاوش می‌کند. وضعیت X_j دارای تراکم غذایی بیشتری نسبت به وضعیت فعلی است و تراکم جمعیتی در نزدیکی آن زیاد نمی‌باشد پس یک گام به سمت X_j می‌رویم که با استفاده از معادله (۴) محاسبه می‌گردد:

$$X_i^{(t+1)}=X_i^{(t)}+\frac{X_j-X_i^{(t)}}{\left\|Xj-X_i^{(t)}\right\|}.\text{Step.Rand()} \qquad (۴)$$

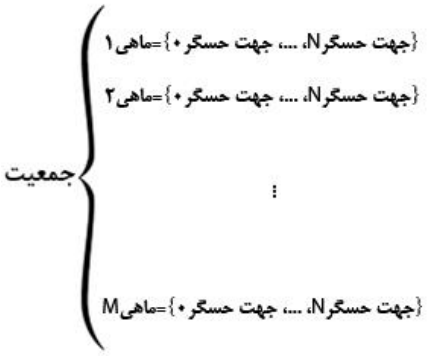
شبه کد الگوریتم دسته ماهی مصنوعی مطابق با شکل ۴ می‌باشد.

```
Procedure AFSA
  for each Artificial Fish i ϵ [1 .. N]
      initialize xi
  end for
      Blackboard=min f(x)
  Repeat
    for each Artificial Fish i ϵ [1 .. N]
        Compute Xi,follow
        IF AF Follow() NOT satisfied;  ELSE Compute AF Prey() ;
        IF AF Prey() NOT satisfied ELSE Compute AF Random Move()
        Compute Xi,swarm;
        if f(Xi,swarm) ≥ f(Xi,follow)
          then Xi(t+1)= Xi,follow
        else
          Xi(t+1)= Xi,swarm
    End for
    if f(XBest-AF) ≤ f(Blackboard)
    then Blackboard = XBest-AF
  Until stopping criterion is met
End AFSA
```

شکل ۴: شبه کد الگوریتم دسته ماهی مصنوعی

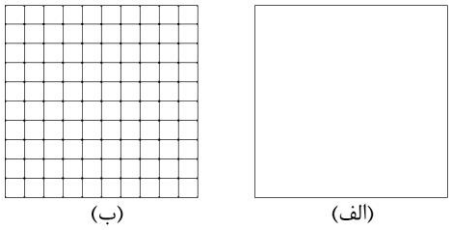
در این روش هر ماهی اندازه‌ای برابر با تعداد حسگرهای شبکه دارد و شامل عددهایی است که زاویه حسگرها با محور x را نشان می‌دهد. مجموعه‌ای از این ماهی‌ها راه‌حل‌هایی را برای جهت قرارگیری حسگرها با هدف حداکثر کردن پوشش ارائه می‌نماید.

جمعیت ماهی‌ها در شکل ۵ نمایش داده شده است که در آن N تعداد حسگرها و M تعداد ماهی‌ها است و هر درایه از این ماهی‌ها وضعیت متناظر با جهت یک حسگر را نشان می‌دهد.



شکل ۵: مجموعه راه‌حل‌ها برای جهت گیری حسگرها

برای بررسی غلظت غذای ماهی‌ها نقاط پوشش داده نشده در شبکه محاسبه می‌شود و فرض می‌شود نقاط فرضی در هر یک متر منطقه مورد نظارت به منظور ارزیابی منطقه در یک فضای گسسته وجود دارد که در شکل ۶ نشان داده شده است.



شکل ۶: (الف) منطقه مورد نظر (ب) نقاط مورد بررسی

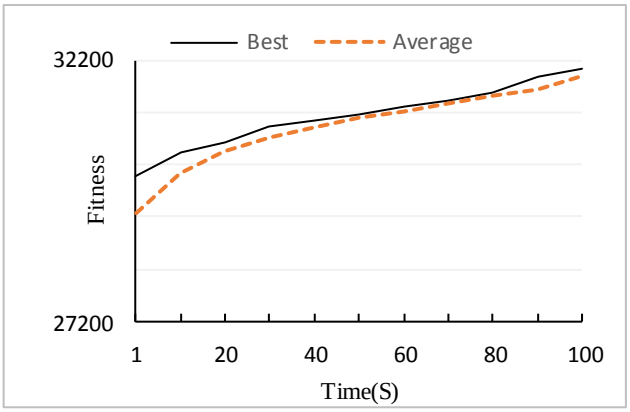
۵- شبیه‌سازی

در این بخش نتایج شبیه سازی راه حل پیشنهادی و مقایسه آن با روش الگوریتم ژنتیک که در [۱] ارائه شده مورد بررسی قرار گرفته است. برای شبیه سازی از Visual C++ استفاده شده است. منطقه مورد ارزیابی ۲۰۰m*۲۰۰m، شامل حسگرهای دوربین به تعداد ۴۰۰ و ۳۰۰ و به شعاع حسگرایی ۱۵m است. پارامترهای الگوریتم ژنتیک مطابق جدول ۱ می باشد.

جدول ۱: پارامترهای الگوریتم ژنتیک

پارامتر	مقدار
سایز جمعیت	۲۰۰
احتمال جهش	۰,۰۵
احتمال تلفیق	۰,۸۵
الگوریتم تلفیق	روش دو نقطه‌ای

با بررسی روند تغییر میانگین تابع ارزیابی کروموزوم‌ها و همچنین تابع ارزیابی بهترین کروموزوم در هر دوره، مشخص گردید که میانگین تابع ارزیابی روند رو به رشدی ندارد که این بدان دلیل است که در [۱] عملیات تلفیق همه کروموزم‌ها با جفت‌گیری تصادفی انتخاب و با احتمال ۰,۸۵ انجام می‌شود و در نتیجه در جریان افزایش دوره‌ها، میانگین تابع ارزیابی و در نهایت بهترین تابع ارزیابی افزایش قابل ملاحظه‌ای نخواهد داشت. برای حل این مسئله جهت بهبود الگوریتم ژنتیک از عملیات جفت‌گیری رتبه‌بندی شده استفاده شد. بدین صورت که جفت‌گیری رتبه‌بندی شده با انتخاب و تلفیق ۵۰ درصد بهترین کروموزم‌ها بصورت دو نقطه‌ای صورت گرفت وکروموزوم‌های جدید ایجاد شده با ۵۰ درصد بدترین کروموزوم‌ها در جمعیت جایگزین می‌شوند. نتایج اصلاحات انجام شده باعث افزایش بهترین مقدار تابع ارزیابی و همچنین میانگین آن الگوریتم ژنتیک پیشنهاد شده در [۱] گردید که در شکل ۷ آورده شده است.



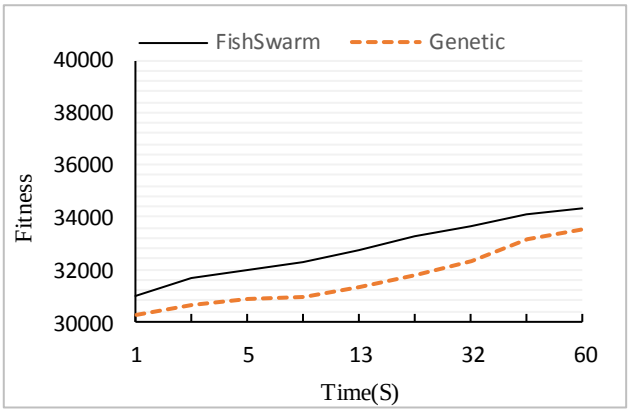
شکل ۷: روند تغییرات در میانگین تابع ارزیابی کروموزوم‌ها و بهترین کروموزوم در هر دوره در منطقه ۲۰۰*۲۰۰ با ۵۰۰ حسگر در الگوریتم ژنتیک اصلاح شده.

با تغییر پارامتر جهش در [۱] میزان پوشش مورد بررسی قرار گرفت و طبق نتیجه نشان داده شده در جدول ۲ میزان p_m=۰,۰۵ به عنوان بهترین ضریب جهش در راه حل ارائه شده در [۱] تأیید شد. (توصیه شده است ۰,۰۵>p_m>۰,۰۰۵)

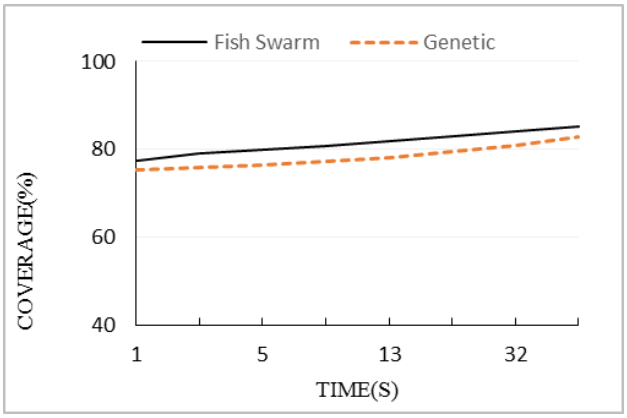
جدول ۲: درصد پوشش برای احتمال جهش مختلف در منطقه ۲۰۰*۲۰۰ با ۵۰۰ حسگر (۱۰۰ نسل).

احتمال جهش	۰,۰۵	۰,۰۳	۰,۰۱	۰,۰۰۵
پوشش (٪)	۸۰	۷۹,۵	۷۸,۹۶	۷۷,۸

پس از بهبود الگوریتم ژنتیک ارائه شده در [۱] نتایج برای مقدار تابع ارزیابی و پوشش با راه حل AFSA مقایسه گردید. همانطور که در شکل۸ ملاحظه می شود مقدار تابع ارزیابی در AFSA در مدت ۶۰ ثانیه بررسی گردید که مقدار آن در الگوریتم پیشنهادی بهتر از الگوریتم ژنتیک می باشد و به عبارتی درصد پوشش در الگوریتم دسته ماهی مصنوعی در طول زمان بهتر از الگوریتم ژنتیک اصلاح شده می باشد (شکل ۹).



شکل ۸: مقایسه تابع ارزیابی در الگوریتم ژنتیک، ژنتیک اصلاح شده و دسته ماهی مصنوعی در منطقه ۲۰۰*۲۰۰ با ۵۰۰ حسگر.



شکل ۹: مقایسه میزان پوشش با استفاده از الگوریتم ژنتیک اصلاح شده و دسته ماهی مصنوعی در منطقه ۲۰۰*۲۰۰ با ۵۰۰ حسگر.

میزان پوشش توسط سه الگوریتم ژنتیک ارائه شده در [۱] و ژنتیک اصلاح شده در این مقاله و الگوریتم دسته ماهی مصنوعی برای تعداد حسگرهای مختلف مورد بررسی قرار گرفت که همانطور که در جدول ۳ نیز آمده است راه حل الگوریتم دسته ماهی مصنوعی جواب بهتری را ارائه داده است.

جدول ۳: مقایسه پوشش در منطقه ۲۰۰*۲۰۰ با تعداد حسگرهای مختلف.

تعداد حسگر	پوشش (٪)		
	ژنتیک	ژنتیک اصلاح شده	دسته ماهی مصنوعی
۳۰۰	۵۸	۶۸	۷۶,۲
۴۰۰	۶۸,۹	۷۷,۷	۸۳,۸
۵۰۰	۷۰	۸۰,۶	۸۵,۷

۶- نتیجه‌گیری

شبکه‌های حسگر دوربین با چالش‌های بسیاری از جمله مسئله پوشش روبرو است. از آنجایی که مدل پوشش در گره حسگر دوربین مانند شبکه‌های حسگر سنتی همه جهته نیست، راه حل‌های پوشش در شبکه‌های حسگر سنتی برای شبکه‌های دوربین مناسب نمی‌باشد.

در این مقاله برای حل این چالش، یک مدل جدید برای بهینه‌سازی پوشش بر پایه الگوریتم دسته ماهی‌های مصنوعی پیشنهاد گردید. همانطور که ذکر شد الگوریتم دسته ماهی‌های مصنوعی از موفق‌ترین روش‌های هوش مصنوعی جمعی است که مبتنی بر رفتارهای جمعی در سامانه‌های نامتمرکز و خودسامانده بنیان شده است. همانطور که نتایج نشان داده است، این راه حل نتایج بهتری را نسبت به الگوریتم ژنتیک موجود در زمان مشابه ارائه می‌دهد.

مراجع

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به‌کارگیری استراتژی آنتروپی و اتوماتای یادگیر برای راهبری روبات‌ها در محیطهای پیچیده

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چکیده - هدف از راهبری روبات‌ها در محیط‌های با مانع پیدا کردن مسیر بهینه از یک نقطه شروع تا نقطه هدف است. پیدا کردن کوتاه‌ترین مسیر از تمام نقاط نقشه به هدف بهینه‌سازی استراتژی کنترل نامیده می‌شود. در این مقاله اتوماتای یادگیر و آنتروپی برای پیدا کردن استراتژی کنترل بهینه استفاده شده است. در روش پیشنهادی با استفاده از مفهوم آنتروپی یک روش یادگیری تطبیقی در اتوماتاهای یادگیر پیشنهاد شده است. نتایج ناشی از شبیه سازی های انجام گرفته حاکی از کارایی مناسب روش پیشنهادی نسبت به سایر روشها در پیدا کردن استراتژی کنترل بهینه دارد. به عبارتی استفاده از آنتروپی باعث بهبود یادگیری در اتوماتای یادگیر شده است.

کلید واژه- اتوماتای یادگیر، استراتژی کنترل، آنتروپی، بهینه‌سازی، مسیریابی.

۱- مقدمه

یکی از ویژگی‌های اصلی روبات‌های متحرک ، توانایی آن‌ها جهت طرح‌ریزی مسیر خود به منظور انجام دادن وظایف تعیین‌شده است. اولین مرحله در طراحی حرکت برای روبات، پیش‌بینی حرکات قابل‌قبول برای روبات محسوب می‌شود. در مسئله طراحی مسیر، می‌خواهیم مسیری را تعیین کنیم که روبات از نقطه آغازین به نقطه هدف برسد، این ساده‌ترین نوع مسئله طرح‌ریزی حرکت و البته، در نوع خود یکی از مسائل محاسباتی پیچیده است. طرح‌ریزی مسیر بر روی به دست آوردن هدف و پرهیز از موانع تأکید دارد، اما به دلیل نداشتن اطلاعات قبلی درباره محیط، به دست آوردن هدف بهینه سراسری مشکل می‌شود، زیرا کنترل روبات فقط وابسته به اطلاعات محلی است. این حالت از مسیریابی کمتر مطالعه و تحقیق‌شده است ولی نتایج اندک به‌دست‌آمده نیز نشان داده است که این حالت از مسئله، به مراتب سخت‌تر از مسئله در حالت اولیه است [۱]. هدف مسیریابی محلی تولید پیوسته و بهنگام حرکت برای هدایت روبات است. در مسیریابی محلی برنامه‌ریز مسیر سعی در بهینه کردن مسیر (به‌طور سراسری) ندارد، بلکه هدف تولید یک رفتار واکنشی ضعیف به سبب ناشناخته بودن محیط است. در این حالت از شبکه‌های عصبی و کنترل‌کننده فازی به‌عنوان ابزاری برای برنامه‌ریزی حرکت و اجتناب از برخورد با موانع استفاده شده است [۲].

مسئله مسیریابی هنگامی پیچیده‌تر خواهد شد که هدف یافتن کوتاه‌ترین مسیر از تمام نقاط موجود در نقشه به نقطه هدف باشد. ضمن اینکه محیط نقشه (مکان موانع) و نقطه هدف از ابتدا ناشناخته است و اطلاع دقیقی از آن‌ها نداریم و تنها راه کسب اطلاع از آن‌ها حرکت در محیط است و روبات زمانی می‌فهمد کدام نقطه هدف است که در آن قرار بگیرد. به یک استراتژی که مسیر به هدف را از هر نقطه مشخص می‌کند، استراتژی کنترل گفته می‌شود. کاربردهای گسترده‌ای از استراتژی کنترل می‌توان ارائه کرد، به‌عنوان‌مثال یک روبات جارو برقی را در نظر بگیرید که در هنگام کم شدن باطری به سمت شارژر می‌رود ولی نه از مکان دقیق آن اطلاع دارد و نه از محیط و موانع آن، اما از این روبات انتظار می‌رود که پس از مدتی حضور در محیط به آن تسلط یابد و مسیرهای کوتاه‌تری را طی نماید، بنابراین با یک مسئله بهینه‌سازی روبرو هستیم که در آن هدف یافتن استراتژی کنترلی است که میانگین طول مسیر از هر نقطه به هدف به کمترین مقدار خود برسد که مسئله پیچیده‌تری نسبت به مسیریابی عادی از یک نقطه شروع به یک نقطه پایان است.

محققین روش‌هایی با استفاده از یادگیری تقویتی برای حل این مسئله ارائه کرده‌اند. یادگیری تقویتی جستجویی در محیط استراتژی انجام می‌دهد تا استراتژی کنترل ابتدایی را به یک استراتژی کنترل بهینه تبدیل کند [۵, ۴]. در [۶] الگوریتم‌های مبتنی بر اتوماتای یادگیر برای یافتن سیاست بهینه در بازی‌های مارکوف به کار رفتند و در [۷] از مفهوم آنتروپی برای افزایش سرعت یادگیری سیستم‌های چندعامله برای تسریع یادگیری استفاده شده است.

در این مقاله روشی با استفاده از اتوماتای یادگیر و آنتروپی برای استراتژی کنترل بهینه در محیط‌های ناشناخته ارائه شده است.

استفاده از مفهوم آنتروپی باعث بهبود روند یادگیری شده است. در ادامه مقاله چنین سازماندهی شده است: در بخش ۲مفهوم اتوماتای یادگیر توضیح داده شده است و پس از آن در بخش ۳، مفهوم آنتروپی و در بخش ۴ الگوریتم پیشنهادی مطرح می‌شود. در پایان عملکرد الگوریتم پیشنهادی و همچنین نتیجه‌گیری ارائه می شود.

۲- اتوماتای یادگیر

اتوماتای یادگیر یکی از مدلهای یادگیری تقویتی است که در آن یک اتوماتا یک عمل بهینه را با توجه به اعمال گذشته و بازخورد محیط فرا می گیرد. هدف نهایی این است که اتوماتا یاد بگیرد تا از بین اعمال خود، بهترین عمل را انتخاب کند. بهترین عمل، عملی است که احتمال دریافت پاداش از محیط را به حداکثر برساند. کارکرد اتوماتای یادگیر در تعامل با محیط، در شکل۱ مشاهده می‌شود.



شکل۱: ارتباط بین اتوماتای یادگیر و محیط

محیط را می‌توان توسط سه‌تایی $E \equiv \{\alpha, \beta, c\}$ نشان داد که در آن $\alpha \equiv \{\alpha_1, \alpha_2, ..., \alpha_r\}$ مجموعه ورودی‌ها، $\beta \equiv \{\beta_1, \beta_2, ..., \beta_m\}$ مجموعه‌خروجیهاو $c \equiv \{c_1, c_2, \ldots c_r\}$ مجموعه احتمال‌های جریمه می‌باشد. هرگاه β مجموعه‌ای دو عضوی باشد، محیط از نوع P است. در چنین محیطی $\beta_1 = 1$ به عنوان جریمه و $\beta_2 = 0$ به عنوان پاداش در نظر گرفته می‌شود. در محیط از نوع Q، $\beta(n)$ می‌تواند به طور گسسته یک مقدار از مقادیر محدود در فاصله [۰,۱] را اختیار کند و در محیط از نوع S، $\beta(n)$ متغیر تصادفی در فاصله [۰,۱] است. c_i احتمال اینکه عمل α_i نتیجه نامطلوب داشته باشد می‌باشد. در محیط ایستا، مقادیر c_i بدون تغییر می‌مانند، حال آن‌که در محیط غیرایستا این مقادیر در طی زمان تغییر می‌کنند. اتوماتاهای یادگیر به دو دسته اتوماتای یادگیر با ساختار ثابت اتوماتای یادگیر با ساختار متغیر[a] (VSLA) دسته بندی می شوند.

اتوماتای‌یادگیر با ساختار متغیر را می‌توان توسط چهارتایی $\{\alpha, \beta, p, T\}$نشان‌دادکه $\alpha \equiv \{\alpha_1, \alpha_2, \ldots, \alpha_r\}$ مجموعه‌عمل‌های اتوماتا، $\beta \equiv \{\beta_1, \beta_2, ..., \beta_r\}$ ورودی‌های اتوماتا، $p = \{p_1, .., p_r\}$ بردار احتمال انتخاب هریک‌ازعمل‌هاو $p(n+1) = T[\alpha(n), \beta(n), p(n)]$ الگوریتم یادگیری می‌باشد. الگوریتم‌زیربراساس‌روابط (۱)و(۲) یک نمونه از الگوریتم‌های یادگیری‌خطی‌است. فرض می‌کنیم عمل α_i در مرحله nام انتخاب شود.

- پاسخ مطلوب از محیط

$$p_i(n+1) = p_i(n) + a[1 - p_i(n)]$$
$$p_j(n+1) = (1-a)\,p_j(n) \qquad \forall j \;\; j \neq i \qquad (۱)$$

- پاسخ نامطلوب از محیط

$$p_i(n+1) = (1-b)\,p_i(n)$$
$$p_j(n+1) = (b/r-1) + (1-b)\,p_j(n) \qquad (۲)$$
$$\forall j \;\; j \neq i$$

در روابط بالا، a پارامتر پاداش وb پارامتر جریمه می‌باشند. با توجه به مقادیرa وb سه حالت را می‌توان درنظر گرفت: اگرa وb با هم برابر باشند، الگوریتم را L_{RP}، هنگامی‌که‌b ازa خیلی کوچکتر باشد، الگوریتم را $L_{R\varepsilon P}$ و اگر b مساوی صفر باشد آن را L_{RI} می‌نامیم[۳]. شمای S-L_{RP} برای مدلهای Q و S براساس‌رابطه (۳) بیان می شود اگر عمل α_i در مرحله nام انتخاب شود در این صورت طبق معادله (۳) داریم :

$$p_i(n+1) = p_i(n) + a(1-\beta_i(n))(1-p_i(n)) - a\beta_i(n)p_i(n) \qquad (۳)$$

$$p_j(n+1) = p_j(n) - a(1-\beta_i(n))p_j(n) + a\beta_i(n)\left[\frac{1}{r-1} - p_j(n)\right] - a(1-\beta_i(n))p_j(n) \qquad (۴)$$
$$j \neq i$$

که در آن r تعداد اعمال ممکن، a پارامتر پاداش وb پارامتر جریمه می‌باشند. برای اطلاعات بیشتر در باره اتوماتاهای یادگیر می توان به [۳] مراجعه نمود.

۳- مفهوم آنتروپی

آنتروپی یکی از مفاهیم مهم در ترمودینامیک است که درجهٔ اختلال در سیستم‌های ترمودینامیکی را بیان می‌کند [۴]. شانون[b] با موفقیت مفهوم آنتروپی را در نظریه اطلاعات معرفی کرده است، یعنی آنتروپی اطلاعات[c]. آنتروپی اطلاعات مجازاً آنتروپی متغیرهای تصادفی است. مفهوم اساسی آنتروپی اطلاعات در نظریه اطلاعات در ارتباط با این مطلب است که یک

سیگنال یا یک رخداد اتفاقی تا چه حد تصادفی است. آنتروپی اطلاعات که به نام آنتروپی شانون هم شناخته می‌شود درواقع میزان تصادفی بودن را به صورت یک معیار ریاضی گزارش می‌کند. آنتروپی متغیرهای تصادفی بیانگر درجهٔ عدم قطعیت آن است که به صورت زیر تعریف می‌شود [۵،۸]:

$$H(X) = -\sum_{x_i \in \Theta} p(x_i)\log(p(x_i)) \qquad (۵)$$

که در آن x بیانگر یک متغیر تصادفی با مجموعه متغیرهای Θ و تابع وزن احتمال $p(x_i)$ است.

۳-۱- آنتروپی استراتژی محلی[d] و آنتروپی استراتژی سراسری[e]

برای یک فضای حالت گسسته، به هر حالت S_i یک مجموعه مقادیر احتمال تصمیم [f] اختصاص می‌یابد. همهٔ مقادیر احتمال تصمیم، ماتریس احتمال P را تشکیل می‌دهند. در فرایند یادگیری، آنتروپی استراتژی D_i بیانگر عدم قطعیت یک تصمیم در حالت S_i است. هرچقدر آنتروپی استراتژی D_i بزرگ‌تر باشد، تصمیم با عدم قطعیت بیشتری روبه‌رو است. به‌علاوه آنتروپی استراتژی محلی در حالت S_i به‌صورت آنتروپی D_i تعریف می‌شود:

$$H_l^{\pi}(s_i) = -\sum_{j=1}^{N} p_j(s_i)\log\left(p_j(s_i)\right) \qquad (۶)$$

که در آن $p_j(s_i)$ احتمال انتخاب j امین عمل در حالت S_i است. آنتروپی استراتژی محلی تنها می‌تواند بیانگر عدم قطعیت تصمیم برای یک حالت تک باشد. این در حالی است که آنتروپی استراتژی سراسری عدم قطعیت کل استراتژی را می‌سنجد. آنتروپی استراتژی سراسری برابر میانگین تمامی آنتروپی استراتژی‌های محلی است و مطابق عبارت زیر تعریف می‌شود:

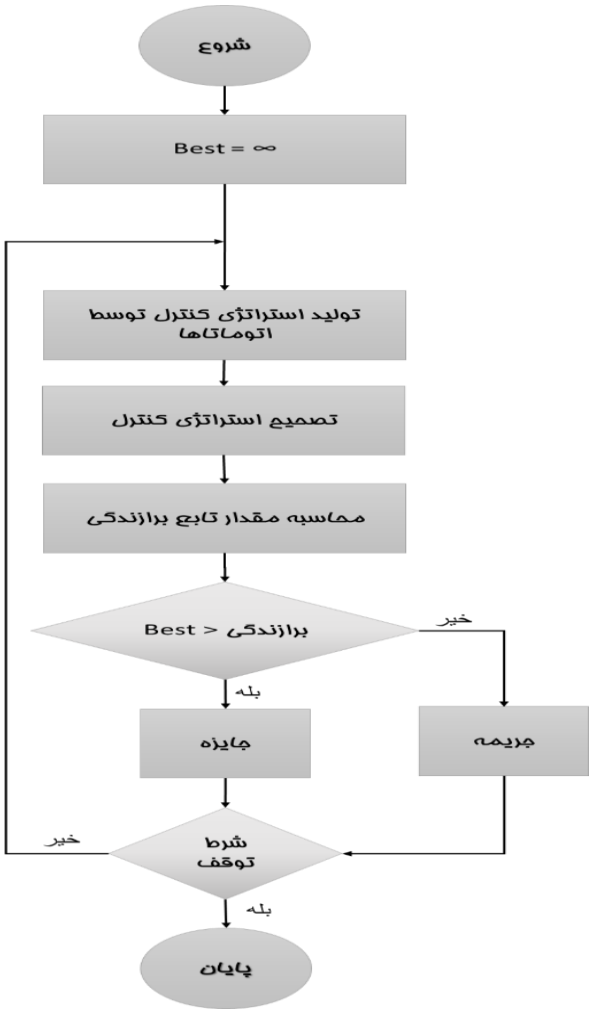
$$H_g^{\pi}(s_i) = \frac{1}{M}\sum_{i=1}^{M} H_l^{\pi}(s_i) = -\frac{1}{M}\sum_{i=1}^{M}\sum_{j=1}^{N} p_j(s_i)\log\left(p_j(s_i)\right) \qquad (۷)$$

که در آن M معادل تعداد المان‌ها در مجموعه حالات است.

۴- الگوریتم پیشنهادی

در روش پیشنهادی فرض می شود محیط از تعدادی حالت تشکیل شده است و هر حالت از محیط با یک اتوماتای یادگیر تجهیز شده است. اعمال هر اتوماتای یادگیر به تعداد حالات همسایه ها هستند. (نقاط مجاز در داخل محیط که مانع نیستند).

هرکدام از اتوماتاها بر اساس بردار احتمال خود یک انتخاب را از مجموعه اقدام‌هایشان برمی‌گزینند و یک استراتژی کنترل ساخته می‌شود. به دلیل انتخاب بر اساس احتمال این استراتژی کنترل ابتدایی کاملاً تصادفی و غیربهینه است و امکان دارد دارای حالات انتقال غیرمجاز (مانند حلقه و برگشت به حالت قبلی) باشد، بنابراین ابتدا استراتژی کنترل توسط تابع بازگشتی تصحیح می‌گردد. سپس در مرحله بعد با استفاده از میانگین تعداد گام‌ها برازندگی محاسبه می‌شود. با توجه به الگوریتم مطرح‌شده، در هر مرحله تابع برازندگی محاسبه شده و چنانچه مقدار تابع برازندگی در هر مرحله از بهترین تابع برازندگی محاسبه شده در مراحل قبل بهتر (کوچک‌تر) باشد احتمال اقدام فعلی هریک از اتوماتاها افزایش (پاداش می‌گیرد) و در غیر این صورت احتمال کاهش می‌یابد (جریمه می‌شود). این روند آن‌قدر ادامه پیدا می‌کند تا گام‌های الگوریتم به انتها برسد و کنترل استراتژی بهینه ایجاد شود. در شکل زیر فلوچارت این روش را مشاهده می‌نماییم:



شکل ۲: فلوچارت الگوریتم پیشنهادی با استفاده از اتوماتای یادگیر

۵- تنظیم احتمالات

در صورت پاداش گرفتن اتوماتاها، احتمال اقدام‌های هر اتوماتا از رابطه (۱) و در صورت جریمه این احتمال‌ها از رابطه (۲) به‌روز می‌شوند. همانطور که از دو رابطه پیداست نرخ پاداش و جریمه یک مقدار از پیش تعیین شده و بین صفر و یک است. در ادامه به روند تنظیم احتمالات به صورت انطباقی با استفاده از آنتروپی می‌پردازیم.

۵-۱- تنظیم احتمالات با استفاده از آنتروپی

می‌توان با استفاده از آنتروپی محلی یک نرخ یادگیری تطبیق پذیر ایجاد کرد. با توجه به این موضوع که در حالت کاملاً تصادفی نرخ یادگیری زیاد و در گام‌های پایانی الگوریتم نرخ یادگیری کم شود (همگرا شدن احتمال‌ها) و از آنجا که آنتروپی بی‌نظمی را به تصویر می‌کشد روابط به‌روزرسانی احتمالات در صورت جایزه و جریمه به ترتیب به شکل زیر در می‌آیند:

$$\begin{aligned} p_i(n+1) &= p_i(n) + (a \times \mathrm{H}_l^{\pi}(\mathrm{x}_t))[1 - p_i(n)] \\ p_j(n+1) &= (1 - (a \times \mathrm{H}_l^{\pi}(\mathrm{x}_t)))\, p_j(n) \qquad \forall j,\ j \neq i \end{aligned} \tag{۸}$$

$$\begin{aligned} p_i(n+1) &= (1 - (b \times \mathrm{H}_l^{\pi}(\mathrm{x}_t)))\, p_i(n) \\ p_j(n+1) &= \frac{b}{r-1} + (1 - (b \times \mathrm{H}_l^{\pi}(\mathrm{x}_t)))\, p_j(n) \qquad \forall j,\ j \neq i \end{aligned} \tag{۹}$$

که در آن‌ها $\mathrm{H}_l^{\pi}(\mathrm{x}_t)$ آنتروپی محلی در زمان x_t است.

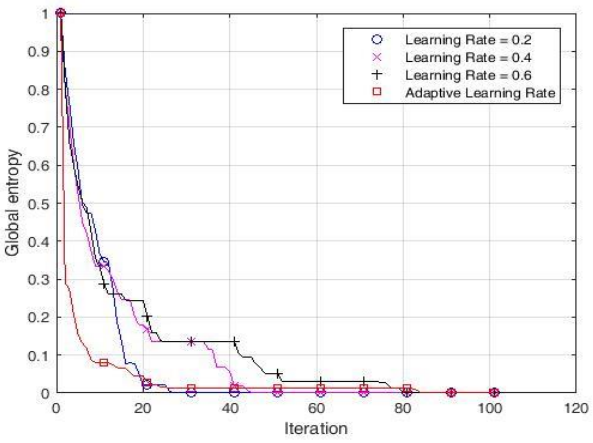
۶- ارزیابی الگوریتم پیشنهادی

در این بخش انواع روش‌های اتوماتای یادگیر ارائه شده شامل اتوماتای یادگیر با نرخ پاداش وجریمه ثابت، و با استفاده از آنتروپی از لحاظ دو معیار ارزیابی عملکرد یعنی میانگین تعداد گام‌ها تا هدف و آنتروپی سراسری مورد مقایسه قرار می‌دهیم. شایان ذکر است که هرکدام از روش‌ها برای رسیدن به استراتژی کنترل بهینه حداکثر صد گام می‌توانند طی کنند و این شبیه‌سازی سی بار تکرار می‌شود و مقدار هرکدام از معیارهای ارزیابی در هر گام میانگین این معیارها در کل سی تکرار است.

۶-۱- مقایسه عملکرد الگوریتم در نرخ یادگیری ثابت با نرخ یادگیری انطباقی با استفاده از آنتروپی

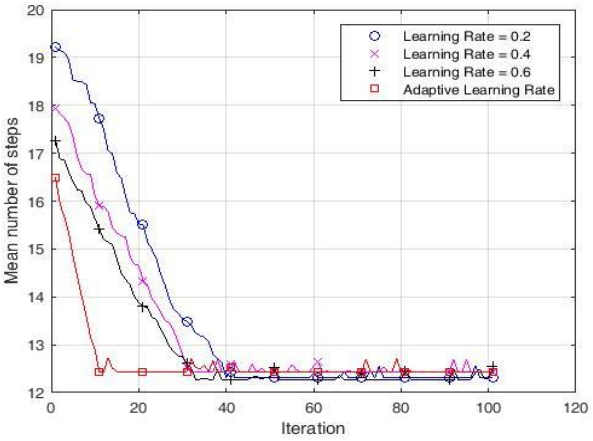
در این بخش عملکرد الگوریتم اتوماتای یادگیر پیشنهادی را با چند نرخ یادگیری ثابت و نرخ یادگیری انطباقی مورد ارزیابی قرار می گیرد. در اینجا در حالت انطباقی که از آنتروپی استفاده می‌شود، در ابتدا نرخ یادگیری را بزرگ (۰/۹) در نظر می‌گیریم و الگوریتم با سپری شدن تکرارها به تنظیم این مقدار می‌پردازد. نرخ یادگیری بسیار بزرگ باعث همگرایی زودرس و نرخ یادگیری بسیار کوچک باعث عدم دستیابی به جواب بهینه نهایی است و تنظیم این پارامتر نقشی اساسی در دستیابی به جواب نهایی و روند یادگیری دارد ولی در حالت تطبیقی ، الگوریتم با استفاده از آنتروپی می‌تواند با همگرا شدن بردار احتمالات به تنظیم این نرخ بپردازد.

در این آزمایش نرخ جریمه ثابت (۰/۰۲) ولی نرخ جایزه متغیر در نظر گرفته شده است. در حالت انطباقی آنتروپی سراسری در ابتدا بسیار سریع و سپس به آرامی کاهش می‌یابد. در حالت انطباقی ما از یک نرخ جایزه بالا به عنوان مثال از ۰/۹ شروع می‌کنیم و این مقدار به تدریج و با کاهش بی‌نظمی و در نتیجه کاهش آنتروپی نرخ یادگیری کم می‌شود و باعث می‌شود که نرخ جایزه در قدم‌های پایانی الگوریتم به صفر میل نماید حالت انطباقی در اکثر موارد در کاهش میانگین تعداد گام‌ها بسیار موفق‌تر از سایر حالات عمل می‌کند. باید متذکر شد که آنتروپی سراسری هرچه سریع‌تر به صفر نزدیک شود نشان‌دهنده همگرایی سریع‌تر احتمالات است و همچنین کاهش در میانگین تعداد گام‌ها مطلوب است و هرچه روند این کاهش سریع‌تر باشد الگوریتم ما بهتر عمل می‌کند. با علم به این موضوع الگوریتم در حالتی بهتر عمل می‌کند که در راستای کاهش آنتروپی سراسری شاهد کاهش میانگین تعداد گام‌ها نیز باشیم. نتایج به دست آمده در شکل های ۳ تا ۶ مشاهده می شود:



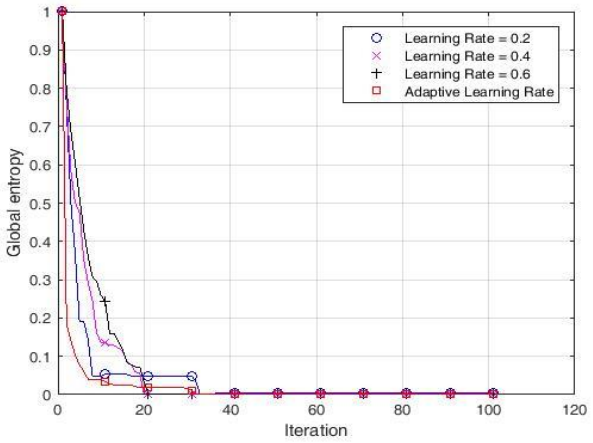
شکل ۳: آنتروپی سراسری الگوریتم اتوماتای یادگیر با نرخ یادگیری متفاوت و نرخ یادگیری انطباقی با استفاده از آنتروپی در محیط ۱۰×۱۰

در شکل ۳ از اتوماتای یادگیر با سه نرخ یادگیری ۰,۲ و ۰,۴ و ۰,۶ و نرخ یادگیری انطباقی با آنتروپی استفاده شده است. نمودار مربوط به اتوماتای یادگیر با نرخ یادگیری ۰,۲ نسبت به سایر نرخ های ثابت بهتر عمل کرده و سریعتر همگرا شده است اما با توجه به شکل اتوماتای یادگیر با نرخ یادگیری انطباقی با استفاده از آنتروپی با سرعت بیشتر به سمت کاهش آنتروپی سراسری پیش می رود و این نشان از عملکرد بهتر آن دارد.



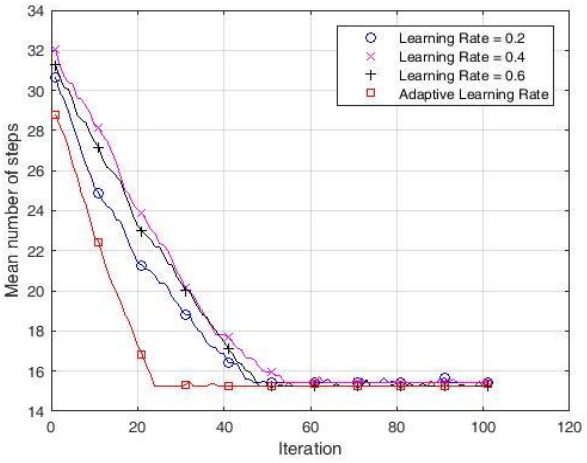
شکل ۴: میانگین گام های الگوریتم اتوماتای یادگیر با نرخ یادگیری متفاوت و نرخ یادگیری انطباقی با استفاده از آنتروپی در محیط ۱۰×۱۰

در شکل ۴ عملکرد الگوریتم با توجه به میانگین گام های رسیدن به هدف سنجیده می شود. با توجه به نتایج بدست آمده اتوماتای یادگیر با نرخ یادگیری انطباقی با استفاده از آنتروپی بهتر عمل کرده است.



شکل ۵: آنتروپی سراسری الگوریتم اتوماتای با نرخ یادگیری متفاوت و نرخ یادگیری انطباقی با استفاده از آنتروپی در محیط۱۲× ۱۲

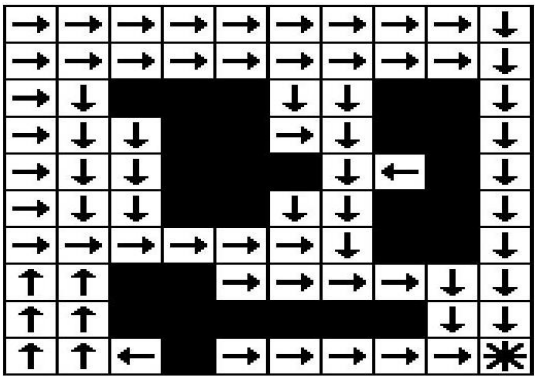
الگوریتم اتوماتای یادگیر با نرخ یادگیری انطباقی با استفاده از آنتروپی در نمودار آنتروپی سراسری شکل۵ نسبت به الگوریتم اتوماتای یادگیر با نرخ یادگیری ثابت سریعتر کاهش یافته و به صفر همگرا شده است.



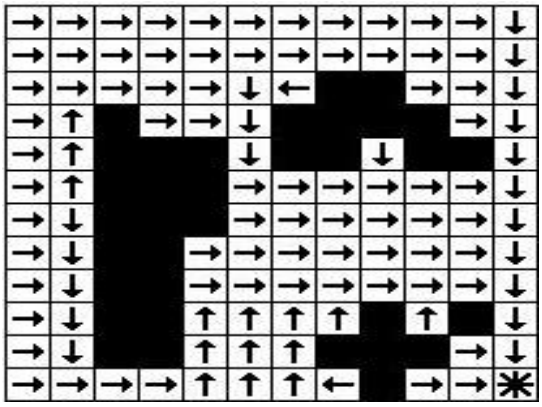
شکل ۶: میانگین گام های الگوریتم اتوماتای یادگیر با نرخ یادگیری های متفاوت و نرخ یادگیری انطباقی با استفاده از آنتروپی در محیط ۱۲×۱۲

همانطور که در شکل ۶ مشخص است الگوریتم اتوماتای یادگیر با نرخ یادگیری انطباقی با استفاده از آنتروپی عملکرد بهتری در میانگین گام داشته و سریعتر کاهش می یابد.

در شکل های ۷و ۸ استراتژی کنترل بهینه را برای دو محیط ۱۰×۱۰، ۱۲×۱۲ را شاهد هستیم، که توسط الگوریتم پیشنهادی به‌دست‌آمده است.



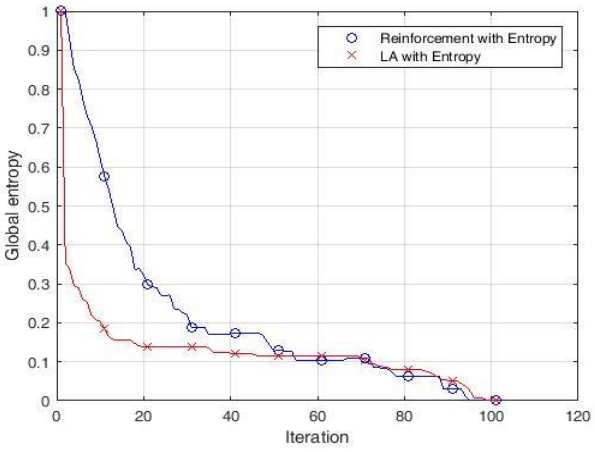
شکل ۷: نمونه ای از استراتژی کنترل بهینه به دست آمده در محیط ۱۰×۱۰



شکل ۸: نمونه ای از استراتژی کنترل بهینه به دست آمده در محیط ۱۲×۱۲

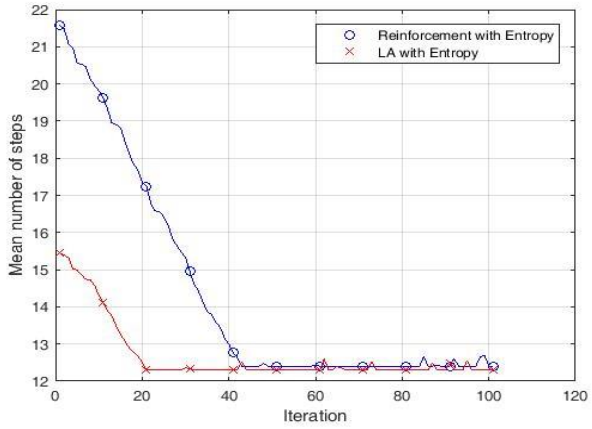
۷- مقایسه عملکرد اتوماتای یادگیر و یادگیری تقویتی با آنتروپی

در این آزمایش قصد داریم نتایج به دست آمده از یادگیری تقویتی با نرخ یادگیری انطباقی [۴] را با نتایج به دست آمده از اتوماتای یادگیر با نرخ جایزه انطباقی ، از لحاظ آنتروپی سراسری و میانگین تعداد گام‌ها تا هدف، در دو محیط ۱۰×۱۰ و ۱۲×۱۲ باهم مقایسه نماییم. این آزمایش به کشف بهترین روش کمک می کند. کلیه شرایط مانند نرخ یادگیری ابتدایی، تعداد تکرارها و تعداد گام‌ها برای هر دو الگوریتم یکسان در نظر گرفته می‌شود. نتایج حاصله در نمودارها قابل مشاهده است:



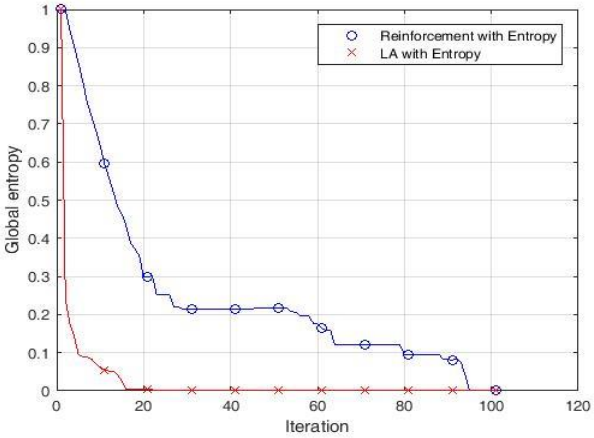
شکل ۹: آنتروپی سراسری الگوریتم اتوماتای یادگیر و یادگیری تقویتی با آنتروپی در محیط ۱۰×۱۰

در شکل ۹ مقایسه ای بین اتوماتای یادگیر با استفاده از آنتروپی و یادگیری تقویتی با استفاده از آنتروپی صورت گرفته است و همانطور که در شکل مشخص است الگوریتم پیشنهادی با سرعت بیشتر در جهت کاهش آنتروپی پیش می رود و این مطلوب ما است.



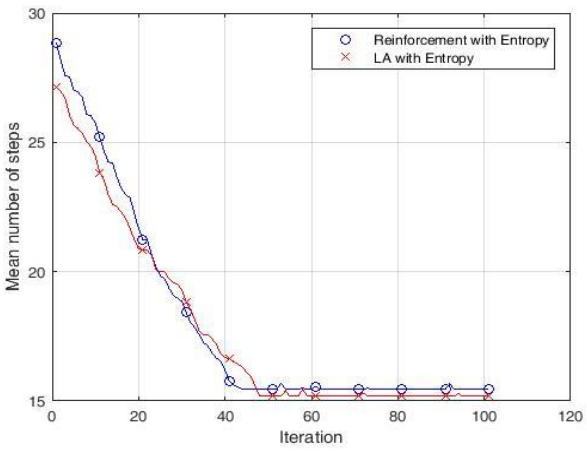
شکل ۱۰: میانگین گام‌های الگوریتم اتوماتای یادگیر و یادگیری تقویتی با آنتروپی در محیط ۱۰×۱۰.

الگوریتم پیشنهادی با آنتروپی در معیار ارزیابی عملکرد، میانگین گام رسیدن به هدف، نیز سریعتر کاهش می یابد و این نشان از عملکرد بهتر این الگوریتم دارد.



شکل۱۱: آنتروپی سراسری الگوریتم اتوماتای یادگیر و یادگیری تقویتی با آنتروپی در محیط ۱۲×۱۲.

در شکل ۱۱ مقایسه برای محیط ۱۲×۱۲ انجام گرفته است و الگوریتم پیشنهادی با آنتروپی با سرعت بیشتری به سمت صفر میل می کند و نسبت به الگوریتم یادگیری تقویتی با آنتروپی بهتر عمل کرده است.



شکل ۱۲: میانگین گام‌های الگوریتم اتوماتای یادگیر و یادگیری تقویتی با آنتروپی در محیط ۱۲×۱۲.

در این مقایسات شاهدیم که در آنتروپی سراسری، الگوریتم اتوماتای یادگیر با آنتروپی نسبت به الگوریتم یادگیری تقویتی با آنتروپی شیب بالاتری در کاهش این معیار دارد و این موضوع برای ما بسیار مطلوب است. در معیار میانگین گام‌ها همانطور که شاهد هستیم اتوماتای یادگیر با آنتروپی نسبت به یادگیری تقویتی با آنتروپی بهتر عمل کرده است. پس می توان نتیجه گرفت که اتوماتای یادگیر با آنتروپی توانسته در معیار آنتروپی سراسری و میانگین گام‌ها بهترین نتایج را نسبت به یادگیری تقویتی با آنتروپی تولید نماید.

۸- نتیجه گیری

در این مقاله به یک روش مبتنی بر اتوماتای یادگیر در مسئله بهینه‌سازی استراتژی کنترل پرداختیم. در این روش از نرخ جایزه ثابت و نرخ جایزه انطباقی با آنتروپی، استفاده شد. برای ارزیابی از دو معیار آنتروپی سراسری و میانگین تعداد گام رسیدن به هدف بهره گرفتیم. با توجه به نتایج به دست آمده روش اتوماتای یادگیر همراه با آنتروپی بهترین نتایج را از لحاظ کاهش میانگین تعداد گام‌ها و آنتروپی سراسری به همراه داشت. در مقایسه ای هم که بین اتوماتای یادگیر با آنتروپی و یادگیری تقویتی با آنتروپی انجام شد، به این نتیجه رسیدیم که اتوماتای یادگیر با آنتروپی عملکرد بهتری با توجه به هر دو معیار ارزیابی دارد.

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a Variable Sturcture Learning Automata

b Shannon

c Information Entropy

d Local Strategy Entropy

e Global Strategy Entropy

f Decision Probability

ارائه یک روش جدید پیش‌بینی لینک مبتنی بر اتوماتای توزیع‌شده در شبکه‌های اجتماعی

سارا یونس زاده جلیلی[۱]، محمدرضا میبدی[۲] و بهناز مرادآبادی[۳]
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[۲]دانشگاه صنعتی امیرکبیر، دانشکده مهندسی کامپیوتر و فناوری اطلاعات، تهران، ایران
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چکیده - با گسترش روزافزون نفوذ شبکه‌های اجتماعی، مسئله پیش‌بینی لینک به یکی از مسائل کلیدی در حوزه آنالیز این شبکه‌ها تبدیل شده است. اگر شبکه اجتماعی را به صورت یک گراف متصور شویم، هدف این مسئله برآورد احتمال ایجاد یک لینک جدید بین گره‌های فعلی گراف می‌باشد. پیش‌بینی لینک در حوزه‌های وسیعی از تجارت الکترونیک گرفته تا شناسایی گروه‌های تروریستی کاربرد دارد. در این مقاله یک روش جدید پیش‌بینی لینک مبتنی بر شباهت که از بردار احتمالات اتوماتای توزیع‌شده به عنوان امتیاز شباهت برای پیش‌گویی استفاده می‌کند، ارائه شده‌است. بدین منظور یک شبکه اتوماتای یادگیر توزیع شده متناظر با گره‌های گراف ایجاد می‌گردد. نتایج حاکی از آن است که روش پیشنهادی نسبت به روش‌های سنتی در برخی از دیتاست‌های استاندارد، دارای بهترین عملکرد است و در برخی دیگر نتایجی نزدیک به بهینه را داراست.

کلید واژه - آنالیز شبکه‌های اجتماعی، اتوماتای یادگیر توزیع شده، امتیاز شباهت، پیش‌بینی لینک

۱- مقدمه

یک شبکه اجتماعی[۱]، مجموعه‌ای از بازیگران است که تعاملات میان آن‌ها به وسیله تعدادی لینک نمایش داده می‌شود. پیش‌بینی‌لینک[۲] فرایندی است که با در نظر گرفتن تصویر لحظه ای از شبکه، تعاملات احتمالی آینده‌ی بین بازیگران را پیش‌گویی می‌کند[۱]. در سال‌های اخیر پیش‌بینی‌لینک در شبکه‌های اجتماعی توجه بسیاری از محققین را به خود جلب کرده و روش‌های گوناگونی ارائه شده است. این روش‌ها در سه دسته‌ی روش‌های مبتنی بر شباهت[۳]، روش‌های احتمال بیشینه[۴] و مدل‌های احتمالاتی[۵] طبقه‌بندی می‌شوند[۲].

در روش های مبتنی بر شباهت یک شاخص به هر زوج از گره‌ها اختصاص داده می‌شود که به‌عنوان امتیاز شباهت[۶] بین دو گره تعریف می‌شود. همه لینک‌های مشاهده نشده بر اساس امتیاز شباهت‌هایشان مرتب می‌شوند، و لینک‌هایی که گره‌هایی با امتیاز شباهت بیشتر را به یکدیگر وصل نمایند به احتمال بیشتری وجود دارند[۲]. شباهت گره‌ها می‌تواند به‌وسیله استفاده از صفات اساسی رئوس تعریف شود: دو گره به‌صورت مشابه در نظر گرفته می‌شوند اگر خصوصیات مشترک زیاد [۳] و یا ساختار توپولوژیکی نزدیکی داشته باشند [۴].

شاخص‌های شباهت ساختاری را می‌توان در سه دسته‌ی شاخص-های محلی، شاخص‌های سراسری و شاخص‌های شبه‌محلی طبقه‌بندی کرد. شاخص‌های محلی فقط از اطلاعات همسایه گره‌ها استفاده می‌کنند. شاخص‌های سراسری نیاز به اطلاعات توپولوژیکی سراسری دارند. شاخص‌های شبه‌محلی به اطلاعات توپولوژیکی سراسری نیازی ندارد اما نسبت به شاخص‌های محلی از اطلاعات بیشتری استفاده می‌نماید[۲].

در این مقاله، یک الگوریتم جدید پیش‌بینی لینک بر پایه اتوماتای یادگیر توزیع شده[۷] (DLA) ارائه شده است که در آن شبکه‌ای از اتوماتاهای یادگیر متناظر با گره های گراف مسئله ایجاد می‌گردد. هر اتوماتا معادل یک گره و هر اقدام اتوماتا معادل یک یال می‌باشد. خروجی DLA ترتیبی از اقدام های انتخاب شده می‌باشد که مسیری شامل تعدادی گره تولید می‌کند. این مسیر توسط تابع برازش[۸] ارزیابی شده و باعث تغییر احتمال اقدام های اتوماتاهای متناظر با گره های واقع در مسیر می‌شود. در نهایت پس از چندبار تکرار الگوریتم از بردار احتمالات DLA به عنوان امتیاز شباهت استفاده می‌شود. نتایج تجربی روی تعدادی از شبکه‌های واقعی نشان می‌دهد دقت الگوریتم پیشنهادی از بسیاری از روش‌های محک بالاتر است.

سازمان و ترتیب مقاله بصورت زیر است : مسئله پیش‌بینی لینک در بخش۲ توضیح داده شده است. در بخش۳، اتوماتای

یادگیر و اتوماتای یادگیر توزیع شده، تشریح شده است. فرموله کردن مسئله و روش های ارزیابی در بخش ۴ آمده است. در بخش ۵ الگوریتم پیشنهادی تشریح گشته است. در بخش ۶ نتایج آزمایش‌ها نشان داده شده و در بخش آخر نتیجه‌گیری شده است.

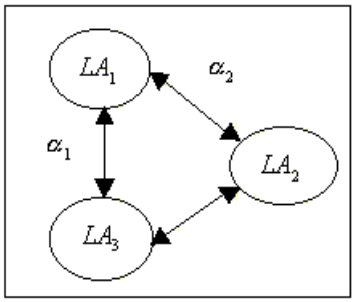
۲- مسئله پیش بینی لینک

اگر فضای مسئله را به صورت یک گراف در نظر بگیریم آنگاه پیش‌بینی لینک عبارت است از پیش‌بینی میزان احتمال ارتباط بین دو گره گراف در آینده، با دانستن این که در وضعیت فعلی هیچ ارتباطی بین این گره‌ها وجود ندارد. بنا بر تعریف قراردادی [۱] پیش‌بینی لینک می‌تواند به صورت زیر فرموله شود: گراف شبکه‌اجتماعی(V, E) داده شده است، یال $e = (u, v) \epsilon E$ نشان دهنده تعامل بین گره های v و u در یک بازه زمانی مشخص است. برای زمان $t \leq t'$ فرض می کنیم که $G[t, t']$ نمایانگر زیرگرافی از G است که شامل تمامی یال های G در بازه زمانی$[t, t']$ است. پس از انتخاب دو بازه زمانی $[t_0, t'_0]$ و $[t_1, t'_1]$ بطوریکه $t'_0 < t_1$، الگوریتم پیش بینی لینک باید تنها با دسترسی به گراف $G[t_0, t'_0]$، در خروجی یال‌هایی را پیش‌بینی کند که در گراف $G[t_0, t'_0]$ وجود ندارند اما در گراف $G[t_1, t'_1]$ به وجود خواهند آمد. بازه $[t_0, t'_0]$ بازه آموزش و بازه $[t_1, t'_1]$ بازه تست نامیده می‌شود.

۳- اتوماتای یادگیر و اتوماتای یادگیر توزیع شده

یک اتوماتای یادگیر را می‌توان بصورت یک شئ مجرد که دارای تعداد متناهی اقدام است، در نظر گرفت. اتوماتای یادگیر با انتخاب یک اقدام از مجموعه اقدامهای خود و اِعمال آن بر محیط، عمل می‌کند. اقدام مذکور توسط یک محیط تصادفی ارزیابی می‌شود و اتوماتا از پاسخ محیط برای انتخاب اقدام بعدی خود استفاده می‌کند. در طی این فرآیند اتوماتا یاد می‌گیرد که اقدام بهینه را انتخاب نماید. نحوه استفاده از پاسخ محیط به اقدام انتخابی که در جهت انتخاب اقدام بعدی استفاده می‌شود، توسط الگوریتم یادگیری مشخص می‌گردد. اتوماتای یادگیر تصادفی را می‌توان با چهارتایی $LA = \{\alpha, \beta, p, T\}$ نمایش داد که r تعداد اقدامها، $\alpha = \{\alpha_1, \alpha_2, .., \alpha_r\}$ مجموعه اقدامها، $\beta = \{\beta_1, \beta_2, .., \beta_r\}$ مجموعه ورودی‌ها، $p = \{p_1, p_2, .., p_r\}$ بردار احتمال‌اقدامها و $T = p(n+1) = T[\alpha(n), \beta(n), p(n)]$ الگوریتم یادگیری اتوماتا است [۵].

اتوماتای یادگیر توزیع شده شبکه‌ای از چند اتوماتای یادگیر است که برای حل یک مسئله مشخص با یکدیگر همکاری می‌کنند. تعداد اقدام‌های یک اتوماتا در DLA برابر تعداد اتوماتاهای یادگیر متصل به این اتوماتای یادگیر می باشد. یک DLA را می‌توان با یک گراف جهت دار مدل کرد، به صورتی که مجموعه گره های آن را مجموعه‌ای از اتوماتاهای یادگیر و یالهای خروجی هر گره را مجموعه اقدام‌های اتوماتای یادگیر متناظر با آن گره دانست. هنگامی که یک اتوماتا یکی از اقدامهای خود را انتخاب میکند، اتوماتایی که در دیگر انتهای یال متناظر با آن اقدام قرار دارد، فعال می‌شود. در هر زمان فقط یک اتوماتای یادگیر در شبکه فعال می‌باشد. بر اساس توضیحات فوق، اتوماتای یادگیر توزیع شده توسط گرا ف $DLA = (V, E)$ که $V = \{LA_1, LA_2, \dots, LA_n\}$ مجموعه اتوماتاهای یادگیر و n تعداد اتوماتاهای یادگیر و $E \subset V \times V$ مجموعه یال‌های گراف می‌باشد، تعریف می‌شود. یال (i, j) اقدام j اتوماتای یادگیر LA_i را نشان می‌دهد و LA_j زمانی فعال خواهد شد که اقدام j اتاماتای یادگیر LA_i انتخاب شود. تعداد اقدام‌های LA_k $(k = 1,2, \dots, n)$ برابر درجه‌ی خروجی گره متناظر با LA_k می‌باشد. برای مطالعه بیشتر درباره اتوماتای یادگیر توزیع شده می‌توان به [۶] مراجعه نمود.



شکل۱: اتوماتای یادگیر توزیع شده (DLA) متشکل از ۳ اتوماتا ی یادگیر[۶]

۴- فرموله کردن مسئله و روش های ارزیابی

در مقاله پیش رو، لینک‌های چندگانه و اتصال به خود وجود ندارد و شبکه به‌صورت گراف ساده و غیرجهت‌دار $G = (V, E)$ تعریف شده؛ به‌طوری‌که V مجموعه گره‌ها، E مجموعه لینک‌ها، $n = |V|$ تعداد گره‌های G و U مجموعه جهانی شامل تمامی لینک‌های ممکن G است.

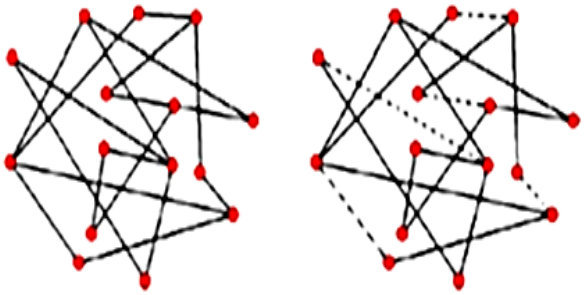
عمل پیش‌بینی لینک یافتن لینک‌های گمشده[۹] و یا لینک‌های ناموجودی[۱۰] است که در آینده ایجاد خواهد شد. هدف این روش اختصاص دادن یک امتیاز، $score(x, y)$ ، به هر زوج از گره‌ها $(x, y) \in U$ است. این امتیاز میزان شباهت بین دو گره را

برمی‌گرداند. برای یک زوج‌گره‌ی (x,y) در $U-E$، $Score(x,y)$ بزرگتر، نشان دهنده‌ی احتمال بیشتر برای وجود یک لینک بین گره‌های x و y است. برای آزمایش دقت نتایج الگوریتم، لینک‌های مشاهده شده‌ی E بصورت تصادفی به دو بخش تقسیم شده‌اند:

E^T: مجموعه آموزشی که به عنوان اطاعات شناخته شده مورد عمل قرار می‌گیرد.

E^P: مجموعه تست که اطلاعات آن برای آزمون دقت نتایج بوده و برای پیش‌بینی لینک استفاده نمی‌شود.

اجتماع دو مجموعه E^T و E^P برابر E و اشتراک آن‌ها برابر $\emptyset$ می‌باشد[۷].



ب- گراف آموزش الف- گراف اصلی

شکل ۲: نمودار گراف یک شبکه [۲]

به عنوان مثال شکل۲. الف شبکه‌ای با ۱۵گره و ۲۱ لینک موجود را نشان می‌دهد. هدف ما یافتن لینک‌های بالقوه‌ی ۸۴ زوج‌گره غیرمتصل است. برای آزمایش دقت الگوریتم نیاز است که برخی از لینک‌های موجود به عنوان مجموعه تست انتخاب شوند و بقیه به عنوان مجموعه آموزش. به عنوان نمونه ۵ لینک به عنوان لینک‌های مجموعه تست ، که در شکل۲.ب با خط‌چین نمایش داده شده، برگزیده شده‌اند. سپس الگوریتم تنها با استفاده از اطلاعات موجود در مجموعه آموزشی یا همان گراف آموزشی که در شکل۲.ب با خطوط پیوسته نمایش داده شده است، عمل می‌کند. الگوریتم در نهایت امتیازی به هر یک از۸۹ زوج‌گره که شامل ۸۴ لینک غیر موجود عضو $U-E$ و ۵ لینک تست عضو E^P می‌دهد. در اصل، یک الگوریتم پیش‌بینی لینک یک لیست مرتب شده از تمام لینک‌های مشاهده نشده $(U-E^T)$ فراهم می‌کند یا به طور معادل برای تعیین احتمال وجود هر لینک مشاهده نشده، امتیاز S_{xy} را به آن نسبت می‌دهد به طوری‌که $(x,y) \in U-E^T$. برای تعیین دقت الگوریتم‌های پیش‌بینی، دو معیار استاندارد AUC[۱۱] و Precision وجود دارد [۲].

۴-۱- AUC

AUC عبارت است از سطح زیر نمودار ROC[۱۲] با منحنی مشخصه عملکرد سیستم. در یک پیاده‌سازی الگوریتمیک برای افزایش سرعت، اغلب به جای تولید یک لیست مرتب از امتیازهای شباهت، امتیاز هر لینک مشاهده نشده را محاسبه می‌کنیم، سپس هر بار به طور تصادفی یک لینک گمشده عضو E^P و یک لینک ناموجود عضو $U-E$ برای مقایسه امتیازشان برگزیده می‌شوند، اگر از میان n مقایسه‌ی مستقل، n' بار لینک گمشده امتیاز بیشتری داشته باشد و n'' بار امتیاز مشابهی داشته باشد آنگاه امتیاز AUC عبارت است از:

$$AUC = \frac{n' + 0.5n''}{n} \qquad (۱)$$

اگر تمام امتیازها از یک توزیع یکسان و مستقل تولید شده باشند، AUC در حدود 0.5 است. بنابراین الگوریتمی که ارزش AUC آن از 0.5 تجاوز می‌کند، نشان‌دهنده‌ی اجرای بهتر الگوریتم نسبت به فقط شانس است[۷].

۴-۲- Precision

با در نظر گرفتن رتبه‌بندی تمام لینک‌های مشاهده نشده، precision به عنوان نسبت آیتم‌های انتخاب شده‌ی مناسب به مجموع آیتم‌های انتخاب شده، تعریف می‌شود. به این ترتیب اگر از بین تمام لینک‌های مشاهده نشده، L لینک بالاتر در نظرگرفته شوند، از میان آنها m لینک درست پیش‌بینی شده باشند، precision به‌صورت زیر تعریف می‌شود[۷]:

$$\text{precision} = \frac{m}{L} \qquad (۲)$$

۵- الگوریتم پیشنهادی DLA_ LP

شبکه‌ای از اتوماتاهای یادگیر متناظر با گره های گراف ایجاد می‌گردد. در این DLA هر اتوماتا معادل یک گره و هر اقدام، معادل یک یال می‌باشد. به دلیل کامل بودن گراف تعداد اقدام های هر اتوماتا در گرافی با n گره، برابر با n-1 است. خروجی DLA ترتیبی از اقدام های انتخاب شده توسط اتوماتاها می‌باشد که مسیری با n گره تولید می‌کند. وجود گره‌های تکراری در مسیر بلامانع می‌باشد. این مسیر با توجه به میزان مطلوبیت (تابع برازش مسیر)، باعث پاداش به اقدام های واقع در آن می‌شود. در نهایت پس از چندین تکرار از بردار احتمالات DLA به عنوان امتیاز شباهت یال‌ها استفاده خواهد شد.

۵-۱- مقداردهی اتوماتا

برای شبکه غیرجهت‌دار و ساده‌ی $G = (V, E)$، اگر $n = |V|$ و $V = \{v_1, v_2, \dots, v_n\}$ و ماتریس $A = [a_{ij}]$ مجاورت $n \times n$ گراف G باشد، الگوریتم پیشنهادی از بردار $S = (s_1, s_2, \dots, s_n)$ برای نمایش یک مسیر شامل گره‌های انتخاب شده بر گراف منطقی G' استفاده می‌کند، به‌طوریکه $s_i \in V$، i-امین گره مسیر است. در ابتدا تمام عناصر S با $\emptyset$ که نشان‌دهنده یک گره خالی است، مقدار دهی می‌شوند. سپس s_i با مقدار یک گره واقعی که توسط i-امین اتوماتای فعال انتخاب شده است، جایگزین می‌شود.

برای مقداردهی اولیه بردار احتمال در صورتی که اتوماتا از احتمال اولیه مساوی برای انتخاب اقدام‌های خود استفاده کند یعنی $p = \frac{1}{n-1}$، جواب‌های به دست آمده تقریبا غیرقابل قبول بوده و نیز نرخ همگرایی الگوریتم بسیار پایین می‌باشد. جهت رفع این مشکل با الهام از [۲] به هر اتوماتای یادگیر اجازه داده می‌شود در مقداردهی اولیه بردار احتمال خود، از اطلاعات ماتریس مجاورت و تعداد همسایگان مشترک گره‌های گراف اولیه استفاده نماید. بنابراین اگر P_{ij} احتمال اولیه این باشد که اتوماتای فعال متناظر با گره iام یعنی LA_i، اقدام j را انتخاب کرده و منجر به فعال شدن LA_j شود آنگاه بر طبق (۳) :

$$P_{ij} = \frac{x_{ij}^{a} * y_{ij}^{b}}{\sum_{k=1}^{n-1} x_{ik}^{a} * y_{jk}^{b}} \qquad (۳)$$

آنگاه مقدار اولیه‌ی x_{ij} مرتبط با یال بین گره‌های (v_i, v_j) به صورت (۴) به‌دست می‌آید:

$$x_{ij} = \lambda * (a_{ij} + \varepsilon_1) \qquad (۴)$$

که ε_1 یک ثابت مثبت می باشد و a_{ij} عبارت است از درایه ماتریس مجاورت متناظر با v_i و v_j در گراف شبکه، یعنی اگر یال $(v_i, v_j) \in E$ باشند، آنگاه $a_{ij} = 1$ و مقدار x_{ij} برابر است با $\lambda * (1 + \varepsilon)$ و در غیراین‌صورت برابر است با $\lambda * \varepsilon$. واضح است که یال‌هایی که لینک هستند مقدار x_{ij} بیشتری دارند. چنین اطلاعاتی اتوماتاها را به انتخاب لینک‌های موجود و همسایه‌های محتمل‌تر هدایت می‌کند.

برای تعریف مقدار y_{ij} روی یال بین گره‌های (v_i, v_j) از مفهوم همسایگان مشترک استفاده می شود. مجموعه همسایگان مشترک نودهای (v_i, v_j) به‌صورت (۵) نمایش داده می‌شود:

$$\Gamma(v_i, v_j) = \{u | u \in V, (v_i, u) \in E \curlywedge (v_j, u) \in E\} \qquad (۵)$$

بنابر (۵) مقدار y_{ij} مرتبط با یال بین گره‌های (v_i, v_j) به صورت (۶) تعریف می شود:

$$y_{ij} = \gamma * |\Gamma(v_i, v_j)| + \varepsilon_2 \qquad (۶)$$

$|\Gamma(v_i, v_j)|$ تعداد همسایگان مشترک گره‌های (v_i, v_j) و γ و ε_2 ثابت‌های مثبت هستند. چنین اطلاعاتی اتوماتا را بر انتخاب گره‌هایی که ارتباط نزدیکی با هم دارند هدایت می‌کند.

پارامترهای a و b تأثیر نسبی x_{ij} و y_{ij} را تعیین می‌کنند. واضح است که اقدامی با x_{ij} و y_{ij} بیشتر، با احتمال بیشتری انتخاب خواهد شد.

۵-۲- تابع برازش

یک تابع برازش برای اندازه‌گیری کیفیت هر مسیر تعیین شده و برای به روز رسانی احتمالات DLA استفاده خواهد شد. یک مسیر با بیشتر بودن لینک‌های موجود و گره‌های دارای ارتباط نزدیک، امتیاز کیفیت بالاتری خواهد داشت؛ زیرا هر زوج از گره‌های مجاور در چنین مسیری به احتمال بیشتری توسط یک لینک بالقوه متصل می‌شوند. بنابراین تابع برازش یک مسیر می‌تواند از دو جنبه‌ی اهمیت گره‌ها و اهمیت یال‌ها عمل برازش را انجام دهد. به طورکلی، اهمیت گره‌ها با معیارهای مرکزیت گره[۱۳] اندازه‌گیری می‌شود. مرکزیت‌های مختلف، توابع مختلفی از گره‌ها را در شبکه به تصویر می‌کشد، از جمله توانایی گسترش[۱۴] و تأثیر گره[۱۵]. مرکزیت مبتنی بر درجه ساده‌ترین این معیارها است. به طور کلی درجه مرکزیت بالاتر یک گره، اهمیت بیشتر آن گره و احتمال بیشتر لینک شدن آن با سایر گره‌ها را نشان می‌دهد. بنابراین یک تعریف برازش برای یک مسیر می‌تواند از حاصل‌جمع درجات گره‌های آن مسیر به‌دست آید.

همانطور که گفتیم پس از هر تکرار، ترتیب فعال شدن اتوماتاها، مسیر $S = (s_1, s_2, \dots, s_n)$ را تشکیل می‌دهد که شامل n گره است. برای محاسبه امتیاز برازش مسیر، مطابق (۷) درجات گره های مسیر را از گراف اولیه مسئله (و نه از گراف کامل) استخراج کرده و با هم جمع می‌کنیم.

$$Q(S) = \sum_{i=1}^{n} d(s_i) \qquad (۷)$$

۵-۳- به‌روز رسانی احتمال ها

پس از هر تکرار و پیدا کردن یک مسیر، الگوریتم احتمال اقدام‌های اتوماتاهای فعال شده را به طبق رابطه‌های (۸) و (۹) به‌روز رسانی می‌کند. بدین ترتیب که امتیاز برازش مسیر محاسبه می‌شود و با امتیاز برازش بهترین مسیری که تا به حال توسط الگوریتم ایجاد شده است مقایسه می‌گردد. بر اساس نتیجه مقایسه، بردار احتمال اقدام DLA به روز رسانی خواهد شد، بدین صورت که اگر امتیاز برازش مسیر ایجاد شده بزرگتر و یا مساوی امتیاز برازش بهترین مسیری که تا به حال ایجاد شده است باشد، همه اتوماتاهای یادگیر فعال شده، اقدام انتخابی خود را طبق الگوریتم یادگیری ، پاداش می دهند. به‌عنوان مثال در صورتی که در تکرار (t) امتیاز برازش مسیر ایجاد شده بزرگتر و یا مساوی امتیاز برازش بهترین مسیر باشد و یک اتوماتای یادگیر DLA از مجموعه اقدام‌های مجاز خود اقدام i را انتخاب کرده باشد، بر اساس[۸] احتمال انتخاب اقدام i در تکرار (t+1) طبق رابطه‌ی (۸) افزایش خواهد یافت:

$$p_i(t+1) = \frac{p_i(t) + \Delta p}{1 + \Delta p} \qquad (۸)$$

و احتمال انتخاب سایر اقدام‌های اتوماتای یادگیر در تکرار (t+1) طبق رابطه‌ی (۹) کاهش خواهد یافت:

$$p_j(t+1) = \frac{p_j(t)}{1 + \Delta p} \qquad 1 \le j \le n, j \ne i \qquad (۹)$$

که طبق رابطه‌ی (۱۰) Δp برابر است با نرخ یادگیری[۱۶] اتوماتا تقسیم بر امتیاز برازش مسیر:

$$\Delta p = \frac{LR}{Q(S)} \qquad (۱۰)$$

۵-۴- شرایط خاتمه و خروجی

الگوریتم تکرارها را هنگامی‌که به آستانه Nc برسد، متوقف می‌کند.خروجی ماتریس احتمالات اتوماتا است که به عنوان امتیاز شباهت توسط معیار AUC تفسیر خواهد شد. شبه کد الگوریتم در شکل۳ به نمایش درآمده است.

۶- نتایج آزمایش‌ها

در این بخش اثر الگوریتم پیشنهادی DLA_LP در شبکه-های دنیای واقعی و همچنین عملکرد آن در برابر الگوریتم‌های سنتی پیش‌بینی لینک مبتنی بر شباهت مانند CN، Salton، Jaccard، Sorensen، HPI، HDI، LHN، PA، LP و Katz نشان داده می‌شود. تمامی آزمایش‌ها در سیستم‌عامل Microsoft windows 7 و نرم‌افزار Matlab14.0 انجام شده‌اند.

Algorithm DLA_ LP (DLA for Link Prediction)

Input
A: Adjacency matrix of the network;
Nc: The maximum number of iterations (stop condition);
Output:
Score: The score matrix;

Begin
1. t = 1;
2. Parameter initialization:
2.1. Set the initial values of matrix **x** and matrix **y** according to (4) and (6);
2.2. Generate n ×n matrix P, P(i , j) means jth actions of ith automata and P(i , i)=0;
2.3. Put one LA in each node, all LA's are disabled ;
3. **Repeat**
3.1. For *i*=1 to n do /* for n node in the network*/
3.1.1. Generate a random number between 1 and n to randomly select a node s_1.
3.1.2. LA s_i is enable and selects the next node s_j according to (3);
3.1.3. $s_i := s_j$;
3.2. End for *i*
3.3. Calculate the fitness of the path formed by LA's according to (7);
3.4. Reward selected actions of all LA's along the path according learning algorithm (Update the LA's P values) according to (8) and (9);
3.5. disabled all the enable actions of LA's;
4. **until (stop condition)**
5. Score for link(i , j) = P(i , j) + P(j , i);
6. Output the score matrix Score ;
End

شکل۳: شبه کد الگوریتم پیشنهادی

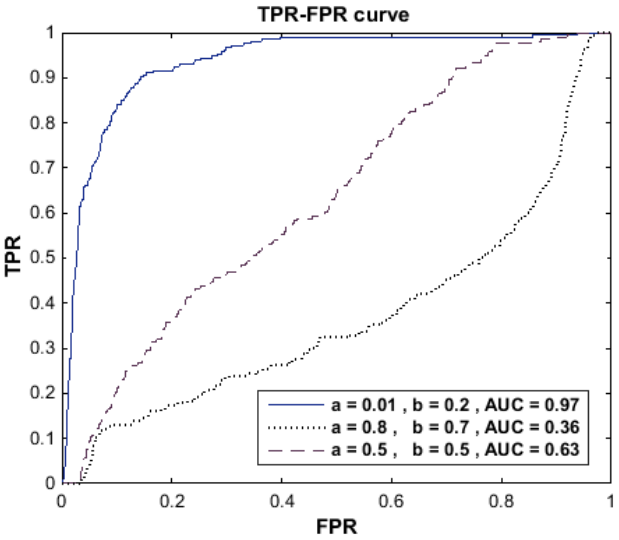
۶-۱- دیتاست‌ها

در این مقاله به شش دیتاست مبنایINT، Grid، PPI، NS، PB و USAir [۹] که هریک نماینده زمینه خاصی می‌باشد، توجه شده است. جدول۱ خصوصیات توپولوژیکی بزرگترین کامپوننت متصل هر یک از این دیتاست ها که آزمایش بر روی آن صورت گرفته است را نمایش می‌دهد. در این جدول N و M به ترتیب تعداد گره‌ها و لینک‌های کل شبکه هستند. NUM_C تعداد کامپوننت‌های متصل و نیز سایز (تعداد گره‌های) بزرگترین کامپوزیت متصل است. به عنوان مثال ۱۲۲۲/۲ نشان می‌دهد که

شبکه دارای ۲ کامپونت متصل است و بزرگترین آنها شامل ۱۲۲۲ گره می‌باشد. همچنین e مقدار efficiency شبکه [۱۰]، C ضریب خوشه‌بندی [۱۱] و r ضریب assorative [۱۲] و K میانگین درجه‌ی شبکه می‌باشند.

۶-۲- مقداردهی پارامترها

بر پایه نتایج تجربی، پارامترهای $a = 0.01$, $b = 0.2$, $\gamma = 1$, $\varepsilon_1 = 0.01$, $LR = 0.1$, $\varepsilon_2 = 0.5$, و $\lambda = 1$ مقداردهی شده‌اند. در شکل۴ نمودار ROC روش DLA_ LP روی دیتاست USAir با مقادیر مختلف پارامترهای a و b به نمایش درآمده است. همانطور که در شکل پیداست پارامترهای $a = 0.01$, $b = 0.2$ دقت AUC بالاتری را به دست آورده‌اند.



شکل ۴: نمودار ROC الگوریتم پیشنهادی بر روی دیتاست USAir در ازای سه مقدار مختلف پارامترهای a, b.

۶-۳- بررسی میزان دقت نتایج DLA_LP

در هر آزمایش یال‌های موجود هر گراف به‌صورت تصادفی به ۱۰زیرمجموعه تقسیم می‌شوند. از این ۱۰ زیرمجموعه، یک زیرمجموعه به عنوان داده‌های معتبر برای آزمایش الگوریتم حفظ می‌شود و بقیه ۹ زیرمجموعه به عنوان داده‌های آموزشی استفاده می‌شوند. سپس برای بررسی دقت نتایج، ماتریس شباهت که عبارت است از ماتریس احتمالات اتوماتا پس از ۱۰۰ تکرار، توسط معیارهای سنجش AUC و Precision بررسی می‌شود. مقادیر جدول‌های ۲ و ۳ به ترتیب حاصل از میانگین گیری بر روی مقادیر AUC و Precision مربوط به۱۰ آزمایش مستقل است که برای تولید یک تخمین واحد، میانگین‌گیری شده‌اند.

جدول۱: خصوصیات توپولوژیک بزرگترین کامپونت متصل۶ دیتاست مورد استفاده

NET	N	M	NUM_C	e	C	K
USAir	332	2126	332/1	0.44	0.74	-0.228
PB	1224	19090	1222/2	0.39	0.36	-0.079
NS	1461	2742	379/268	0.01	0.87	0.462
PPI	2617	11855	2375/92	0.18	0.38	0.454
grid	4941	6594	4941/1	0.05	0.10	0.004
INT	5022	6258	5022/1	0.16	0.03	-0.138

جدول۲: مقایسه دقت الگوریتم‌ها توسط معیار AUC

	US Air	PB	NS	PPI	Grid	INT
CN	0.937	0.925	0.933	0.889	0.59	**0.559**
Salton	0.898	0.874	0.911	0.869	0.585	0.552
Jaccard	0.901	0.882	0.933	0.888	0.59	**0.559**
Sorensen	0.902	0.881	0.933	0.888	0.59	**0.559**
HPI	0.857	0.852	0.911	0.868	0.585	0.552
HDI	0.895	0.877	0.933	0.888	0.59	**0.559**
LHN1	0.758	0.772	0.911	0.866	0.585	0.552
PA	0.886	0.907	0.623	0.828	0.446	0.464
LP	0.925	0.922	0.932	0.888	0.59	**0.559**
Katz	0.955	**0.931**	0.933	0.890	0.59	**0.559**
DLA_LP	**0.963**	0.912	**0.977**	**0.899**	**0.639**	0.456

جدول ۲ میانگین امتیاز AUC به‌دست آمده توسط الگوریتم پیشنهادی DLA_LP را در مقایسه با ۱۰ الگوریتم مختلف و بر روی ۶ دیتاست نشان می‌دهد. در این جدول، بالاترین امتیاز AUC مشاهده شده برای هر دیتاست‌ها به صورت ضخیم مشخص شده است. در مطالعات قبلی نشان داده شده است که به طور کلی شاخص Katz بهترین عملکرد AUC را بر روی دیتاست‌ها دارد اما همانطور که در این جدول می‌بینیم، در میان ۱۱ الگوریتم، DLA_LP بالاترین امتیاز AUC را بر روی ۴ دیتاست دارا بوده و نتایج به‌دست آمده بر روی ۲ دیتاست دیگر نیز با توجه به امتیازات سایر الگوریتم‌ها از جمله Katz قابل قبول است. با مقایسه جدول‌های ۱ و ۲ متوجه می‌شویم که امتیازهای AUC دیتاست با ضرایب خوشه‌بندی آنها تقریباً متناسب است و الگوریتم روی دیتاست‌هایی با ضریب خوشه‌بندی بالاتر، نتایج بهتری تولید می‌کند.

جدول۳: مقایسه دقت الگوریتم‌ها توسط معیار Precision

	US Air	PB	NS	PPI	grid	INT
LP	0.557	0.132	**0.734**	0.292	**0.51**	**0.627**
KATZ	0.368	0.063	0.719	0.29	0.45	0.623
LHN2	0	0.005	0	0.06	0	0.005
DLA_LP	**0.79**	**0.574**	0.477	**0.72**	0.12	0.105

در جدول۳ مقدار Precision الگوریتم DLA_LP در مقایسه با ۳ الگوریتم مختلف و بر روی ۶ دیتاست مقایسه شده و نتایج برای $L = 100$ به نمایش درآمده است. بر اساس مطالعات گذشته شاخصLP بهترین عملکرد Precision را بر روی دیتاست‌ها دارد اما همانطور که در این جدول می‌بینیم، الگوریتم DLA_LP بر روی نیمی از دیتاست‌ها با اختلاف فاحشی دقت بالاتری را به‌دست آورده است. از مقایسه جدول‌های ۱ و ۳ متوجه می‌شویم که امتیازهای AUC دیتاست با مقدار efficiency آنها متناسب است و الگوریتم روی دیتاست‌هایی با efficiency بالاتر، نتایج بهتری تولید می‌کند. دلیل آنکه DLA_LP به چنین نتایج خوبی دست می‌یابد این است که از هردوی اطلاعات همسایگان مشترک و توپولوژیک گراف استفاده می‌نماید که منعکس کننده دو ساختار محلی و سراسری شبکه و یافتن می‌باشند.

۷- نتیجه گیری

با توجه به اهمیت شبکه‌های اجتماعی و مسئله پیش‌بینی لینک، در این مقاله یک روش پیش‌بینی لینک مبتنی بر اتوماتای یادگیر توزیع شده پیشنهاد شده است که سعی می‌کند با پیمایش گراف به صورت احتمالاتی مجموعه‌ای از لینک‌های محتمل آینده را پیش‌بینی کند. نتایج آزمایش‌ها حاکی از عملکرد خوب الگوریتم پیشنهادی بر روی تعدادی از دیتاست‌های استاندارد شبکه اجتماعی در مقایسه با سایر روش‌ها می‌باشد. این عملکرد خوب ناشی از به‌کارگیری اطلاعات همسایگان مشترک و توپولوژیک گراف و نیز استفاده از اتوماتای یادگیر تصادفی به صورت توزیع شده است که می تواند عملکرد خود را بر اساس بازخورد محیط اصلاح کرده و مسئله را به سمت پاسخ بهینه هدایت کند.

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پانوشت ها

[1] Social Network
[2] Link Prediction
[3] Similarity based
[4] Maximum likelihood
[5] Probabilistic model
[6] Similarity Score
[7] Distributed learning automata
[8] Fitness
[9] Missing
[10] Non-existing
[11] Area under curve
[12] Receiver Operating Characteristic
[13] Node centrality
[14] Spreading ability
[15] Influence
[16] Learning Rate

حل مساله تخصیص درجه دوم به روش الگوریتم جستجوی گرانشی ترکیبی

سید حامد ساعی[۱]، بهروز معصومی[۱]
[۱]دانشگاه آزاد اسلامی، واحد قزوین، دانشکده برق، رایانه و فناوری اطلاعات

چکیده - مساله تخصیص درجه دوم[۱]، یک مساله *NP-hard* می باشد که به دست آوردن جواب بهینه برای مسائل سایز بزرگ آن به صورت دقیق امکان پذیر نیست. از این رو از روشهای فراابتکاری برای حل آن استفاده میشود. در این مقاله، از یک روش ترکیبی از ترکیب الگوریتم جستجوی گرانشی[۲] با الگوریتم ژنتیک[۳] به نام *GSA-GA* برای حل مساله *QAP* استفاده شده است. این الگوریتم بر روی تعدادی از مسائل نمونه *QAP* موجود در *QAPLIB* آزمایش شده و در اکثر موارد قادر به یافتن بهترین جواب به دست آمده تا کنون بوده و نتیجه عملکرد آن در مقایسه با سایر روشهای به کار رفته از کارایی بهتری برخوردار است.

کلید واژه- الگوریتم جستجوی گرانشی، الگوریتم ژنتیک، الگوریتم های فراابتکاری، بهینه سازی ترکیبی، مساله تخصیص درجه دوم.

۱- مقدمه

مساله تخصیص درجه دوم یکی از مسائل بهینه سازی ترکیبی[۴] است که به تخصیص مجموعه ای از تسهیل ها به مجموعه ای از مکان ها می پردازد به طوری که فاصله بین مکان ها و همچنین جریان بین تسهیل ها مشخص است. هدف این مساله، تخصیص هر تسهیل به یک مکان می باشد به صورتی که هزینه کل(مجموع حاصل ضرب جریان ها در فاصله ها) حداقل گردد[۱].

با فرض موجود بودن مجموعه $N = \{1,2,\dots,n\}$ که متناظر با تعداد مکان ها و تسهیل ها می باشد، و ماتریس های فاصله $D = d_{kl}$ و جریان $F = f_{ij}$ و هزینه $C = c_{ik}$ با اندازه $n \times n$، مساله تخصیص درجه دوم به صورت زیر بیان می شود:

$$z = \sum_{i=1}^{n}\sum_{j=1}^{n} f_{ij}\, d_{p(i)p(j)} + \sum_{i=1}^{n} c_{ip(i)} \qquad (۱)$$
$$p \in \pi_N$$

هدف در مساله تخصیص درجه دوم، یافتن یک جایگشت از مجموعه N می باشد که تابع فوق را کمینه کند[۲]. که در آن π_N، مجموعه تمام جایگشت های N، f_{ij} جریان بین تسهیلات i و j است، d_{kl} فاصله بین مکان k و مکان l می باشد، c_{ik} هزینه جایگیری تسهیل i در مکان k می باشد که معمولا این هزینه های جایگیری در نظر گرفته نمی شوند. یکی از انواع این مساله، مساله تخصیص درجه دوم عمومی است که در آن مختصات مکان ها دقیق فرض شده، تمامی فعالیت ها قطعی بوده و فعالیت احتمالی نداریم، و هچنین تعداد مکان ها با تسهیل ها برابر بوده و هر تسهیل فقط و فقط به یک مکان اختصاص می یابد. در این مقاله، مدل عمومی این مساله در نظر گرفته شده است.

یکی از کاربردهای اصلی QAP در تئوری جایابی می باشد. از کاربردهای دیگر آن می توان به چیدمان ساختمان ها در بیمارستان ها، مدیریت انبارها و استراتژی های توزیع، حداقل سازی طول کل سیم در مدارهای الکترونیکی، تخصیص برخی کارخانجات به برخی مکان ها، طراحی پنل های کنترلی و صفحه کلید ماشین نویس ها اشاره نمود.

با توجه به اینکه QAP یک مساله بهینه سازی NP-hard است[۳]، بنابراین یک مساله با پیچیدگی نمایی است و الگوریتم های دقیق قادر به حل این مسائل با سایز متوسط یا بزرگ نیستند. به طور کلی مسائل با ابعاد بزرگتر از ۲۰ معمولا از روش های دقیق قابل حل نیستند و یا در صورت حل شدن به لحاظ زمانی توجیه اقتصادی ندارند. از این رو، الگوریتم های فراابتکاری برای حل مسائل QAP مورد استفاده قرار گرفته اند. چندین الگوریتم فراابتکاری به طور موفق بر روی QAP به کار برده شده اند از جمله الگوریتم ژنتیک[۴و۵]، الگوریتم جستجوی تطبیقی تصادفی حریصانه[۵][۶]، سیستم های مورچه[۶][۷و۸]، الگوریتم انجماد تدریجی[۷][۹و۱۰]، الگوریتم مهاجرت پرندگان[۸][۱۱] و الگوریتم خفاش اصلاح شده[۹][۱۲] که یکی از الگوریتمهایی است که در سال ۲۰۱۵ برای حل این مساله استفاده شده است.

در این مقاله، روشی با استفاده از الگوریتم جستجوی گرانشی برای حل مساله QAP ارائه شده است. الگوریتم جستجوی گرانشی به صورت پیش فرض برای مسائل پیوسته طراحی شده، بنابراین برای استفاده از آن برای حل مساله QAP که ذاتا یک

مساله گسسته است، نسخه گسسته الگوریتم جستجوی گرانشی را به کار می بریم که در آن از تکنیک کلیدهای تصادفی[10] برای تبدیل یک موقعیت از فضای پیوسته به فضای گسسته استفاده شده است.

ادامه مقاله به این صورت سازماندهی شده است: در بخش ۲ الگوریتم جستجوی گرانشی استاندارد و نسخه گسسته آن معرفی می شود. در بخش ۳ الگوریتم پیشنهادی براساس الگوریتم جستجوی گرانشی گسسته ارائه می شود و در بخش ۴ نتایج حاصل از پیاده سازی الگوریتم پیشنهادی بر روی نمونه های مساله QAP، تحلیل نتایج و مقایسه با سایر الگوریتمها بیان می شود و در نهایت در بخش آخر به نتیجه گیری می پردازد.

۲- الگوریتم جستجوی گرانشی

در این قسمت ابتدا الگوریتم جستجوی گرانشی استاندارد[۱۳] بیان شده، و سپس نسخه گسسته آن برای حل مساله تخصیص درجه دوم ارائه می شود.

۲-۱- الگوریتم جستجوی گرانشی استاندارد

در الگوریتم GSA، بهینه یابی به کمک طرح قوانین و حرکت، در یک سیستم مصنوعی با زمان گسسته انجام می شود.

محیط سیستم همان محدوده تعریف مساله می باشد. طبق قانون گرانش هر جرم محل و وضعیت سایر اجرام را از طریق نیروی جاذبه گرانشی درک می کند. بنابراین می توان از این نیرو به عنوان ابزاری برای تبادل اطلاعات استفاده کرد. از بهینه یاب طراحی شده، می توان برای حل هر مساله بهینه سازی که در آن هر جواب مساله به صورت یک موقعیت در فضا قابل تعریف است و میزان شباهت آن با سایر جوابهای مساله به صورت یک فاصله قابل بیان باشد، استفاده نمود. میزان اجرام با توجه به تابع هدف تعیین می شوند. در قدم اول فضای سیستم مشخص می شود. محیط شامل یک دستگاه مختصات چند بعدی در فضای تعریف مساله است. هر نقطه از فضا، یک جواب مساله است. عاملهای جستجو کننده، مجموعه ای از اجرام می باشند. هر جرم سه مشخصه دارد: الف: موقعیت جرم، ب: جرم گرانشی و ج: جرم اینرسی.

اجرام فوق برگرفته از مفاهیم جرم گرانشی فعال و جرم اینرسی در فیزیک می باشند. در فیزیک، جرم گرانشی فعال معیاری از میزان شدت نیروی گرانشی حول یک جسم و جرم اینرسی معیاری از مقاومت جسم در مقابل حرکت است. این دو مشخصه بر خلاف واقعیت می توانند با یکدیگر برابر نباشند و مقدار آنها با توجه به برازندگی هر جرم تعیین می شود. موقعیت جرم، نقطه ای در فضا است که جوابی از مساله است. پس از تشکیل سیستم، قوانین حاکم بر آن مشخص می شوند. فرض می کنیم تنها قانون گرانش و قوانین حرکت حاکمند. صورت کلی این قوانین تقریبا شبیه قوانین طبیعت است و به صورت زیر تعریف شده اند.

قانون گرانش: هر جرم در سیستم مصنوعی، تمام اجرام دیگر را به سمت خود جذب می کند. مقدار این نیرو متناسب است با جرم گرانشی آن جرم و عکس فاصله آن دو جرم. **قوانین حرکت:** سرعت فعلی هر جرم برابر است با مجموع ضریبی از سرعت قبلی جرم و تغییر سرعت آن. تغییر سرعت یا شتاب هر جرم نیز برابر است با نیروی وارد بر آن تقسیم بر جرم اینرسی.

حال سیستم را به صورت مجموعه ای از N جرم تصور کنید. موقعیت هر جرم، نقطه ای از فضا است که جوابی از مساله می باشد. موقعیت بعد d از جرم i را با X_i^d نشان داده شده است.

$$X_i = (X_i^1, \dots X_i^d, \dots X_i^n) \quad (۲)$$

در این سیستم در زمان t و در هر بُعد d نیرویی به اندازه $F_{ij}^d(t)$ از سوی جرم j به جرم i وارد می شود. مقدار این نیرو از رابطه زیر به دست می آید:

$$F_{ij}^d(t) = G(t)\frac{M_{pi}(t) \times M_{aj}(t)}{R_{ij}(t) + \varepsilon}(x_j^d(t) - x_i^d(t)) \quad (۳)$$

که در رابطه بالا $M_{aj}(t)$ مقدار جرم گرانشی فعال مربوط به عامل j و $M_{pi}(t)$ جرم گرانشی منفعل مربوط به عامل i می باشد. و $G(t)$ مربوط به ثابت گرانش در زمان t و $R_{ij}(t)$ فاصله اقلیدسی بین عامل های i و j می باشد. ε نیز یک مقدار ثابت کوچک می باشد. فاصله اقلیدسی به صورت زیر تعریف می شود:

$$R_{ij}(t) = ||X_i(t), X_j(t)||_2 \quad (۴)$$

برای حفظ تصادفی بودن الگوریتم، نیروی وارد بر ذره(عامل) i ام در بعد d ام از طرف هر ذره را در یک عدد تصادفی با توزیع یکنواخت در بازه [۰،۱] ضرب کرده و کل نیروی وارد بر ذره i ام در بعد d ام، حاصل جمع نیروهای وارده از طرف همه ی ذره ها به جز ذره i ام در نظر گرفته می شود.

$$F_i^d(t) = \sum_{j=1, j\neq i}^{N} rand_j\, F_{ij}^d(t) \quad (۵)$$

با توجه به قانون دوم نیوتن چنانچه به ذره ای نیرو وارد شود، متناسب با آن نیرو شتاب می گیرد. بنابراین براساس قانون حرکت، شتاب ذره i ام در زمان t و در جهت بعد d ام به این صورت به دست می آید:

$$a_i^d(t) = \frac{F_i^d(t)}{M_{ii}(t)} \quad (۶)$$

که در آن $M_{ii}(t)$ جرم اینرسی مربوط به ذره i ام است.

سرعت بعدی یک ذره ضریبی از سرعت فعلی و شتاب فعلی ذره

است. بنابراین موقعیت و سرعت ذره از روابط زیر به دست می آید:

$$v_i^d(t+1) = rand_i \times v_i^d(t) + a_i^d(t) \quad (۷)$$

$$x_i^d(t+1) = x_i^d(t) + v_i^d(t+1) \quad (۸)$$

که در این بخش نیز $rand_i$ یک متغییر تصادفی یکنواخت در بازه [۰،۱] برای این در نظر گرفته شده است که خاصیت تصادفی جستجو از بین نرود.

ثابت گرانش G در ابتدا مقداردهی می شود و سپس به منظور دقت جستجو، کاهش می یابد. برای تنظیم ثابت گرانش از رابطه زیر استفاده می شود.

$$G(t) = G_0 . e^{-\alpha \frac{t}{T}} \quad (۹)$$

که در آن G_0 و α مقادیر ثابتی در نظر گرفته شده اند و T و t به ترتیب بیانگر کل تکرار ها و تکرار فعلی است.

برای تنظیم اجرام، از نگاشت تابع هدف اجرام استفاده می شود. به گونه ای که به اجرام با شایستگی بهتر، جرم بیشتری نسبت داده شود.

$$M_{ai}(t) = M_{pi}(t) = M_{ii}(t) = M_i(t) \quad (۱۰)$$

$$m_i(t) = \frac{Value_i(t) - worst(t)}{best(t) - worst(t)} \quad (۱۱)$$

$$M_i(t) = \frac{m_i(t)}{\sum_{j=1}^{N} m_j(t)} \quad (۱۲)$$

که در روابط بالا $Value_i(t)$ مقدار برازندگی ارزیابی برای ذره i ام در زمان t است. همچنین $best(t)$ و $worst(t)$ که به ترتیب نشان دهنده برازندگی قوی ترین و ضعیف ترین ذره های جمعیت در زمان t هستند که با استفاده از روابط زیر به دست می آیند:

$$best(t) = min_{j \in \{1,\dots,N\}} fit_j(t) \quad (۱۳)$$

$$worst(t) = max_{j \in \{1,\dots,N\}} fit_j(t) \quad (۱۴)$$

برای بهبود عملکرد الگوریتم جستجوی گرانشی با کنترل بهره برداری[۱۱] و اکتشاف[۱۲]، به جای همه اجرام، تنها تعداد Kbest عامل، موثر بر عوامل دیگر در نظر گرفته می شوند و اجرام دیگر را جذب می کنند. Kbest یک تابع از زمان است، با مقدار اولیه K_0 آغاز می شود و با گذشت زمان کاهش می یابد. در این روش، در آغاز، تمام عامل ها نیرو اعمال می کنند، و با گذشت زمان، Kbest به صورت خطی کاهش می یابد و در پایان فقط نیروی اعمال شده از سوی یک عامل به عامل های دیگر وجود دارد خواهد شد. بنابراین رابطه (۵) بصورت زیر اصلاح می شود:

$$F_i^d(t) = \sum_{j \in Kbest, j \neq i} rand_j \, F_{ij}^d(t) \quad (۱۵)$$

۲-۲- الگوریتم جستجوی گرانشی برای مسائل گسسته

با توجه به اینکه نسخه اصلی الگوریتم جستجوی گرانشی برای جستجو راه حل در یک فضای پیوسته طراحی شده است، به منظور استفاده از آن برای مساله تخصیص درجه دوم، که در واقع یک مساله در فضای حالت گسسته است از تکنیک کلیدهای تصادفی[۱۴] استفاده شده است. تکنیک کلید های تصادفی را می توان برای تبدیل یک موقعیت در یک فضای پیوسته به فضای گسسته مورد استفاده قرار داد. مطابق با تکنیک کلید تصادفی، موقعیت یک جرم در فضا می تواند به صورت یک جایگشت متشکل از اعداد گسسته ارائه شود. برای رمزگشایی موقعیت از فضای کلید تصادفی به فضای راه حل واقعی، موقعیت هر جرم را به ترتیب صعودی مقدار هر بُعدشان مشاهده می کنیم. یک نمونه در شکل ۱ نشان داده شده است:

موقعیت یک جرم در فضا:	0.42	0.06	0.38	0.48	0.81
جایگشت رمزگشایی شده:	3	1	2	4	5

شکل ۱: نمونه ای از تکنیک کلید تصادفی برای تبدیل یک موقعیت در فضای پیوسته به یک جایگشت در فضای گسسته

مطابق با شکل ۱ موقعیت یک جرم در فضا، به یک جایگشت تبدیل شده است که می تواند معادل یک راه حل برای مساله QAP باشد، به این صورت که این جایگشت معادل مکان ها و اعداد، معادل تسهیل های اختصاص یافته به آنها هستند یعنی تسهیل ۳ به مکان ۱، تسهیل ۱ به مکان ۲، تسهیل ۲ به مکان ۳ و ... .

شبه کد الگوریتم جستجوی گرانشی برای مسائل گسسته در شکل ۲ آمده است:

1. *random initialization X(1);*
2. *for t=1,…, iteration*
   - 2.1. *for j=1,…, N*
     - 2.1.1. *convert agents' position ($X_j(t)$) to permutation(P_j) by Random-key encoding;*
     - 2.1.2. *fitness evaluation of agents;*
   - 2.2. *update G(t),best(t),worst(t) by Eq. (9), Eq. (13), Eq. (14);*
   - 2.3. *for k=1,…, N*
     - 2.3.1. *calculation of the force on each agent by Eq. (15);*
     - 2.3.2. *calculation mass($M_k(t)$) and acceleration($a_k(t)$)) for each agent by Eq. (12), Eq. (6);*
     - 2.3.3. *update velocity($v_k(t+1)$) and position($X_k(t+1)$) of the agents by Eq. (7), Eq. (8);*

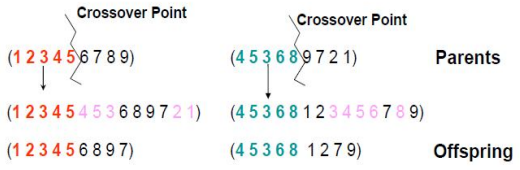
شکل ۲: شبه کد الگوریتم جستجوی گرانشی برای مسائل گسسته

۳- الگوریتم پیشنهادی براساس الگوریتم جستجوی گرانشی

اگر چه ثابت شده است GSA یک الگوریتم بهینه موثر است، ولی پس از همگرایی، GSA توانایی اکتشاف خود را از دست می دهد و غیر فعال می شود. در مقابل، الگوریتم ژنتیک قادر به پیدا کردن راه حل های جدید با عملگرهای تقاطع و جهش هنگام مواجهه با همگرایی زودرس است، هر چند GA در پیدا کردن یک راه حل دقیق مشکلاتی دارد. از این رو، برای مقابله با همگرایی زودرس GSA، الگوریتم پیشنهادی GSA-GA، که ترکیبی از قوانین به روز رسانی سرعت و موقعیت GSA استاندارد با ایده های تقاطع و جهش در GA است، ارائه شده است. بنابراین، الگوریتم پیشنهادی، عملگرهای تقاطع و جهش از الگوریتم ژنتیک را برای تولید پرش به منظور اجتناب از مشکل گیر افتادن در بهینه محلی در GSA مورد استفاده قرار داده است.

۳-۱- عملگر تقاطع

برای عملگر تقاطع از تقاطع تک نقطه ای استفاده شده است. در این روش دو عامل به صورت تصادفی براساس چرخ رولت انتخاب می شوند. چرخ رولت با وجود تصادفی بودن، هوشمندانه عمل می کند به این صورت که شانس انتخاب هر عامل متناسب با میزان برازندگی آن عامل است و عامل هایی که برازندگی بیشتر دارند، شانس انتخاب بیشتری دارند. دو عامل انتخاب شده معادل کروموزوم های والد در الگوریتم ژنتیک در نظر گرفته می شوند و به صورت تصادفی از یک نقطه شکسته می شوند. بخش اول از کروموزوم والد به کروموزوم فرزند منتقل می شوند. برای تکمیل بخش دوم کروموزوم هر فرزند، کروموزوم والد دیگر را از ابتدا اسکن نموده و هر عددی که در کروموزوم فرزند موجود نیست، به آن منتقل می شود. این عملگر به تعداد کل عامل ها صورت می گیرد که نمونه ای از آن در شکل ۳ نشان داده شده است.



شکل۳: نمونه عملگر تقاطع

۳-۲- عملگر جهش

عملگر جهش نیز در هر تکرار بر روی کل عامل ها اعمال می شود. در عملگر جهش، دو نقطه به صورت تصادفی انتخاب می شوند و مقدار آن ها با هم جا به جا می شود. نمونه ای از عملگر جهش در شکل ۴ نشان داده شده است.



شکل۴: نمونه عملگر جهش

پس از اعمال عملگرهای تقاطع و جهش، از بین عامل های ایجاد شده از این عملگرها و همچنین عاملهای قبلی، N عامل برتر که برازندگی بیشتری دارند انتخاب شده و الگوریتم با این عامل ها ادامه می یابد.

در نتیجه شبه کد الگوریتم پیشنهادی برای حل مساله تخصیص درجه دوم به صورت شکل ۵ خواهد بود:

1. *random initialization X(1);*
2. *for t=1,…, iteration*
   - 2.1. *for j=1,…, N*
     - 2.1.1. *convert agents' position ($X_j(t)$) to permutation(P_j) by Random-key encoding;*
     - 2.1.2. *fitness evaluation of agents;*
   - 2.2. *for l=1,…, N*
     - 2.2.1. *perform mutation operator on each agent;*
     - 2.2.2. *select two random agents by roulette wheel;*
     - 2.2.3. *perform crossover operator on two selected agents;*
   - 2.3. *select N best agents;*
   - 2.4. *update G(t),best(t),worst(t) by Eq. (9), Eq. (13), Eq. (14);*
   - 2.5. *for k=1,…, N*
     - 2.5.1. *calculation of the force on each agent by Eq. (15);*
     - 2.5.2. *calculation mass($M_k(t)$) and acceleration($a_k(t)$)) for each agent by Eq. (12), Eq. (6);*
     - 2.5.3. *update velocity($v_k(t+1)$) and position($X_k(t+1)$) of the agents by Eq. (7), Eq. (8);*

شکل ۵: شبه کد الگوریتم جستجوی گرانشی ترکیبی برای مسائل گسسته

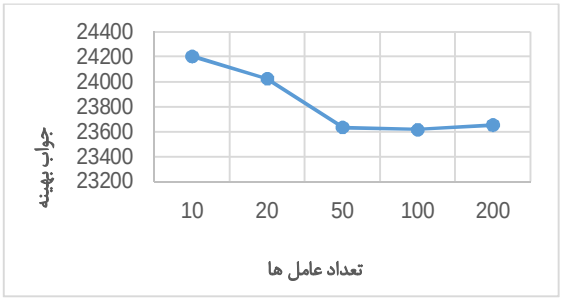
۴- آزمایشها، ارزیابی و مقایسه

در این بخش، نتایج اعمال الگوریتم پیشنهادی بر روی نمونه های استاندارد QAP از معتبرترین مرجع، مورد بررسی قرار گرفته است. این مرجع، سایت معتبر QAPLIB می باشد که شامل بیش از ۱۰۰ نمونه مساله QAP می باشد.

۴-۱-آزمایش اول: بررسی نقش پارامتر های ورودی مساله در دقت الگوریتم

۴-۱-۱ بررسی نقش تعداد عامل ها (N) در دقت الگوریتم

برای بررسی نقش پارامتر N در دقت الگوریتم، ما به ازای مقادیر ۱۰، ۲۰، ۵۰، ۱۰۰، ۲۰۰ برای آن، الگوریتم ارائه شده را بر روی ۱۰ مساله مرجع به کار بردیم که به عنوان نمونه، تاثیر آن روی مساله sko49 در شکل ۶ آورده شده است. نتایج سایر مسائل نیز تقریبا مشابه این مساله است.

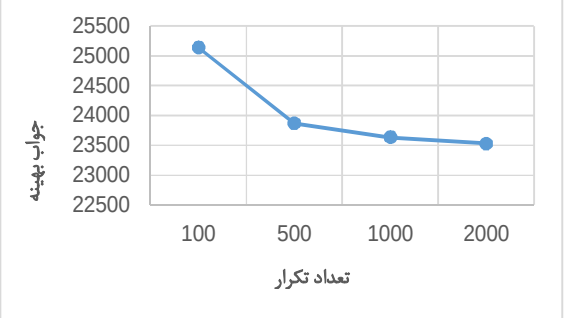


شکل ۶- تاثیر تعداد عامل ها در دقت الگوریتم برای مساله sko49

همانطور که مشخص است برای N>۵۰ الگوریتم پیشنهادی تقریبا غیر قابل پیش بینی بوده و نتایج آن وابستگی زیادی به جستجوی تصادفی دارد ولی در اکثر مسائل شیب تغییرات برای N=۵۰ زیاد بوده و پس از آن معمولا با شیب ملایمی بهبود صورت می گیرد. در واقع برای N<۵۰ اگر چه عمدتا بهبود صورت می گیرد اما این بهبود با توجه به افزایش مقدار عامل ها چندان چشمگیر نیست. بنابراین با توجه به اینکه تعداد عامل ها تاثیر مستقیمی در سرعت اجرای لگوریتم پیشنهادی دارند بنابراین مقدار N=۵۰ را به عنوان مقدار بهینه برای آن در نظر می گیریم.

۴-۱-۲ بررسی نقش تعداد تکرارها در دقت الگوریتم

برای بررسی نقش تعداد تکرارها، ما به ازای مقادیر ۱۰۰، ۵۰۰، ۱۰۰۰، ۲۰۰۰ الگوریتم ارائه شده را بر روی همان مسائل منتخب به کار بردیم که تاثیر آن روی مساله sko49 در شکل ۷ آورده شده است.



شکل۷- تاثیر تعداد تکرارها در دقت الگوریتم برای مساله sko49

همانگونه که انتظار می رفت با افزایش تعداد تکرارهای الگوریتم، درصد خطای آن کاهش پیدا می کند. در اکثر مسائل بررسی شده، الگوریتم ارائه شده در ۱۰۰۰ تکرار تقریبا به حالت پایدار رسیده و اختلاف بین ۱۰۰۰ تکرار و ۲۰۰۰ تکرار (اگرچه عمدتا بهبود صورت می گیرد) چندان قابل توجه نیست و از لحاظ زمانی توجیه اقتصادی ندارد، بنابراین ما مقدار ۱۰۰۰ تکرار را به عنوان مقدار بهینه برای حل مسائل مورد نظر انتخاب می کنیم.

۴-۱- آزمایش دوم: بررسی کارایی الگوریتم پیشنهادی

پس از تعیین مقادیر بهینه برای پارامترهای الگوریتم مورد نظر، در این قسمت نتایج حاصل از حل مسائل منتخب توسط الگوریتم پیشنهادی را مورد ارزیابی قرار می دهیم. در بخش اول، دقت الگوریتم پیشنهادی در مقایسه با الگوریتم های برتر به کار رفته برای مسائل QAP [۱۱،۱۵،۱۶،۱۷] در جدول ۳ آورده شده است. برای هر مساله، نتایج ثبت شده، درصد خطای بهترین جواب به دست آمده از ۱۰ بار اجرای الگوریتم پیشنهادی نسبت به بهترین جواب به دست آمده تا کنون می باشد که از رابطه زیر به دست آمده است:

$$gap = \frac{Solution - BKS}{BKS} \times 100 \qquad (۱۶)$$

که در آن BKS[۱۳] بیانگر بهترین جواب به دست آمده تا کنون و Solution بهترین جواب به دست آمده از ۱۰ بار اجرای الگوریتم پیشنهادی می باشد.

با توجه به جدول ۱، الگوریتم پیشنهادی در اکثر موارد عملکردی مشابه با بهترین الگوریتم (الگوریتم مهاجرت پرندگان) داشته و حتی در برخی از نمونه ها عملکرد بهتری از الگوریتم مذکور داشته است. و همچنین مشاهده می شود که در مجموع ۱۰ مورد بررسی شده به صورت میانگین الگوریتم پیشنهادی ما خطای کمتری از بقیه الگوریتم ها داشته است. پس از آن به مقایسه نتایج الگوریتم پیشنهادی با یکی از جدیدترین الگوریتم های به کار رفته برای QAP یعنی الگوریتم خفاش اصلاح شده[۱۰] می پردازیم. این نتایج در جدول ۲ آورده شده است که در آن پس از ۱۰ بار اجرا، بهترین جواب، میانگین جواب ها، انحراف معیار از میانگین، و درصد خطای میانگین ثبت گردیده است. همانطور که ملاحظه می شود در مجموع ۱۹ مورد نمونه ارزیابی، به جز ۳ مورد در باقی موارد الگوریتم GSA-GA درصد خطای میانگین برابر یا بهتری نسبت به الگوریتم BAT داشته است. در صورتی که ملاک ارزیابی را درصد خطای بهترین جواب در نظر می گرفتیم در تمامی موارد این برتری قابل رویت بود. پس از مقایسه نتایج الگوریتم پیشنهادی با سایر الگوریتم های فراابتکاری

جدول ۱- مقایسه نتایج اجرای الگوریتم پیشنهادی با الگوریتم های مشابه

نام مساله	ابعاد مساله	BKS	DE[۱۴]	PSO[۱۵]	SS[۱۶]	GA	H14 (SA)	MBO	GSA	GSA-GA
Esc32e	32	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Esc32g	32	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Esc32h	32	438	15.07	5.02	4.57	0.91	5.94	0.00	7.76	0.45
Esc64a	64	116	24.14	8.62	12.07	5.17	31.03	0.00	10.3	0.00
Tai64c	64	1855928	0.19	0.32	4.89	1.78	5.23	0.00	1.17	0.00
Lipa40b	40	476581	24.73	22.46	21.32	21.74	21.15	5.29	22.01	0.00
Sko49	49	23386	12.50	7.92	8.04	5.94	8.41	1.27	4.00	1.07
Wil50	50	48816	7.58	4.17	3.42	3.48	4.15	0.57	2.81	0.34
Lipa70a	70	169755	1.76	1.41	1.49	1.38	1.44	0.81	1.47	0.81
Lipa80a	80	253195	1.59	1.28	1.29	1.32	1.32	0.74	1.35	0.78
میانگین خطا			8.75	5.12	5.70	4.17	7.86	0.86	5.08	0.34

و مشاهده عملکرد قابل قبول آن در حل مسائل منتخب، در انتها الگوریتم پیشنهادی را بر روی دو گروه دیگر از مسائل نمونه به نام های *had و *nug امتحان کردیم که نتایج آن در جداول ۳ و ۴ آورده شده است. همانطور که از این جداول نیز مشخص است الگوریتم پیشنهادی در اکثر موارد توانسته بهترین جواب به دست آمده تا کنون را تکرار کند که نشان از قدرت بالای این الگوریتم در حل نمونه های مختلف QAP دارد.

جدول ۳- نتایج اجرای الگوریتم پیشنهادی روی برخی مسائل گروه *had

نام مساله	BKS	بهترین جواب	میانگین جواب	درصد خطای بهترین	درصد خطای میانگین	درصد انحراف معیار
Had12	1652	1652	1654	0	0.12	0.22
Had14	2724	2724	2726	0	0.07	0.07
Had16	3720	3720	3723	0	0.08	0.16
Had18	5358	5358	5396	0	0.70	0.39
Had20	6922	6922	6953	0	0.44	0.25

جدول ۴- نتایج اجرای الگوریتم پیشنهادی روی برخی مسائل گروه *nug

نام مساله	BKS	بهترین جواب	میانگین جواب	درصد خطای بهترین	درصد خطای میانگین	درصد انحراف معیار
Nug12	578	578	583	0	0.86	1.18
Nug15	1150	1150	1194	0	3.82	2.31
Nug16b	1240	1240	1273	0	2.66	1.64
Nug20	2570	2570	2649	0	3.07	1.24
Nug25	3744	3744	3818	0.26	1.97	1.15
Nug30	6124	6124	6279	0.35	2.53	0.85

۵- نتیجه گیری

در این مقاله الگوریتم جستجوی گرانشی ترکیبی برای حل مسائل QAP پیشنهاد شد که در آن از عملگرهای جهش و تقاطع الگوریتم ژنتیک جهت جلوگیری از به دام افتادن الگوریتم GSA در بهینه محلی استفاده شده است. همچنین تاثیر تعداد عامل ها و تعداد تکرارها در دقت الگوریتم، مورد بررسی قرار گرفت و پس از تعیین پارامترهای مناسب، آزمایش های متعددی بر روی مسائل منتخب در QAPLIB صورت گرفت. نتایج حاصل شده حاکی از آن است که الگوریتم پیشنهادی در حل اکثر

جدول ۲- مقایسه نتایج اجرای الگوریتم پیشنهادی با الگوریتم خفاش

نام مساله	BKS	میانگین جواب BAT	میانگین جواب GSA-GA	بهترین جواب BAT	بهترین جواب GSA-GA	انحراف جواب BAT	انحراف جواب GSA-GA	درصد خطا جواب BAT	درصد خطا جواب GSA-GA
Bur26a	5426670	5530825	5446500	5519108	5435688	104155	8962	1.90	**0.36**
Bur26b	3817852	3898402	3832900	3895507	3817852	80550	7274	2.10	**0.39**
Bur26c	5426795	5523970	5434400	5520289	5426801	97175	5783	1.79	**0.14**
Bur26d	3821225	3887216	3831400	3879814	3821667	65991	1040	1.72	**0.26**
Bur26e	5386879	5500460	5402400	5491088	5387539	113581	16179	2.10	**0.28**
Bur26f	3782044	3850692	3799100	3830614	3782680	68648	12869	1.80	**0.45**
Bur26g	10117172	10328699	10145000	10320120	10118177	211527	28666	2.09	**0.27**
Bur26h	7098658	7267393	7126400	7251046	7098905	168735	27162	2.37	**0.39**
Esc32e	2	2	2	2	2	0	0	0	**0**
Es32g	6	6	6	6	6	0	0	0	**0**
Esc16a	68	68	68.8	68	68	0	1.03	0	1.17
Esc16b	292	292	292	292	292	0	0	0	**0**
Esc16c	160	160	161.4	160	160	0	1.64	0	0.87
Esc16d	16	16	16	16	16	0	0	0	**0**
Esc16e	28	28	28.6	28	28	0	1.26	0	2.1
Esc16f	0	0	0	0	0	0	0	0	**0**
Lipa20a	3683	3824	3779	3821	3756	141	14.23	3.8	**2.6**
Lipa30a	13178	13618	13437	13614	13414	440	104.2	3.3	**1.96**

مسائل منتخب قادر به یافتن بهترین جواب به دست آمده تا کنون بود و در مقایسه با سایر الگوریتم های فراابتکاری مثل MBO و BAT از دقت بالاتر (خطای کمتری) برخوردار است.

در الگوریتم GSA مقادیر K و α فاکتور های مهمی در تنظیم دو خاصیت بهره برداری و اکتشاف می باشند که تنظیم مناسب این پارامترها می تواند عملکرد آن را بهبود بخشد لذا می توان در پژوهش های آتی این پارامتر ها را به وسیله کنترلرهای منطق فازی کنترل نمود تا به این وسیله عملکرد الگوریتم GSA را بهبود داد.

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۱ Quadratic Assignment Problem (QAP)
۲ Gravitational Search Algorithm (GSA)
۳ Genetic Algorithm (GA)
۴ Combinatorial Optimization (CO)
۵ Greedy Randomized Adaptive Search Procedure (GRASP)
۶ Ant Colony Optimization
۷ Simulated Annealling (SA)
۸ Migrating Birds Optimization (MBO)
۹ Modified Bat Algorithm
۱۰ Random-key encoding
۱۱ Exploitation
۱۲ Exploration
۱۳ Best Known Solution (BKS)
۱۴ Differential Evolution (DE)
۱۵ Particle Swarm Optimization (PSO)
۱۶ Scatter Search (SS)

ارائه مدل جدیدی برای خوشه بندی مشتریان براساس ارزش طول عمر مشتری با استفاده از تلفیق مدل های ریسک و مدل های RFM (مطالعه موردی شرکت بیمه البرز)

مستوره معینی[1]، ساسان حسینعلی زاده[1]
[1]دانشگاه آزاد اسلامی، واحدقزوین دانشکده برق،رایانه و فناوری اطلاعات

چکیده - یکی از چالش های مهم در حوزه مدیریت ارتباط با مشتری در سازمان ها شناخت مشتری و درک تفاوت و رتبه بندی و تخصیص بهینه منابع به آنها با توجه به ارزشی که برای شرکت می باشد. رویکرد استفاده شده در این پژوهش، ارائه مدلی برای خوشه بندی مشتریان بیمه خودرو براساس تکنیک مرسوم *RFM* و افزودن متغیرهای سن و جنسیت در طول 5 سال (از سال1388 تا 1392) است . پس از تعیین متغیرها ، با استفاده از الگوریتم های خوشه بندی *K-Means* و *Fuzzy K-Means* مشتریان خوشه بندی شده اند . در این تحقیق به بررسی ریسک مشتریان که ناشی از دریافت خسارت می باشد نیز پرداخته شده است . برای هر یک از این رویکردها، تعداد خوشه‌های بهینه با شاخص دیویس- باولدین تعیین شده است. بعد از تفسیر خوشه‌ها و نامگذاری آن‌ها درخت تصمیم مناسب برای مدل ساخته شده و وفاداری مشتریان تحلیل گردیده و الگوهای مناسب استخراج شده است . نهایتا از تلفیق ریسک و تحلیل *RFM* رویکردی جامع استخراج شده که منجر به افزایش دقت درخت تصمیم شده و دقیق ترین مدل این پژوهش را ایجاد می کند .

کلید واژه- خوش بندی ، درخت تصمیم ، ریسک ، RFM، K-Means

1- مقدمه

امروزه از داده های مشتریان به شیوه های مختلف و در جهت اهداف مختلف می توان استفاده کرد . یکی از استفاده هایی که امروزه بسیار مورد توجه سازمان ها قرار گرفته است ، خوشه بندی[1] مشتریان بر اساس داده های آنها می باشد . خوشه بندی معمولا براساس یک ویژگی[2] خاص انجام می شود ، در واقع سازمان ها می توانند با استفاده از داده های موجود و داده کاوی این داده ها به اطلاعات و الگوهای ارزشمندی از آنها دست یابند و در نهایت تصمیم بگیرند که برای بازاریابی و انتخاب مشتریان چه اقدام هایی انجام دهند و یا پیش بینی کنند که یک مشتری جدید با ویژگی های مشخص در کدام خوشه قرار می گیرد.

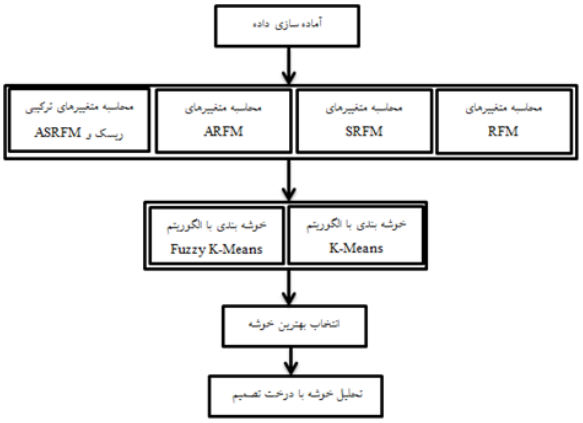
2- مدل پیشنهادی

مدل پیشنهاد شده شامل دو بخش اصلی است بخش بندی مشتریان و تحلیل بخش های تشکیل شده. پس از آماده سازی داده ها و استخراج متغیرهایRFM و متغیرهای جدید A(سن)،S(جنسیت)و متغیرریسک از بانک اطلاعاتی موجود با استفاده از الگوریتم خوشه بندی K-Meansو Fuzzy K-Means مشتریان خوشه بندی شده اند. عملکردخوشه بندی به روش دیویس بولدین[3] با معیار شباهت درون خوشه ای ارائه شده و در نهایت تعداد خوشه بهینه مشخص شده است. در بخش دوم با در نظر گرفتن تحلیل خوشه ها در فضای RFM به کمک درخت تصمیم گیری مشتریان دسته بندی و استراتژی مناسب برای هر بخش تبیین شده است. چارچوب کلی مدل پیشنهاد شده در شکل 1نشان داده شده است.

2-1- مجموعه داده ها و آماده سازی

در این راستا اطلاعات مربوط به بیمه‌های خودرو از شرکت بیمه‌ی البرز از سال 88 تا 92 جمع‌آوری شده است. تعداد داده‌ها برابر 656583 رکورد می‌باشد. متغییرهای موجود در این مجموعه داده در جدول 1خلاصه شده است. از آنجایی که به هر مشتری یک کد بیمه گذار اختصاص داده

می شود ، بنابراین پس از خلاصه سازی داده ها تعداد 205106 مشتری یافت خواهد شد که برای هر یک از آنها اطلاعات مربوط به متوسط تعداد



شکل 1: چارچوب مدل پیشنهاد شده

دفعات خرید خدمات در سال، مبلغ خرید، آخرین خرید انجام شده، جنسیت و سن محاسبه شده است. متغیرهای استفاده شده در تحلیل، ردیف 4 (برای شناسایی مشتری)، 6 (برای شناسایی جنسیت)، 7 (برای محاسبه سن) و در نهایت متغیرهای جدیدی با نام آخرین تاریخ مراجعه و متوسط تعداد دفعات مراجعه که از روی داده‌ها محاسبه شده‌اند می‌باشد.

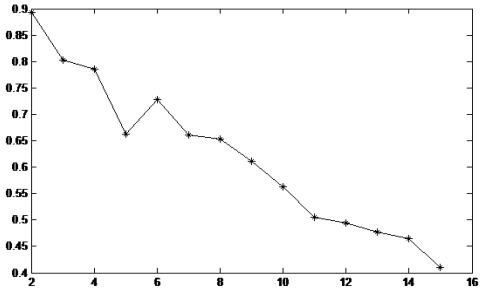
جدول 1 : مشخصات مربوط به مجموعه داده مورد استفاده

ردیف	نام متغیر	توضیحات
1	کد رایانه بیمه نامه	به هر بیمه نامه در حین صدور یک کد رایانه‌ای منحصر بفرد اختصاص داده می‌شود
2	شماره بیمه نامه	شماره‌ای که هرنمایندگی بعنوان شناسه به بیمه‌ی صادر شده ارائه می‌دهد
3	تاریخ شروع و خاتمه	نشان دهنده تاریخ شروع و پایان اعتبار بیمه نامه است
4	بیمه گذار	شماره‌ای که به هر فرد تخصیص داده می‌شود و شناسایی افراد از این طریق امکانپذیر است
5	مدت	طول مدت اعتبار بیمه را نشان می‌دهد که معمولا برابر با 365 روز است
6	جنسیت	جنسیت صاحب بیمه‌نامه
7	سال تولد	سال تولد صاحب بیمه‌نامه
8	سال عدم خسارت	تعداد سال‌هایی است که شخص از حمایت بیمه استفاده ننموده است (عدم استفاده از بیمه)
9	ارزش خودرو	نشان دهنده قیمت خودرو که ارتباط مستقیم با هزینه‌ی بیمه‌ی خودرو دارد
10	شهر	شهر محل اسکان صاحب بیمه‌نامه
11	کد تیپ خودرو	نشان دهنده‌ی تیپ و سیستم خودرو. مثلا 10425 کد خودروی پراید 141 است
12	تیپ خودرو	معادل حروفی کد تیپ خودرو
13	کد مورد استفاده	کاربری خودرو را نشان می‌دهد. مثلا 67 کد استفاده‌ی بارکشی است
14	مورد استفاده	معادل حروفی کد مورد استفاده
15	گروه خودرو	سواری، موتور سیکلت، بارکش و...
16	تعداد سیلندر	-
17	تعداد سرنشین	ظرفیت خودرو
18	رنگ	-
19	سال ساخت	-

2-2- تحلیل RFM[4]

یکی از مدل های مطرح در تحلیل ارزش مشتری[5] مدل RFM است که توسط هوگس[6] در سال 1994 ارائه شده است و به بیان تفاوت مشتریان با استفاده از سه متغیر تازگی، تکرار و ارزش پولی می پردازد[14]. این مدل برپایه رفتار می باشد که به تجزیه و تحلیل رفتار مشتریان می پردازد و پیش بینی رفتار مشتریان را با استفاده از اطلاعات مشتریان که در پایگاه داده مشتریان می باشد میسر می سازد[15].

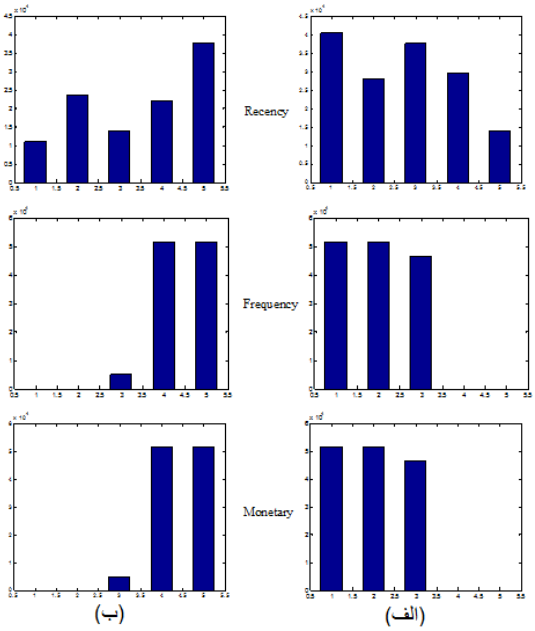
به منظور شروع محاسبات در اولین گام با استفاده از روش دیویس باولدین تعداد بهینه خوشه تعیین شده و سپس با الگوریتم k-means عمل خوشه‌بندی بر روی داده‌های مربوط به RFM انجام شده است[13]. روش دیویس باولدین یک روش اعتبارسنجی در خوشه‌بندی است که با تخصیص یک عدد به هر داده درجه‌ی تعلق آن داده را به خوشه نشان می‌دهد[6]. این شاخص در حالت اصلی خود با تخصیص عدد کمتر به یک خوشه، برتری آن را نشان می-دهد. ولیکن در برخی از منابع با اصلاح جزئی این شاخص و استفاده از منطق معیار شباهت بین خوشه‌ها این شاخص را به صورت هر چه بیشتر بهتر[7]تبدیل می‌کنند. نتایج بدست آمده برای تعداد خوشه‌ها در شکل 2 بصورت گرافیکی نمایش داده شده است.



شکل 2 : نمودار شاخص دیویس باولدین برای تعداد خوشه‌های مختلف

بر اساس نتایج حاصل شده، تعداد بهینه‌ی خوشه‌ها برابر 2 خواهد بود، زیرا حداکثر مقدار شاخص دیویس در همین تعداد خوشه بدست آمده است. بنابراین داده‌های موجود به روش k-means به دو خوشه تقسیم شده و نمودار خوشه‌ها نیز به تفکیک متغیرها در شکل 3 مشخص شده است.

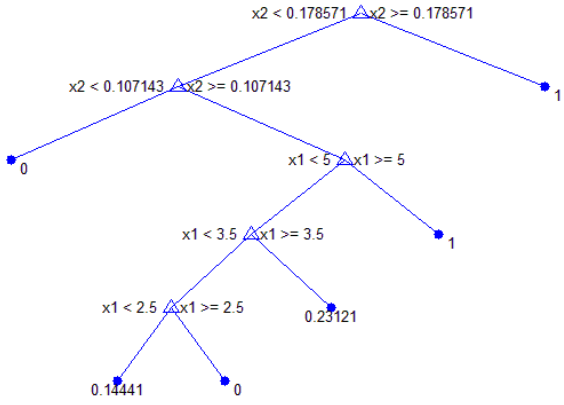
پس از استخراج شاخص‌های مقایسه و بررسی امتیازات کسب شده، می‌توان به وضوح استنباط نمود که خوشه‌ی شماره(2)متعلق به مشتریان وفادار بوده و خوشه‌ی شماره(1) نیز مشتریان با وفاداری کمتر را در بر می‌گیرد.



شکل 3 : هیستوگرام توزیع فراوانی R، F و M در: (الف) خوشه‌ی1 (ب) خوشه‌ی 2

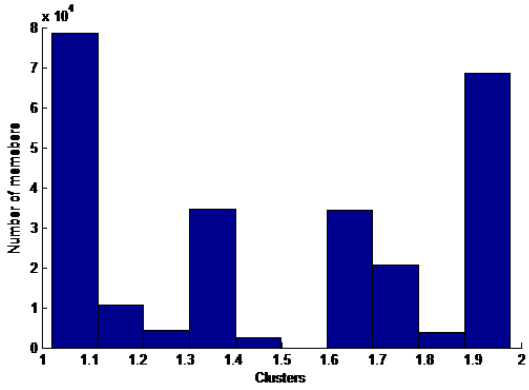
با درنظر گرفتن برچسب 1 برای مشتریان وفادار و برچسب 0 برای مشتریان با وفاداری کمتر، درخت تصمیم[8] مربوط به هر دو خوشه با استفاده از الگوریتم CART[9] مطابق با شکل 4 ظاهر شده است. بر طبق همین منطق می‌توان عمل تعیین مشتریان وفادار را انجام داد. توجه کنید که در این شکل X1 نشان دهنده‌ی متغیر R، X2 نشان دهنده‌ی متغیر F و X3 نیز متعلق به متغیر M است.

پس از ساخت این درخت و استفاده از آن در فاز تست دقت مدل برابر 0/7414 بوده است.



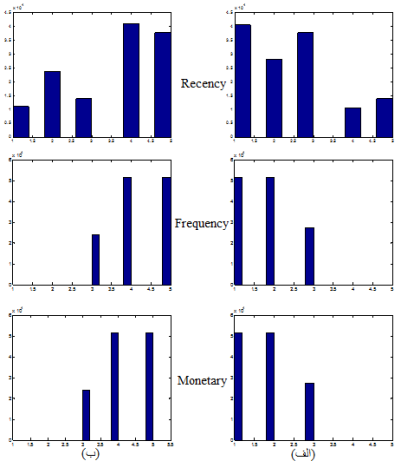
شکل4 : درخت تصمیم و قواعد استخراج شده برای تعیین مشتریان وفادار

در روش k-means فازی هر داده با یک درجه عضویت به یکی از خوشه‌ها تعلق پیدا می‌کند. سپس با تعیین یک مرز تفکیک، اعضای هر خوشه مشخص می‌گردد. به همین منظور خوشه‌بندی فازی انجام شده و نتایج توزیع داده‌ها بر حسب درجه‌ی عضویت آن‌ها بصورت شکل 5 است. قابل مشاهده است که تعداد داده‌هایی با درجه عضویت بالا برای هر یک از خوشه‌های 1 و 2 بیشتر است و لیکن تعدادی از داده‌ها نیز با درجه عضویت‌های کمتر در بین دو خوشه قرار گرفته‌اند.تعمیم نتایج برای خوشه بندی فازی در شکل 6 نشان می دهد که خوشه دوم



شکل5 : توزیع فراوانی داده‌ها بر حسب درجه‌ی عضویت هر داده

متعلق به مشتریان وفادار بوده و خوشه‌ی شماره‌ی 1 نیز در برگیرنده‌ی مشتریانی با وفاداری کمتر است. برای ساخت درخت تصمیم متناظر و تحلیل عملکرد آن 70٪ از داده های هر خوشه به عنوان داد های آموزش و 30٪ مابقی به عنوان داده های تست انتخاب شده اند. در نتایج بدست آمده مقدار حساسیت و شفافیت مدل و همچنین شاخص دقت عملکرد برای مقایسه گزارش شده.

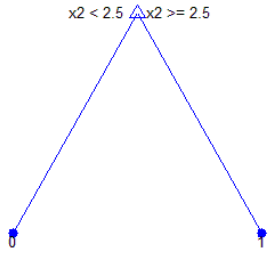


شکل6 : هیستوگرام توزیع فراوانی R، F و M در خوشه‌بندی فازی: (الف) خوشه‌ی 1 (ب) خوشه‌ی 2

نتایج نشان از بیش‌برازش[10] شدن روش مورد تحلیل دارند. به علاوه، ساختار ساده‌ی درخت تصمیم بدست آمده نیز نشان می‌دهد که تعیین وفادار بودن مشتری تنها با استفاده از متغیر F قابل انجام است. به اینصورت که اگر متوسط تعداد دفعات خرید مشتری بیشتر از 2/5 باشد، به عنوان مشتری وفادار در نظر گرفته خواهد شد.

جدول 2: نتایج بدست آمده برای درخت تصمیم حاصل شده از خوشه-بندی فازی

شاخص	فاز آموزش	فاز تست
دقت	٪100	64/39٪
حساسیت	٪100	٪100
شفافیت	٪100	58/07٪
AUC	٪100	64/87٪

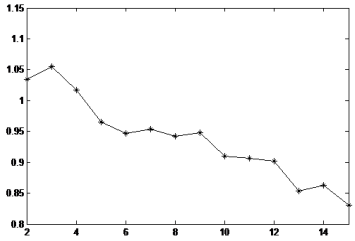


شکل7 : درخت تصمیم و قواعد استخراج شده برای خوشه‌بندی فازی در تحلیل RFM

3-2- تحلیل SRFM

ایده‌ی پایه برای توسعه‌ی این رویکرد(SRFM) استفاده از جنسیت در تحلیل وفاداری مشتریان است. بدلیل مشخص نبودن امتیاز جنسیت نمی‌توان از پیش استدلال نمود که امتیاز مربوط به کدام جنس (مذکر یا مونث) بیشتر است. به همین دلیل یکی از حالت‌ها در نظر گرفته شده و امتیاز 5 به مشتریان مذکر و امتیاز 1 به مشتریان مونث تخصیص داده می‌شود و تحلیل SRFM بر روی آن‌ها صورت می-پذیرد.

در شکل 8 شاخص دیویس نشان می‌دهد که تعداد خوشه-های بهینه برابر 3 می‌باشد.



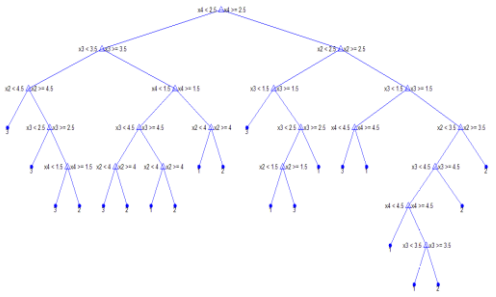
شکل 8 : شاخص دیویس باولدین در تحلیل RFM با تعداد خوشه‌های مختلف

جدول3 نیز برای تعیین اینکه هر خوشه به چه ترتیبی در برگیرنده مشتریان وفادار است می‌تواند مورد استفاده قرار بگیرد.

جدول 3 : مقایسه‌ی خوشه‌های SRFM در امتیازات کسب شده

شاخص	خوشه‌ی 1		خوشه‌ی 2		خوشه‌ی 3	
	مجموع	میانگین	مجموع	میانگین	مجموع	میانگین
امتیاز کسب شده در کل متغیرها	756500	3/31	1479760	4/21	1160774	2/57
امتیاز کسب شده در متغیر S	238576	4/17	359282	4/09	476220	4/21
امتیاز کسب شده در متغیر R	104404	1/82	379935	4/32	289977	2/56
امتیاز کسب شده در متغیر F	201161	3/52	374182	4/26	198977	1/76
امتیاز کسب شده در متغیر M	212359	3/71	366361	4/17	195600	1/73

بر طبق اطلاعات موجود در همین جدول و با توجه به امتیازات کسب شده در خوشه‌ها، می‌توان استدلال نمود که خوشه‌ی دوم مربوط به مشتریان وفادار، خوشه‌ی سوم مربوط به مشتریانی با وفاداری متوسط و خوشه‌ی یکم نیز مختص مشتریان با وفاداری کم است. درخت تصمیم حاصل شده برای 3 خوشه‌ی بدست آمده بصورت شکل 9 است.



شکل 9- درخت تصمیم در خوشه‌بندی با متغیرهای S، R، F و M

در مرحله تحلیل SRFM فازی نتایج به صورت زیر است که نشان از بیش برازش شدن مدل دارد.

جدول 4 : نتایج بدست آمده برای درخت تصمیم حاصل شده از خوشه-بندی فازی برای تحلیل SRFM

شاخص	فاز آموزش	فاز تست
دقت	0/6175	0/9642

2-4- تحلیل ARFM

دراین رویکرد(ARFM)، متغیری با نام سن مشتریان در تحلیل RFM در نظر گرفته می‌شود. بصورت منطقی، متغیر سن ممکن است بر روی وفاداری مشتری اثرگذار باشد و در صورت صحت این مطلب وجود آن در بین متغیرهای موثر در وفاداری مشتری دقت مدل پیشگو را افزایش خواهد داد. با هدف کد گذاری و تخصیص امتیاز به متغیر سن در ابتدا همبستگی بین دو به دوی متغیرها اندازه گیری شده است (به جدول5 توجه کنید. این مقادیر ضریب همبستگی پیرسون نام داشته و برای دو متغیر X و Y از رابطه‌ی 1 محاسبه می‌شود:

$$\rho_{X,Y} = \frac{\sum_{i=1}^{n}(x_i-\bar{X})(y_i-\bar{Y})}{\sum_{i=1}^{n}(x_i-\bar{X})^2 \sum_{i=1}^{n}(y_i-\bar{Y})^2} \qquad 1$$

مقادیر بدست آمده نشان از همبستگی مثبت بین هر سه متغیر دارد، بدین معنی که افزایش سن منجر به افزایش دفعات مراجعه، مبلغ خرید شده و همچنین موجب بهبود در وضعیت آخرین تاریخ خرید نیز می‌شود. به عبارت دیگر بسیار منطقی است که استدلال کنیم افراد مسن بصورت متوسط دارای وفاداری بالاتری هستند.

جدول 5 :ضریب همبستگی متغیر سن با سایر متغیرها

	A	R	F	M
A	1	-0/04	-0/1348	-0/0642

تعداد خوشه‌های بهینه برای این حالت برابر 3 بوده و کلیه‌ی محاسبات ناشی از آن بصورت خلاصه در جدول 9 نشان داده شده است.

جدول 6 : نتایج تحلیل ARFM : (الف) خوشه‌بندی غیرفازی (ب) خوشه بندی فازی

شاخص	فاز آموزش	فاز تست
دقت	0/6469	0/0912

(الف)

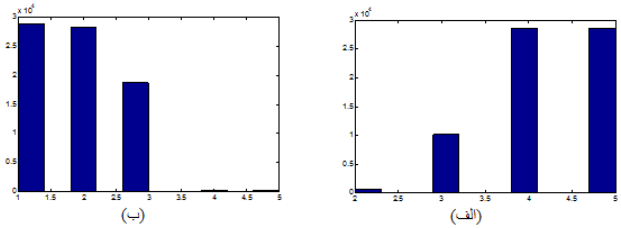
شاخص	فاز آموزش
دقت	0/0839

(ب)

نتایج نشان از بیش برازش شدن مدل دارند. چنین مدل-هایی در عمل کفایت نخواهند داشت.

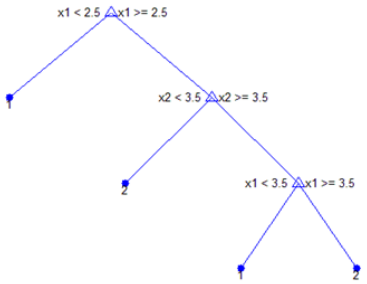
2-5- تحلیل ریسک ناشی از خسارت

این بخش مشتریان با ریسک کمتر را به عنوان مشتری وفادار در نظر می‌گیرد. به عبارت بهتر، مشتری وفادار خدمت گیرنده‌ای در نظر گرفته می‌شود که تعداد دفعات استفاده‌ی او از بیمه کمتر باشد[9]. به همین منظور، از متغیرهای R، F و M استفاده نخواهد شد و تنها متغیر مورد استفاده مقدار خسارت تحمیل شده در طول مدت گرفتن خدمت (معمولا در طول یکسال) می‌باشد[10]. تحلیل RFM با توسعه‌های معرفی شده (متغیرهای سن و جنسیت)، ترکیب شده و تحلیل جامع‌تری بر روی داده‌ها صورت خواهد پذیرفت. برای تحلیل وفاداری با استفاده از ریسک مشتریان تعداد خوشه‌های بهینه برابر 2 خوشه محاسبه شده و هیستوگرام بدست آمده نشان می‌دهد که خوشه‌ی اول متعلق به مشتریان کم خسارت و خوشه‌ی دوم نیز متعلق به مشتریان پرخسارت است.



شکل 10: نتایج تحلیل ریسک : (الف) خوشه‌ی 1 (ب) خوشه‌ی 2

درخت تصمیم متناظر این مدل و دقت آن در شکل 10 بیش‌برازش شدن آن را نشان می‌دهد.



شاخص	فاز آموزش	فاز تست
دقت	1	0/5045

شکل 11- درخت تصمیم و دقت دسته‌بندی در تحلیل ریسک

بیش برازش مدل هنگامی حادث می‌شود که تعداد متغیرها برای داده‌های آموزش مناسب بوده ولیکن ساختار داده‌های تست به گونه‌ای است که از فقدان تعدادی متغیر که در تحلیل مد نظر نبوده‌اند رنج می‌برد. بر اساس یک نتیجه-گیری منطقی، می‌توان استدلال نمود مدل ترکیبی ریسک و RFM دارای عملکرد بهتری خواهد بود.

تحلیل نتایج حاصل از ریسک با خوشه‌بندی فازی در جدول 7 اعلام شده.

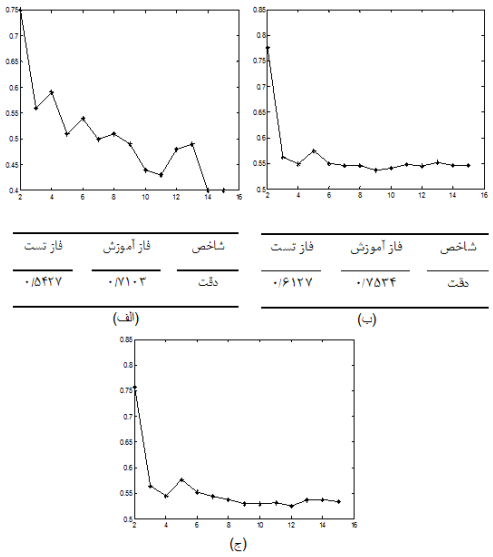
جدول 7 : تحلیل ریسک با خوشه‌بندی فازی

شاخص	فاز آموزش	فاز تست
دقت	٪95/87	٪44/39
حساسیت	٪92/14	٪36/23
شفافیت	٪100	٪50/59
AUC	٪94/29	٪54/37

6-2- تحلیل RFM با در نظر گرفتن ریسک

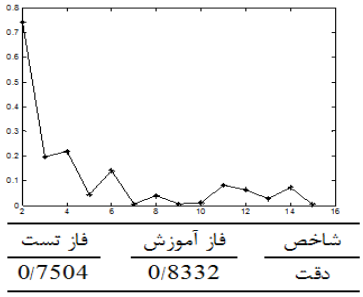
بطور کلی، افزایش متغیرها در تحلیل RFM (متغیرهای سن و جنسیت) و یا ترکیب آن با سایر رویکردها (مثل تحلیل ریسک) دقت خوشه‌بندی و تحلیل وفاداری مشتریان را کاهش نمی‌دهد. ولیکن ممکن است منجر به افزایش پیچیدگی مدل شود[13]. از همین رو اگر افزایش دقت مقدار قابل توجهی نباشد، تحلیل‌های ساده‌تر ارجحیت خواهند داشت. اما اگر مقدار بهبود قابل توجهی ایجاد گردد در این صورت استفاده از مدل ترکیبی نتایج بهتری را ایجاد خواهند نمود. بدلیل بیش برازش شدن روش فازی و همچنین وجود ابهام در تحلیل نتایج آن، در این قسمت کلیه‌ی محاسبات بصورت قطعی انجام شده است.

در هر مورد، تعداد خوشه‌های بهینه مورد استفاده بوده است و مطابق استدلال پیشین، نتایج گزارش شده اثری از بیش برازش را نشان نمی‌دهند.



شکل 12: تحلیل ترکیبی ریسک با: (الف) RFM (ب) ARFM (ج) SRFM

به عنوان آخرین نتیجه‌ی محاسباتی کلیه متغیرهای سن، جنسیت و متغیرهای موجود در RFM و همچنین ریسک هر مشتری را ترکیب نموده و تحلیل را بر اساس آنها صورت می دهیم و در نهایت از بین کلیه‌ی مطالعات انجام شده بهترین مدل را برای تحلیل درخت تصمیم انتخاب می کنیم.

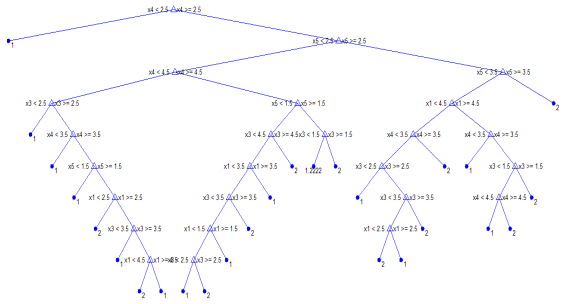


شکل 13 : خوشه بندی ترکیب ریسک و ASRFM

واضح است که دقت مدل مذکور بالاتر از سایر تحلیل‌ها بوده و بنابراین درخت تصمیم حاصل از آن بهترین مدل برای کشف الگو و آنالیز رفتار مشتری خواهد بود. به همین علت درخت تصمیم حاصل شده از تحلیل ترکیبی ریسک و ASRFM بطور دقیقتری مورد بررسی قرار خواهد گرفت. از این بررسی می‌توان الگوهایی را در تعیین وفاداری مشتریان کشف نمود.

7-2- کشف الگو

در ابتدا خاطر نشان می‌گردد که پس از بررسی کلیه‌ی رویکردهای مطرح شده در پیشنهادیه، برترین مدل بدست آمده انتخاب شده و سپس با استفاده از تحلیل درخت تصمیم حاصل از آن، الگوهایی برای تعیین وفاداری مشتریان تعیین می‌گردد. همانطور که شکل 13 نشان می-دهد، تعداد بهینه‌ی خوشه‌ها برابر 2 می‌باشد که پس از بررسی آنها برای خوشه‌ها نام‌های خوشه‌ی مشتریان وفادار و مشتریان با وفاداری کم شناخته می‌شوند. برخی از الگوهای بدست آمده از ساختار درخت تصمیم ترکیبی ریسک و ASRFM به شرح زیر است:



شکل14 :درخت تصمیم ترکیبی ریسک و ASRFM

اگر متوسط تعداد دفعات مراجعه‌ی مشتری در سال کمتر از 2/5 باشد، وفاداری مشتری پایین است.

وفاداری مشتری مستقل از جنسیت اوست (زیرا در درخت تصمیم متغیر جنسیت وجود ندارد).

بطور متوسط، مشتریان جوان از مشتریان مسن وفادارترند.

متغیر M بیشترین تأثیر را در تعیین وفاداری مشتری دارد.

پس از آن متغیرهای F، R و سن قرار دارند.

مشتریانی که بیش از 2/5 از آخرین مراجعه‌ی آنها می‌گذرد در صورت مسن بودن وفاداری ندارند. ولی در صورت جوان بودن اگر آخرین مبلغ پرداختی آنها بیش از 2 500 000 میلیون باشد وفادارند.

3- نتیجه‌گیری

رویکرد استفاده شده در این پژوهش، استفاده از روش RFM و همچنین افزودن متغیرهای سن و جنسیت به آن در نظر گرفته شد. این رویکردها با نام ARFM (با افزودن متغیر سن) و SRFM (با افزودن متغیر جنسیت) معرفی گردیدند و سپس از رویکردهای قطعی و فازی برای آن استفاده شد. بطور کلی نتایج بدست آمده نشان از بیش برازش مدل‌های فازی داشته‌اند و در کنار آنها نتایج قطعی نشان از کمتر بودن بیش برازش و مناسب‌تر بودن برای استفاده در تحلیل درخت تصمیم می‌باشند. برای هر یک از این رویکردها، تعداد خوشه‌های بهینه با شاخص دیویس-باولدین تعیین گردیده و نتایج بدست آمده خوشه‌بندی شدند. سپس بعد از تفسیر خوشه‌ها و نامگذاری آن‌ها درخت تصمیم مناسب برای مدل ساخته شده تا با استفاده از آن وفاداری مشتریان تحلیل گردیده و الگوهای مناسب استخراج شوند. از بین رویکردهای مورد آزمایش و این منطق که افزایش متغیرها منجر به بهبود عملکرد مدل خواهند شد، رویکرد در نظر گرفتن ریسک نیز به مدل افزوده شده و نهایتا از تلفیق ریسک و تحلیل RFM رویکردی جامع استخراج گردید که منجر به افزایش دقت درخت تصمیم شده و دقیقترین مدل این پژوهش را ایجاد نمود.

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[1] Clustering
[2] Attribute
[3] Davies-Bouldin
[4] Recency,Frequency,Monetary
[5] Customer Value Analysis
[6] Hughes
[7] Higher is better
[8] Decision Tree
[9] Classification and regression trees (CART)
[10] Over-fitting

انتخاب ویژگی مبتنی بر الگوریتم ژنتیک چندهدفه برای ماشین بردار پشتیبان

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چکیده –روش‌های گوناگونی برای انتخاب ویژگی پیشنهاد شده‌اند تا یک زیرمجموعه مناسب از ویژگی‌ها در بین مجموعه داده‌های اولیه به دست آید. این روش‌ها بر اساس جستجو در فضای ویژگی‌ها مبتنی بر یک معیار یا همان تابع هدف استوار هستند. این توابع هدف به دو دسته کلی فیلتر و پوشاننده تقسیم می‌شوند. در روش‌های فیلتر زیر مجموعه ویژگی‌ها بر اساس معیارهایی نظیر فاصله درون و میان کلاسی و همبستگی ویژگی‌ها که فقط وابسته به داده‌ها هستند انتخاب می‌شوند. در حالی‌که در روش‌های پوشاننده از یک دسته بند برای ارزیابی مجموعه ویژگی‌ها استفاده می‌شود که از طریق سنجش دقت دسته بند انتخاب ویژگی انجام می‌شود در روش‌های فیلتر معمولا یک معیار را به تنهایی برای انتخاب ویژگی در نظر می‌گیرند که لزوما بهترین نتیجه را حاصل نمی‌کند. دراین مقاله، پیشنهاد می‌شودکه ضمن در نظر گرفتن معیارهای روش‌های فیلتر، معیار خطای دسته بندی هم در انتخاب ویژگی در نظر گرفته شود که به این منظور ماشین بردار پشتیبان برای دسته بندی استفاده شده است. در راستای این هدف، از روش تکاملی چندهدفه و به طورخاص از الگوریتم ژنتیک برای انتخاب ویژگی چند هدفه استفاده شده است. به این منظورمعیارهای اطلاعات متقابل و لاپلاسین که به ترتیب بیانگر، محتویات اطلاعاتی ویژگی‌ها وقدرت حفظ ساختارویژگی‌هاهستند، درنظرگرفته شده اند و ترکیب آن‌ها با معیار خطای دسته بندی ماشین بردار پشتیبان، به عنوان اهداف توام انتخاب ویژگی درتابع برازندگی الگوریتم تکاملی پیشنهاد شده‌اند. نتایج برروی برخی مجموعه داده‌های منتخب از *UCI* کارایی این روش را نشان می‌دهد.

کلید واژه- انتخاب ویژگی، الگوریتم ژنتیک چند هدفه، ماشین بردار پشتیبان.

۱- مقدمه

دسته بندی به نسبت دادن یک داده به یک دسته یا دسته خاص گفته می‌شود. در ابتدا ما به یک سیستم دسته بندی کننده که بتواند بر پایه ای به داده های ورودی، دسته وابسته را مربوط کند احتیاج داریم. مورد دیگر در اینجا اطلاعات استخراج شده از داده-هاست که معیار سیستم دسته‌بندی کننده قرار خواهدگرفت. این اطلاعات که ما آن‌ها را ویژگی می‌نامیم می‌توانند هر تعداد باشند. بنابراین برای هر داده یک بردار ویژگی تعیین می‌شود. برای سهولت، الگوها توسط یک بردار نشان داده می‌شوند.

احتمال دارد ویژگی‌های زیادی بشناسیم که شاید تاثیر آن‌ها در دسته بندی زیاد باشد، بنابراین مراحل انتخاب ویژگی‌ها و پردازش بر روی آن‌ها برای پیدا کردن دسته‌های وابسته سخت‌تر خواهد شد. علاوه بر این ممکن است که بعضی از این ویژگی‌های مورد کاربرد، اثر زیادی بر بهبود دسته بندی نداشته باشند. با ملاحظه موارد یاد شده برای بهینه ساختن عملکرد و سرعت انتخاب، پردازش و طبقه بندی ویژگی‌ها، نیاز به کاهش بعد ویژگی‌ها داریم.

شیوه‌های مختلفی برای کاهش ویژگی موجود است که می‌توان از آن‌ها استفاده نمود. با این هدف ویژگی‌هایی را انتخاب و برمی-گزینیم که تمایز افضل را مهیا سازند[۱]. در انتخاب ویژگی دو رویکرد وجود دارد: اول رویکرد فیلترینگ که بر مبنای مرتب سازی ویژگی‌ها بر مبنای اهمیتشان می‌باشد که اهمیت هر ویژگی بر مبنای توابع ارزیابی یا سنجش مختلف تعریف می‌شود و روش دوم پوشاننده که بر مبنای دقت طبقه بندی، بهینه ترین زیرمجموعه از ویژگی‌ها را انتخاب خواهند کرد[۲].

ماشین بردار پشتیبان دسته‌بندی کننده‌ی متمایز ساز قدرتمندی از روش‌های باناظر است، که برای دسته بندی و رگرسیون از آن استفاده شده است. رویکردهای مختلفی با استفاده از ماشین بردار پشتیبان برای انتخاب ویژگی مطرح گشت که نشان داد روش‌هایی با رویکرد ترکیبی قویتر و موثرتر در یافتن زیر مجموعه‌ی بهینه و امیدوار کننده‌تر در زمینه‌ی داده کاوی هستند. روش‌های مختلفی برای بالا بردن کیفیت انتخاب ویژگی ارائه گشته اند که باعث کاهش فضای جستجو و زمان محاسبات شده است. برخی روش-های انتخاب ویژگی بدون وابستگی به ماشین بردار پشتیبان هستند یعنی ویژگی‌های مهم را انتخاب می‌کنند و سپس از

ماشین بردار پشتیبان برای طبقه بندی استفاده می‌شود. مطالعات نشان دادند که ماشین بردار پشتیبان به طور مستقیم نمی‌تواند اهمیت یک ویژگی را برای ما استخراج کند، با بررسی روش‌های مختلف انتخاب ویژگی با ماشین بردار پشتیبان معلوم شد که روش‌های کلی انتخاب ویژگی از ماشین بردار پشتیبان مستقل هستند و ماشین بردار پشتیبان می‌تواند از عهده‌ی مجموعه‌ای بزرگ از ویژگی‌ها برآید[۳]. همچنین اخیرا روش‌های فیلتر و پنهان ساز توسعه داده شده‌اند و انتخاب ویژگی نیز به عنوان مسئله‌ی چند هدفه مورد توجه قرار گرفته است[۴].

تجربه نشان داده که اگر از ماشین بردار پشتیبان در مرحله‌ی پیش پردازش داده‌ها استفاده کنیم زمان آموزش و فضا کاهش میابد و ماشین بردار پشتیبان به یک عملکرد طبقه‌بندی قابل مقایسه‌ای با داده‌های خام می‌رسد[۵]. روش‌های قدیمی برای انتخاب ویژگی معمولا ویژگی‌ها را استخراج و پارامترهای ماشین بردار پشتیبان را به طور مستقل یاد می‌گیرند که اجرای به صورت مستقل این دو مرحله ممکن است موجب از دست رفتن اطلاعات مورد نیاز برای مرحله‌ی طبقه‌بندی گردد. در روش‌های جدیدتر عملکرد انتخاب ویژگی و یادگیری پارامترهای ماشین بردار پشتیبان به اشتراک گذاشته می‌شود که باعث کاهش قابل توجهی از ویژگی‌های مورد استفاده می‌گردد در حالیکه عملکرد طبقه‌بندی کاملا حفظ گردیده است یکی از متدهای موثر ارائه شده از انتخاب ویژگی برای ماشین بردار پشتیبان متدیست که بر خلاف روش‌های جستجوی ترکیبی قبلی، انتخاب ویژگی به یک انتخاب مدل از ماشین بردار پشتیبان تبدیل شده است[۶].

در برخی دیگر از روش‌های انتخاب ویژگی از الگوریتم‌های تکاملی و از ماشین بردار پشتیبان به عنوان تابع برازندگی این الگوریتم-های تکاملی استفاده شد، که نتایج نشان داد این روش‌ها منجر به افزایش کارایی، ساده شدن، افزایش دقت طبقه‌بندی و کاهش منابع محاسباتی مورد نیاز شده است [۷]. گاهی تابع برازش را یک ترکیب خطی از دقت بازشناسی و تعداد اعضای زیرمجموعه ویژگی انتخاب شده در نظر می‌گیرند، در برخی از روش‌ها از الگوریتم‌های فرا ابتکاری و از مرزهای موجود در خطای تعمیم برای ماشین بردار پشتیبان استفاده نموده اند [۸].

در مقاله حاضر، هدف ارائه‌ی یک روش چند هدفه‌ی انتخاب ویژگی است. که در کنار معیارهایی نظیر لاپلاسین و اطلاعات متقابل، خطای ماشین بردار پشتیبان را نیز در نظر بگیرد. برای این منظور از الگوریتم ژنتیک چند هدفه استفاده شده است و این معیارها برای تعیین تابع برازندگی آن بکار گرفته شده اند.

در ادامه‌ی این مقاله در بخش دوم به معرفی معیارهای مورد استفاده و کاربردهای آن در انتخاب ویژگی پرداختیم، سپس در بخش سوم روش پیشنهادی را با استفاده از الگوریتم ژنتیک چندهدفه شرح می‌دهد. بخش چهارم حاوی آزمایش‌ها و نتایج است بخش پنجم نیز نتیجه گیری می‌باشد.

۲- معیارهای مورد استفاده و کاربردآن‌ها در انتخاب ویژگی

در روش‌های فیلتر، از هیچ تابع دسته بندی استفاده نمی‌شود. به عبارت دیگر از هیچ فیدبکی از الگوریتم یادگیری اعمال شده استفاده نخواهد شد. این یک روش از پیش انتخاب شده‌ای است که مستقل از الگوریتم یادگیری ماشین اعمال شده می‌باشد و زیر مجموعه‌های ویژگی به وسیله مفاهیم دیگری ارزیابی می‌شوند. روش فیلتر به صورت زیر کار می‌کند:

در مرحله اول، برای هر ویژگی یک رتبه اعتبار محاسبه می‌شود. سپس این رتبه‌ها مرتب شده و ویژگی‌هایی با کمترین رتبه حذف می‌شود (از یک آستانه برای رتبه‌های ویژگی استفاده می‌شود) سپس نتایج زیر مجموعه‌ای از ویژگی‌ها به عنوان ورودی به یک سیستم دسته بند داده می‌شود. در ادامه دو روش فیلتر به کارگرفته شده در این مقاله را شرح می‌دهیم.

۲-۱- اطلاعات متقابل

اطلاعات مشترک بین دو متغیر تصادفی، اطلاعات متقابل تعریف می‌شود. متغیر تصادفی X مفروض چقدر می‌تواند در مورد Y اطلاعات به دست آورد، که اطلاعات متقابل $I(X,Y)$ است :

$$I(X,Y) = H(X) - H(X|Y) = \\ -\sum_{x\in X, y\in Y} P(x,y)\log_2 \frac{P(x,y)}{p(x)P(y)} \qquad (۱)$$

بر طبق فرمول اگر دو متغیر Y وX به هم وابستگی نزدیکی داشته باشند، اطلاعات متقابل I(X,Y)، خیلی زیاد خواهد شد. در غیر اینصورت، اگرX وY کاملاً غیرمرتبط باشند0=I(X,Y) ، خواهد بود. و P(x,y) تابع چگالی احتمال دو متغیر xوy است. تئوری اطلاعات، به طورکلی اطلاعات متقابل، برای اندازه‌گیری ارتباط بین ویژگی‌های انتخاب شده و برچسب کلاس در انتخاب ویژگی فیلتر به کار می‌رود[۹]. حداکثرسازی اطلاعات میان کلاس و ویژگی و حذف ویژگی‌های زائد هدف اصلی به کارگیری معیار اطلاعات متقابل می‌باشد.

۲-۲- لاپلاسین

این معیار به دنبال یافتن یک بیان بعد پایین توسط حفظ خواص محلی کمینه است. در این صورت سعی در کمینه کردن فاصله میان نقاط در فضای با بعد پایین، با در نظرگرفتن فاصله‌ی آن نقاط درفضای با بعد بالا داریم. نگاشت داده‌های ورودی X در یک فضایd بعدی هدف این روش می‌باشد، این نگاشت به صورتی است که ارتباط‌ها به شکل محلی و در همسایگی‌های نزدیک حفظ می-شود.[۱۰].

این الگوریتم از سه گام زیر تشکیل می‌گردد:

گام اول :ساختن گراف همسایگی با استفاده از روش K همسایگی نزدیک یا همسایگیε

گام دوم :وزن دهی یال‌ها با روش کرنل گرمایی

گام سوم : محاسبه از روی ماتریس لاپلاسین نرمالیزه شده. در این صورت مسئله بهینه سازی به منظور کمینه سازی تابع هزینه زیر خواهد بود:

$$E = \sum_{i,j} (y_i, y_j)^2 W_{i,j} \qquad (۲)$$

که در فرمول بالا $W_{i,j}$ برابر وزن هر یالی که نقطه‌ی iو j را به هم متصل می‌کند است و d بردار ویژه متناظر با d کوچکترین مقادیر ویژه غیر صفر در ماتریس $y_i = (f_1(i), \dots, f_d(i))$ قرار داده شده است و در نهایت نقاط با فاصله کم در بعد بالا به نقاط نزدیکتری در بعد کم نگاشت خواهند یافت.

۳- روش پیشنهادی

چنانچه گفته شد، درروش‌های فیلتر زیرمجموعه ویژگی‌ها براساس معیارهایی نظیرفاصله درون و میان کلاسی و همبستگی ویژگی‌ها که فقط وابسته به داده‌ها هستند، انتخاب می‌شوند. بنابراین، روش-های فیلتر معمولا یک معیار را به تنهایی برای انتخاب ویژگی درنظر می‌گیرند که به خاطر عدم توجه به دسته بند مورد استفاده، و معیار آن بهترین نتیجه را به دست نمی‌آورد. دراین مقاله، پیشنهاد می‌شود که ضمن در نظر گرفتن معیار روش‌های فیلتر، معیارخطای دسته بندی هم درانتخاب ویژگی در نظرگرفته شود. برای دسته بندی، ماشین بردارپشتیبان و برای انتخاب ویژگی، الگوریتم ژنتیک چند هدفه در نظر گرفته شده است. به عنوان معیارهای فیلتر اطلاعات متقابل ومعیار لاپلاسین که به ترتیب بیانگر محتویات اطلاعاتی ویژگی‌ها وقدرت حفظ ساختارویژگی‌ها هستند، درنظرگرفته شده اند و ترکیب آن‌ها بامعیار خطای دسته بندی ماشین بردار پشتیبان، به عنوان اهداف توام انتخاب ویژگی درتابع برازندگی الگوریتم ژنتیک چند هدفه پیشنهاد شده‌اند.

۳-۱- تولید جمعیت اولیه

در قسمت تولید جمعیت اولیه با فرض داشتن d ویژگی در مجموعه داده مربوطه به تعداد npop تا جمعیت اولیه تصادفی بین ۰ و۱ تولید می‌کنیم. قاعدتا هرچقدر این جمعیت تولید شده بیشتر باشد کیفیت الگوریتم بالا می‌رود ولی زمان حل نیز افزایش خواهد یافت. کروموزوم به صورت یک رشته‌ی باینری به طول d است، که عدد ۱به عنوان ویژگی‌های انتخاب شده درنظر گرفته می‌شود.

۳-۲- ارزیابی جمعیت تولید شده

پس از مرحله تولید تصادفی جمعیت، جمعیت اولیه از دید توابع هدف ذکر شده ارزیابی می‌شود.

۳-۳- روش مرتب سازی غیر مغلوب

بعد از ارزیابی جمعیت تولید شده وارد فاز چندهدفه سازی الگوریتم ژنتیک می‌شویم.

اعضای جمعیت در داخل دسته هایی قرار گرفته به گونه ای که اعضای موجود در دسته اول، یک مجموعه کاملاً غیرمغلوب توسط دیگر اعضاء جمعیت فعلی می باشند، به این معنی که جواب‌هایی که هیچ جواب دیگری از آن بهتر نباشد در دسته اول قرار می-گیرند .اعضای موجود در دسته دوم نیز بر همین مبنا تنها توسط اعضای دسته اول مغلوب شده و این روند به همین صورت در دسته‌های دیگر ادامه یافته تا به تمام اعضای موجود در هر دسته، یک رتبه بر مبنای شماره دسته اختصاص داده شود.

۳-۴- محاسبه پارامتر کنترلی به نام فاصله ازدحامی

پس از اینکه مرتب سازی نامغلوب بر اساس رتبه، کامل می‌شود، فاصله ازدحام هریک از اعضای جمعیت با یک مقدار فاصله‌ی ازدحام تخصیص داده می‌شود. فاصله ازدحام بر اساس فاصله اقلیدسی بین فرزندان در یک جبهه به فرزندان هر جبهه تخصیص داده می‌شود. به این ترتیب که، بعد از مرتب شدن ذرات در هر جبهه بر اساس تابع هدف i ام، فاصله ازدحامی ذره نخست و آخر در هر جبهه برابر بی‌نهایت قرار می‌گیرد، این پارامتر برای هر عضو در هر گروه محاسبه می شود و بیان گر اندازه ای از نزدیکی نمونه مورد نظر به دیگر اعضای جمعیت آن دسته و گروه می باشد که بین دو فرزند به صورت زیر محاسبه می‌گردد:

$$d_j(k) = \sum_{i=1}^{n} \frac{f_i(K-1) - f_i(K+1)}{f_i^{\max} - f_i^{\min}} \qquad (۳)$$

که در آن $f_i(k-1)$ ، فاصله‌ی ازدحام تابع هدف i ام از فرزند k ام را نشان می‌دهد.

۳-۵- عملگر انتخاب

این عملگر از بین کروموزوم‌های موجود در یک جمعیت, تعدادی کروموزوم را برای تولید مثل انتخاب می‌کند. کروموزوم‌های برازنده‌تر شانس بیشتری دارند تا برای تولید مثل انتخاب شوند. در اینجا دو والد بر اساس چرخ رولت انتخاب می-گردند.

۳-۶- عملگر آمیزش

عملگر آمیزش بر روی یک زوج کروموزوم از نسل مولد عمل کرده و یک زوج کروموزوم جدید تولید می‌کند. عملگرهای آمیزش متعددی از قبیل, آمیزش تک نقطه‌ای و آمیزش دو نقطه‌ای وجود دارد. در آمیزش تک نقطه‌ای, یک موقعیت تصادفی بین دو ژن در نظر گرفته می‌شود. سپس تمامی ژن‌های طرف راست یا طرف چپ این موقعیت در کروموزوم‌های والد با یکدیگر جابجا می‌شوند تا کروموزوم‌های جدید بدست آیند. در آمیزش دو نقطه‌ای, دو موقعیت به صورت تصادفی انتخاب می‌شود و تمامی ژن‌های بین این دو موقعیت در کروموزوم‌های والد با یکدیگر جابجا می‌شوند. در اینجا از امیزش تک نقطه ای برای تولید فرزند استفاده نموده ایم.

۳-۷- عملگر جهش

پس از اتمام عمل آمیزش, عملگر جهش بر روی کروموزوم‌ها اثر داده می‌شود. و در اینجا با انتخاب تصادفی دو ویژگی در والد و عوض کردن جای این دو ویژگی اینکار را انجام می‌دهیم و فرزندان جدید را تولید می‌نماییم.

۳-۸- بدست آوردن جمعیت جدید

سپس جمعیت بدست آمده در قسمت جهش و آمیزش را به جمعیت قدیم که داشتیم اضافه نموده و دوباره مراحل چند هدفه سازی (مرتب سازی غیر مغلوب و فاصله ازدحامی)را روی جمعیت جدید انجام می‌دهیم. و تعداد جواب نامغلوب که مد نظر است را انتخاب کرده و چون فاصله ازدحامی این جواب‌های نامغلوب نسبت بهم تغییر می‌کند، دوباره عملیات چندهدفه را برای این تعداد انتخابی انجام می‌دهیم.

۳-۹- شرط توقف

این عملیات در الگوریتم ژنتیک چندهدفه تا زمانی که شرط توقف (در اینجا بیشترین تعداد تکرار) برقرار نشده باشد انجام می-شود.

۴- آزمایش‌ها و نتایج

برای تست کارائی روش ارائه شده، این الگوریتم در محیط متلب پیاده سازی شد، برای پیاده سازی SVM از تولباکس متلب استفاده گردید و روش ارائه شده روی تعدادی مجموعه داده تست گردید. اطلاعات مربوط به این مجموعه داده‌ها در جدول۱ آمده است.

جدول ۱: مجموعه داده‌های مورد استفاده

نام مجموعه داده	تعداد کلاس ها	تعداد نمونه‌ها	تعداد ویژگی‌ها
wine	۳	۱۷۸	۱۳
Ionosphere	۲	۳۵۱	۳۴
Lung-cancer	۳	۳۲	۵۶
glass	۶	۲۱۴	۹

تنظیمات به ترتیب زیر رعایت شده‌اند:

اندازه‌ی جمعیت ۵۰، نرخ crossover ۰.۹، نرخ mutation ۰.۱ و شرط پایان نیز زمانی که تعداد دفعات تکرار به ۱۰۰ رسید می-باشد.

از SVM به صورت خطی و کرنل دار برای ارزیابی روش پیشنهادی استفاده شد. برای ارزیابی روش ۶۰٪ داده‌ها از هر دادگان به عنوان داده‌های آموزشی و ۴۰٪ به عنوان داده های تست در نظر گرفته شده است. نتایج برای متوسط ۵ جواب برتر الگوریتم ژنتیک چندهدفه ارائه گردیده است.

نتایج بدست آمده توسط آزمایشات ما با روش انتخاب ویژگی تک هدفه مبتنی بر الگوریتم ژنتیک مقایسه گردید. جدول ۳ برای نمایش و مقایسه‌ی روش‌های تک هدفه هدفه‌ی موجود با روش دوهدفه‌ی پیشنهادی تنظیم شده است و در جدول ۲ نام اختصاری روش‌ها و شرح آن‌ها را آورده ایم.

جدول ۲: نام اختصاری روش‌ها و شرح آن‌ها

شرح روش	نام اختصاری روش‌ها
روش مبتنی بر الگوریتم ژنتیک و معیار خطای دسته بندی SVM	GA-E
روش مبتنی بر الگوریتم ژنتیک و معیاراطلاعات متقابل	GA-MI
روش مبتنی بر الگوریتم ژنتیک و معیار لاپلاسین	GA-LAP
روش مبتنی بر الگوریتم ژنتیک چند هدفه و ترکیب دو معیار خطای دسته بندی SVMواطلاعات متقابل	MOGA-EMI
روش مبتنی بر الگوریتم ژنتیک چند هدفه و ترکیب دو معیار خطای دسته بندی SVMو لاپلاسین	MOGA-ELAP

۴-۱- مقایسه نتایج

در روش پیشنهادی روشی برای انتخاب ویژگی با استفاده از الگوریتم ژنتیک چند هدفه مطرح گشت به طوری که بتوان معیارهای فیلتر و خطای دسته بندی ماشین بردار پشتیبان را باهم در انتخاب ویژگی در نظر گرفت. با مقایسه نتایج بدست آمده (در جدول ۳) از ترکیب هر معیار فیلتر با خطای دسته بندی ماشین بردار پشتیبان(پوشاننده) و روش‌های تک هدفه ای که قبلا انجام شده بود یافتیم که روش پیشنهادی در اکثر مواقع کارایی بیشتری دارد. همچنین در روش پیشنهادی نتایج مبتنی بر هسته نسبت به حالت خطی در اکثر دادگان نتایج بهتری را داشتند.

در روش‌های تک هدفه روش GA-E عملکرد بهتری نسبت به روش‌های تک هدفه‌ی دیگر دارد، که این نشانگر موثر بودن ترکیب توام این معیار با معیارهای دیگر(اطلاعات متقابل ولاپلاسین) است. بدین ترتیب با مقایسه‌ی نتایج بدست آمده می‌توان گفت که استفاده‌ی توام معیارهای اطلاعات متقابل و لاپلاسین با معیار کمینه کردن خطای دسته بندی SVM به صورت دو هدفه توسط الگوریتم ژنتیک چندهدفه بعضا نتایج بهتری نسبت به روش تک هدفه ارائه داده است. از یک سو، جواب‌های بدست آمده از الگوریتم ژنتیک چندهدفه، باتوجه به دارا بودن تکنیک‌های منحصر به فرد جستجو و بازه‌ای از جواب‌های بهینه با اطمینان بیشتری به عنوان جواب‌های بهینه طرح می‌شود و محدود به پذیرفتن جواب واحد بهینه نیست از سویی دیگر، الگوریتم ژنتیک چند هدفه برگرفته شده از روش‌های تصمیم گیری در دنیای واقعی است که شخص تصمیم گیرنده با مجموعه ای از اهداف و معیارهای متضاد و متعارض روبروست، در واقع استفاده از الگوریتم ژنتیک چندهدفه انعطاف پذیری و مزیت بیشتری را نسبت به الگوریتم ژنتیک تک هدفه فراهم می‌کند که تنها استفاده از یک روش تصمیم گیری در هربار استفاده وجود دارد، از این رو بهینه سازی چندین تابع هدف متفاوت وگاها متضاد در برخی موارد کمی منجر به کاهش دقت دسته بندی شده است. در جدول ۳ جاهایی که نتایج روش پیشنهادی درمقایسه با نتایج تک هدفه (ازدید هر دو تابع هدف به صورت تک تک) بهتر شده است را با ضخیم و زیرخط نشان داده ایم.

متوسط کارایی این دو روش پیشنهاد شده مورد بررسی قرار گرفت واز بین روش های پیشنهادی روش MOGA-ELAP نسبت به روش MOGA-EMI عملکرد بهتری داشته است.

۵- نتیجه‌گیری

در این مقاله یک روش چند هدفه‌ی انتخاب ویژگی مطرح گشت، به صورتی که چند معیار انتخاب ویژگی را باهم در نظر بگیرد و موجب بهبود کارایی ماشین بردار پشتیبان گردد. برای اینکار از الگوریتم ژنتیک چندهدفه بهره گرفتیم. ارزیابی بر روی مجموعه دادگان UCI نشان می‌دهد که روش پیشنهادی که دو معیار فیلترینگ(اطلاعات متقابل و لاپلاسین) و پوشاننده(خطای دسته بندی SVM) را به طور توام برای انتخاب ویژگی بکار گرفته است موجب کاهش تعداد ویژگی‌های انتخابی و بعضا باعث حفظ عملکرد یا بهبود درصد بازشناسی و عملکرد ماشین بردار پشتیبان شده است. برای ادامه‌ی اینکار می‌توان از الگوریتم‌های تکاملی دیگری بهره جست و نتایج آن‌ها را با عملکرد الگوریتم ژنتیک مورد بررسی قرار داد. هم چنین می‌توان از ترکیب معیارها به صورت سه هدفه استفاده کرد و حتی معیارهای بیشتری مانند معیارهای فاصله درون برون کلاسی و ضریب همبستگی پیرسون را نیز استفاده نمود.

جدول ۳: مقایسه روش پیشنهادی چند هدفه با روش تک هدفه و نتایج دقت دسته بندی ماشین بردار پشتیبان.

نام روش	نوع کرنل	glass		Lung-cancer		ionospher		wine	
		درصد بازشناسی	تعداد ویژگی انتخابی	درصد بازشناسی	تعداد ویژگی انتخابی	درصد بازشناسی	تعداد ویژگی انتخابی	درصد بازشناسی	تعداد ویژگی انتخابی
GA-E	Linear	۸۳.۷۲	۷	۱۰۰	۲۴	۹۷.۱۳	۱۱	۱۰۰	۸
	RBF(پارامترینج)	۸۸.۳۸	۸	۱۰۰	۲۲	۹۸.۵۷	۱۷	۱۰۰	۸
	Polnomial(درجه دو)	۷۴.۴۱	۷	۱۰۰	۲۵	۹۷.۶۵	۱۶	۱۰۰	۹
GA-MI	Linear	۶۵.۱۱	۵	۸۳.۳۳	۲۱	۸۵.۷۱	۸	۸۶.۱۱	۴
	RBF(پارامترینج)	۷۴.۴۱	۸	۸۳.۳۳	۱۶	۹۰	۷	۸۳.۳۳	۴
	Polnomial(درجه دو)	۶۲.۷۹	۶	۸۳.۳۳	۲۳	۹۰	۷	۸۰.۵۵	۴
GA-LAP	Linear	۷۴.۴۱	۴	۸۳.۳۳	۱۰	۷۸.۵۷	۱۵	۵۲.۷۷	۱
	RBF(پارامترینج)	۷۴.۴۱	۴	۸۳.۳۳	۲۲	۸۰	۳	۴۱.۶۶	۱
	Polnomial(درجه دو)	۳۰.۲۳	۱	۸۳.۳۳	۹	۷۲.۸۵	۴	۴۴.۴۴	۱
MOGA-EMI	Linear	۷۹.۰۷	۴	**۱۰۰**	۲۲	۹۵.۷۱	۱۰	**۱۰۰**	۵
	RBF(پارامترینج)	۷۹.۰۷	۷	۸۳.۳۳	۲۰	۹۵.۷۱	۱۷	۹۷.۲۲	۶
	Polnomial(درجه دو)	**۷۶.۷۴**	۵	**۱۰۰**	۲۰	**۹۷.۸۶**	۱۰	**۱۰۰**	۸
MOGA-ELAP	Linear	۷۹.۰۷	۷	**۱۰۰**	۱۸	۹۲.۱۵	۷	**۱۰۰**	۴
	RBF(پارامترینج)	۷۹.۰۷	۸	**۱۰۰**	۱۱	۹۵.۷۱	۱۲	**۱۰۰**	۲
	Polnomial(درجه دو)	**۸۸.۳۷**	۴	**۱۰۰**	۱۲	**۹۷.۸۶**	۲۰	**۱۰۰**	۸

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الگوریتم مسیریابی زوج و فرد چرخشی به روش همیلتونی برای تحمل پذیری خطا در سیستم‌های چند پردازنده‌ای

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[۲]دانشگاه آزاد اسلامی ، واحد قزوین ، دانشکده برق و کامپیوتر

چکیده - با پیشرفت فن‌آوری و سیستم‌های چند پردازنده‌ای نیاز به بستر ارتباطی سریع و قابل اطمینان برای عناصر پردازشی بر روی یک تراشه احساس شد .در این مقاله یک روش برای تحمل پذیری خطا در مسیریابی بسته ها بر روی یک تراشه که از معماری توری[۱] و روش ارسال خط لوله‌ای بسته ها [۲] استفاده می کنند، ارائه شده است.روش ارائه شده می تواند انطباق پذیری و قابلیت اطمینان بهتری را نسبت به روش های موجود برای رساندن بسته ها به مقصد فراهم نماید. در این روش یک الگوریتم همیلتونی زوج و فرد چرخشی ارائه شده که با افزایش مسیرهای ممکن در مسیریابی بسته‌ها می تواند انطباق پذیری و قابلیت اطمینان در شبکه بر روی تراشه را نسبت به الگوریتم همیلتونی بهبود ببخشد.این الگوریتم بدون بن بست بوده و بدون استفاده از کانال مجازی با افزایش مسیرهای جایگزین در نقاط حساس از وقوع ترافیک در ورودی های نودهای خراب شبکه جلوگیری می‌کند. نتایج این روش با الگوریتم تحمل پذیر خطا به روش همیلتونی مقایسه شده و ۱۰٪ بهبود قابلیت اطمینان در شبکه و ۵٪ بهبود در بازدهی الگوریتم در الگوی ترافیکی کانونی نشان داده می شود.

کلید واژه- انطباق پذیری[۳]، تحمل پذیری خطا[۴]، سیستم بر روی تراشه[۵]، شبکه بر روی تراشه[۶]

[1]mesh
[2] wormhole-switched 2D mesh
[3]adaptivity
[4]Fault tolerance
[5] System on chip
[6] Network on chip

۱- مقدمه

امروزه ارتباطات بر پایه باس[7] و ارتباطات نقطه به نقطه [8] نمی تواند پاسخگوی ارتباط بین سیستم‌های پیاده سازی شده بر روی تراشه باشد. از جمله این سیستم ها ربات‌ها هستند که بر روی یک تراشه عناصر مختلف از جمله واحد پردازش سیگنال، واحد پردازش تصویر و واحد پردازنده اصلی وجود دارد.هدف از ارایه یک الگوریتم مسیریابی تحمل پذیر خطا ارتباط سریع و مطمئن برای حداکثر بازدهی مسیریابی بسته‌ها در هنگام بروز خطا در یک عنصر پردازشی و یا یک لینک ارتباطی خراب می‌باشد.

۲- پیش زمینه و کارهای مرتبط

الگوریتم تحمل پذیر خطا به روش همیلتونی از مزایای الگوریتم زوج و فرد چرخشی و استراتژی همیلتونی در مسیریابی گراف شبکه استفاده نموده است. همچنین در[1]و[6]دو الگوریتم انطباق پذیر به روش زوج و فرد چرخشی ارائه شده و در [7] یک الگوریتم تحمل پذیر خطا به روش همیلتونی برای شبکه‌های توری ۳ بعدی ارائه شده است. هدف این مقاله ارائه یک الگوریتم تحمل پذیر خطا به روش زوج و فرد چرخشی و استراتژی همیلتونی

می باشد که علاوه بر حفظ حداکثر انطباق پذیری ارائه شده در[1]و[6]بتواند در هنگام بروز خطا با جایگزین کردن مسیر مناسب به روش همیلتونی بازدهی و قابلیت اطمینان شبکه را نسبت به الگوریتم تحمل پذیر خطا به روش همیلتونی [7] افزایش بدهد.

۲-۱- الگوریتم زوج و فرد چرخشی

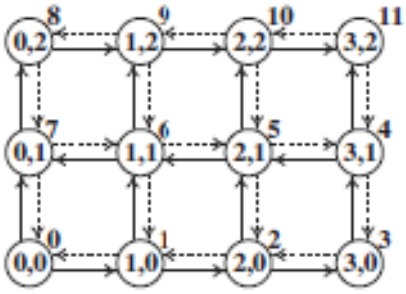
مدل چرخشی اولین بار در [2] به عنوان یک رویکرد سیستماتیک برای الگوریتم‌های بدون بن‌بست در حالت تک-پخشی[9]و بدون استفاده از کانال مجازی ارائه شده است.مدل چرخشی بر اساس تحلیل اینکه هر بسته مجاز به چرخش در کدام جهت محور عمودی یا افقی شبکه می باشد،ارائه شده است. با غیر مجاز کردن تعدادی از چرخش‌ها می توان به حداکثر انطباق پذیری در الگوریتم مسیریابی نسبت به الگوریتم های مسیریابی مطلق رسیده و همچنین از وقوع بن بست جلوگیری نمود [6].

اساساً مزیت الگوریتم‌های انطباق‌پذیر در مجاز بودن انتخاب مسیرها در هنگام بروز خطا و یا کاهش هزینه مسیریابی می باشد و انتخاب نامناسب محدودیت‌های چرخش می تواند باعث بروز بن‌بست و یا کاهش سطح انطباق‌پذیری شود.

۲-۲- استراتژی مسریابی همیلتونی

اساساً هر شبکه توری دو بعدی با m سطر و n ستون($m \times n$) با تعداد کل $m \times n = N$مسیریاب، را می توان در صفحه مختصات نمایش داد. به این صورت که هر مسیر یاب $0 \le i < N$با مختصات (x_i, y_i) مشخص شده کهx_i $(0 \le x_i < n)$ و y_i $(0 \le y_i < m)$ موقیت هر مسیر یاب را مشخص می کند.[8]

در روش مسیریابی همیلتونی هر مسیریاب با یک برچسب بین صفر و N-1 مشخص می شود. شروع مسیریابی از نود (۰،۰) بوده و مسیریاب‌های سطرهای زوج برچسب از چپ به راست به آن‌ها تعلق خواهد گرفت. و همچنین مسیریاب‌های سطرهای فرد با برچسب راست به چپ مطابق شکل زیر مشخص می شوند.[8]



شکل ۲-۱ برچسب گذاری همیلتونی یک مش ۳×۴

در مسیر همیلتونی ایجاد شده در گراف شبکه، هر مسیر معین دقیقاً یک بار هر نود را پوشش می دهد. بر اساس روش برچسب گذاری همیلتونی دو شبکه مجزا (مسیر همیلتونی) در شبکه ایجاد می گردد. کانال بالا (H_h) و کانال پایین (H_l). بر این اساس اگر برچسب مقصد بزرگتر از برچسب مبدا باشد مسیریابی در کانال (H_h)به صورت افزایشی خواهد بود و همچنین اگر برچسب مقصد کوچکتر از برچسب مبدا باشد مسیریابی در کانال (H_l)به صورت کاهشی ادامه پیدا خواهد کرد.

در استراتژی همیلتونی کانال مجازی وجود ندارد. و به دلیل نزدیک شدن قدم به قدم به مقصد و همچنین عدم وجود حلقه

[7] bus-based
[8] ad-hoc interconnects
[9] unicast

در گراف شبکه، این الگوریتم از انطباق‌پذیری خوبی برخوردار بوده و به صورت کمینه[10] قابل پیاده سازی می باشد.

$$l(x,y)=\begin{cases} y\times n+x & If\ y\ is\ even \\ y\times n+n-x-1 & If\ y\ is\ odd \end{cases}$$

۲-۳- الگوریتم مسیریابی انطباق پذیر به روش همیلتونی[11]

الگوریتم مسیریابی چند پخشی به روش همیلتونی در [1]ارائه شد. در این روش با به کارگیری روش همیلتونی و محدود کردن مسیر چرخش بسته‌ها به بازدهی و انطباق پذیری خوبی در الگوریتم های چند پخشی و تک پخشی انطباق پذیر رسیده است. این الگوریتم از مسیریابی بر پایه مسیر[12] و درخت پوشا[13] برای انطباق پذیری و جلوگیری از بن بست استفاده نموده است. به عبارت دیگر در این روش محدودیت‌های اعمال شده در مسیر چرخش بسته در محدوده زیر مجموعه‌هایی که به روشهای درختی و مسیری انتخاب شده ، اعمال می گردد.

قواعد این الگوریتم به طور خلاصه به این صورت است:

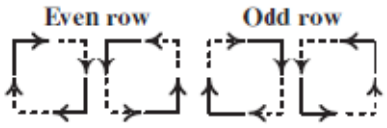
برای نودهای زیر مجموعه پایینی:

- چرخش به جنوب و غرب در سطرهای زوج مجاز است.
- چرخش به جنوب و شرق در سطرهای فرد مجاز است.

برای نودهای زیر مجموعه بالایی:

- چرخش به شمال و شرق در سطرهای زوج مجاز است.
- چرخش به شمال و غرب در سطرهای فرد مجاز است.

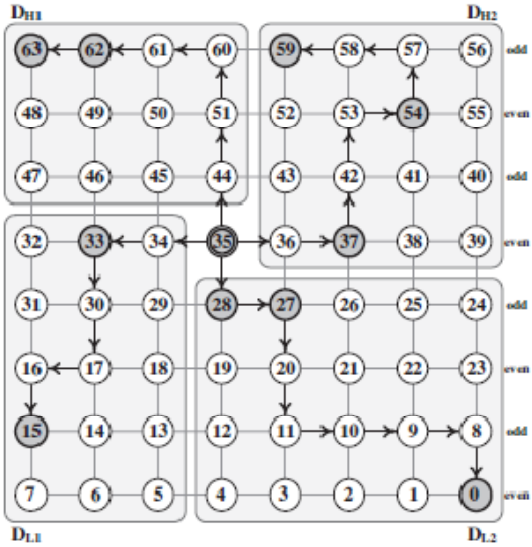
اگر منبع و مقصد حرکت یک بسته در یک سطر باشد رفتار این الگوریتم به صورت مطلق خواهد بود. این الگوریتم تا زمانی که بسته ها در مسیر همیلتونی به صورت افزایشی و یا کاهشی حرکت کنند بدون بن بست می باشد.



شکل ۲-۲- چرخشهای مجاز و غیر مجاز الگوریتم انطباق پذیر به روش همیلتونی

۳- الگوریتم پیشنهادی تحمل پذیر خطا به روش همیلتونی

همانطور که اشاره شد استفاده از روش همیلتونی شبکه را به چند زیر شبکه شامل کانال بالایی (H_h) و کانال پایینی (H_l) تقسیم می‌نماید. در روش همیلتونی برای تحمل پذیری خطا که در [7] ارایه شده، برای رسیدن به مقصد در روش چند پخشی کوتاهترین مسیر همیلتونی به صورت افزایشی در کانال بالایی و یا کاهشی در کانال پایینی تا رسیدن به تمامی مقاصد ادامه پیدا می کند (شکل۳-۱).



شکل ۳-۱-مسیر یابی بسته ها در حالت چند پخشی به روش همیلتونی

اما در صورتی که در مسیر همیلتونی خطایی رخ بدهد باعث کاهش سطح بازدهی و قابلیت اطمینان در گراف شبکه می شویم. برای جلوگیری از این مورد از بهبود یافته الگوریتم HAMUM که در[6] ارایه شده استفاده می کنیم.در روش HOE با مجاز کردن تعدادی از چرخش های غیر مجاز ارائه شده در [1] به طوری که بن بست در شبکه رخ ندهد بازدهی و انطباق پذیری الگوریتم زوج و فرد چرخشی بهبود داده شده است. انطباق پذیری بالا در الگوریتم‌های مسیریابی باعث تاثیر مستقیم در افزایش بازدهی و کاهش توان مصرفی در شبکه های بر روی تراشه می شود. هدف اصلی این مقاله استفاده از راهکار ارائه شده [6]در جهت بهبود تحمل پذیری خطا در شبکه می باشد.

[10] minimal
[11] Hamiltonian Adaptive Multicast Unicast Model (HAMUM)
[12] Path base
[13] Tree base

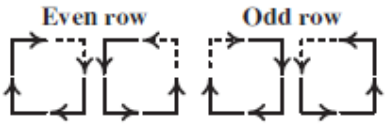
همانطور که در شکل ۲-۲ مشخص است دو چرخش از چهار چرخش ممکن در هر حلقه طبق الگوریتم HAMUM غیر مجاز است. همچنین غیر مجاز کردن فقط یک چرخش از هر حلقه نمی تواند بدون بن بست بودن الگوریتم را تضمین کند اما می تواند حداکثر انطباق پذیری را فراهم کند. در حقیقت می توان با محدود کردن حرکت بسته ها طبق الگوریتم همیلتونی از وقوع بن بست در این الگوریتم پیش گیری نمود.
البته انتخاب درست چرخش های غیر مجاز در هر چرخه برای جلوگیری از بن بست مهم است.

۳-۱- مقایسه الگوریتم های HOE و HAMUM در تحمل پذیری خطا

در روش HOE با مجاز کردن تعدادی از چرخش های غیر مجاز ارائه شده در [1] مطابق شکل ۳-۲ می تواند در جایگزین کردن مسیر همیلتونی در زمان وقوع خطا از کاهش بازدهی شبکه جلوگیری و در نهایت قابلیت اطمینان کل سیستم را افزایش بدهیم. قوانین الگوریتم HOE در مواقع بروز خطا در یک لینک ارتباطی یا نود خراب به شرح زیر می باشد:

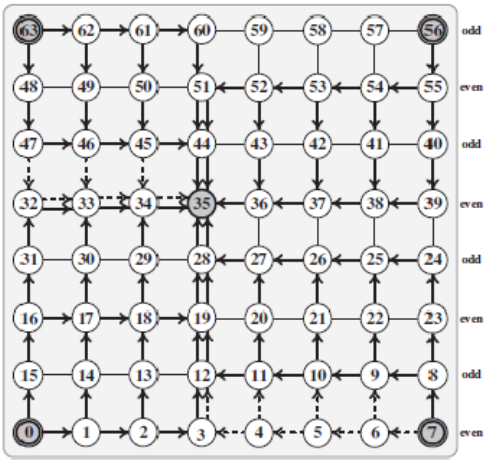
۱. چرخش های شرق به جنوب و شمال به غرب در سطر های زوج غیر مجاز است .
۲. چرخش های شمال به شرق و غرب به جنوب در سطرهای فرد غیر مجاز است.

بر اساس این الگوریتم چرخش های شرق به جنوب و شمال به شرق در یک سطر قرار نمی گیرد همچنین چرخش های شمال به غرب و غرب به جنوب هم نمی توانند در یک سطر قرار بگیرند. همچنین چرخش ۱۸۰ درجه در این الگوریتم غیر مجاز است.
لازم به ذکر است اولویت چرخش ها در دو قانون بالا می تواند جابجا شود.



شکل ۳-۲-چرخشهای مجاز و غیرمجاز الگوریتم زوج و فرد چرخشی به روش همیلتونی

به عنوان نمونه در شکل ۳-۳ مسیریاب ۳۵ مقصد نهایی ارسال بسته از چهار مسیریاب دیگر می باشد. مسیریاب های منبع در موقعیت جنوب غرب (نودصفر) ، جنوب شرق (نود۷) ، شمال شرق (نود ۵۶) وشمال غرب (نود ۶۳) مسیریاب مقصد قرار دارند.
خطوط پیوسته مسیرهای ممکن با الگوریتم HAMUM و خطوط نقطه چین شامل مسیرهای ممکن با الگوریتم HOE می باشد. همان طور که مشخص است همواره می توان یک مسیر کیمنه از مبدا به مقصد با الگوریتم HOE پیدا نمود.

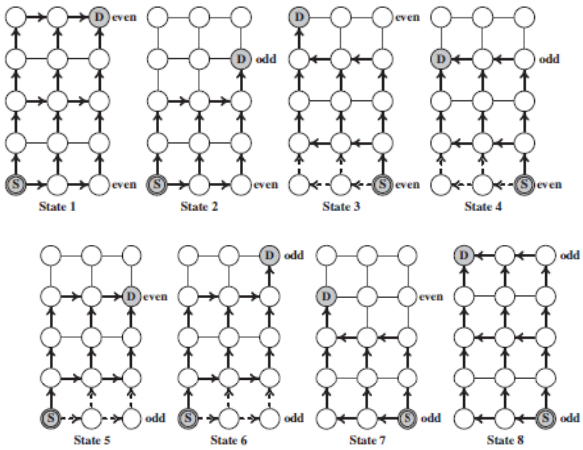


شکل ۳-۳-مقایسه مسیرهای ممکن برای دو الگوریتم HOE و HAMUM

همانطور که در این مثال مشخص است الگوریتم HOE به دلیل ممکن کردن برخی از چرخش های غیر مجاز روشHAMUM از نظر انطباق پذیری بهتر می باشد. همچنین از نظر درجه انطباق پذیری[۱۴] این الگوریتم از درجه بالاتری برخوردار است [4]. در صورت بروز خطا در لینک ارتباطی با مسیریابی به روش همیلتونی مطلق[7] ، به دلیل محدودیت حرکت بسته ها و هدر رفتن منابع جهت تولید مجدد داده ها باعث کاهش قابلیت اطمینان شبکه می شود اما اگر در انتخاب نود بعدی جهت رسیدن به مقصد از روش HOE استفاده نماییم به دلیل افزایش مسیرهای مجاز علاوه بر انطباق پذیری شبکه در حالت عادی ، بسته‌های بیشتری امکان رسیدن به مقصد را داشته و در نهایت تحمل پذیری شبکه افزایش می یابد.

به عنوان مثال هشت وضعیت ممکن در زیر مجموعه بالایی (H_h) به روش HOE به صورت شکل ۳-۴ می باشد:

[14]Degree of Adaptiveness (DoA)



شکل ۳-۴-هشت وضعیت ممکن در زیر مجموعه بالایی با مسیریابی زوج و فرد چرخشی همیلتونی

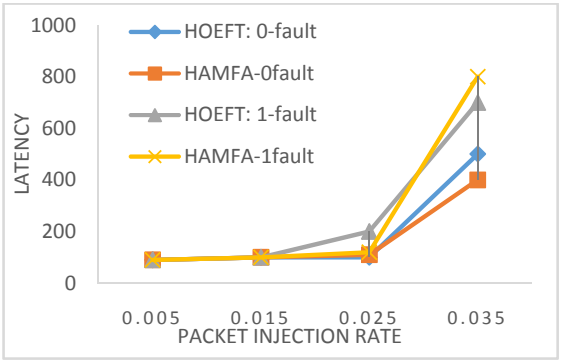
۴- نتایج شبیه سازی الگوریتم ارائه شده

برای بررسی تاثیر الگوریتم ارائه شده از شبیه ساز NIRGAM[5]که برپایه زبان SYSTEMC برای توصیف شبکه بر روی تراشه پیاده سازی شده ، استفاده شده است. برای تمام مسیریاب ها از بسته های ۳۲ بیتی استفاده شده است. همچنین بافر های ورودی کانال ها به اندازه ۸ فیلیت در نظر گرفته شده است. توپولوژی مورد بررسی در این تحقیق مش ۴×۴ می باشد. و زمان تاخیر اولیه ۵ ثانیه[15] درنظر گرفته شده و در محاسبه تاخیر بسته ها و بازدهی الگوریتم اعمال نمی شود. الگوریتم ارائه شده با نام HOEFT نشان داده شده و با الگوریتم HamFA[7] از نظر بازدهی و قابلیت اطمینان مقایسه می شود. قبل از مقایسه نتایج شبیه سازی به صورت خلاصه نگاهی به تفاوت های این دو الگوریتم می اندازیم.HamFAیک روش تحمل پذیر خطا برای پشتیبانی از لینک خراب در شبکه بر روی تراشه های دو بعدی و سه بعدی به روش همیلتونی می باشد. در الگوریتم HOEFT علاوه بر تقسیم شبکه به چند زیر مجموعه بالایی و پایینی ، امکان انتخاب مسیرهای بیشتری را به روش زوج و فرد چرخشی به بسته‌ها داده و همچنین با استفاده از روش HOE حداکثر انطباق پذیری و جلوگیری از بن بست در رودی کانال مسیریاب را بدون استفاده از کانال مجازی در الگوریتم مسیریابی خواهیم داشت.

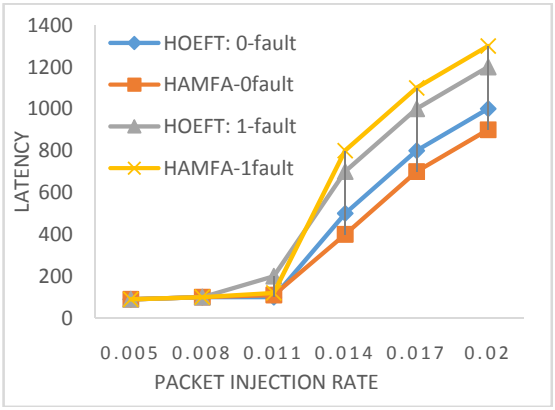
۴-۱- بررسی بازدهی الگوریتم

در این تحقیق دو الگوی ترافیکی یکنواخت[16] و کانونی[17] برای بررسی بازدهی الگوریتم مسیریابی در حالتی که یک لینک خطادار در شبکه وجود داشته باشد، مورد بررسی قرار گرفته است. در الگوی ترافیکی یکنواخت هر عنصر پردازشی شبکه بسته ها را به صورت یکنواخت به عناصر همسایه ارسال می کند اما در الگوی کانونی یک نود خاص اولویت بیشتری نسبت به سایر نودها داشته و اساساً کانون شبکه می باشد.

در الگوهای ترافیکی یکنواخت دو الگوریتم HOEFT و HAMFA بازدهی یکسانی داشته و در الگوی ترافیکی کانونی در نرخ ارسال بسته های ۰.۰۱۱ و بالاتر، از بازدهی ۵٪ بهتری برخوردار بوده. البته می توان با ثابت کردن مسیر بعضی از مقصد ها برای نودهای کانون در الگوهای ترافیکی پر حجم بازدهی الگوریتم را تا ۱۵ ٪ افزایش داد.



نمودار ۱-مقایسه بازدهی الگوریتم HOEFT و HAMFA در الگوی ترافیکی یکنواخت

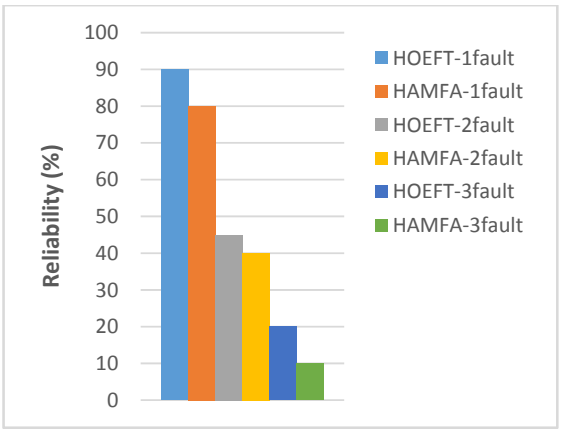


نمودار ۲-مقایسه بازدهی الگوریتم HOEFT و HAMFA در الگوی ترافیکی کانونی

۴-۲- بررسی قابلیت اطمینان شبکه

یک شبکه را در صورتی کاملاً مطمئن می گویند که اگر تمام بسته های تولید شده به مقصد نهایی خود پیرو الگوریتم مسیریابی برسند [4]. طبق این تعریف قابلیت اطمینان شبکه با دو الگوریتم مورد مقایسه بررسی شده است.

همچنین تعداد لینک‌های خطا دار شبکه از یک به سه افزایش داده شده اند.



[15]Warm-up
[16]Uniform
[17]hotspot

نمودار ۳-مقایسه قابلیت اطمینان دو الگوریتم HOEFT وHAMFA

نرخ رسیدن بسته ها در هنگام بروز خطا در یک لینک در الگوریتم HOEFT با ۱۰٪ افزایش نسبت به الگوریتم HAMFA بوده است.

۵- نتیجه‌گیری

در این مقاله یک الگوریتم تحمل پذیرخطا به روش زوج و فرد چرخشی و با استراتژی همیلتونی پیاده سازی شده و نتایج تحمل پذیری در مقابل خطای لینک های ارتباطی با الگوریتم تحمل پذیر خطای همیلتونی مقایسه گردید که افزایش تا ۱۰ ٪ قابلیت اطمینان در شبکه و تا ۵٪ بهبود بازدهی در الگوریتم ارائه شده را نشان داد. البته روش ارائه شده در الگوی ترافیکی کانونی از بازدهی بهتری برخورد بود و برای الگوهای ترافیکی یکنواخت به دلیل بهبود نداشتن و سربار پردازشی الگوریتم پیشنهاد نمی گردد.

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ارائه‌ی یک نسخه‌ی اصلاح‌شده از الگوریتم جست‌وجوی فاخته با رویکرد دینامیک

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چکیده - الگوریتم جست‌وجوی فاخته یک روش بهینه‌سازی فرا اکتشافی است که رویکردی تکاملی در جست‌وجوی راه‌حل بهینه دارد. این الگوریتم از رفتار فاخته در پرورش تخم الهام گرفته است و آن را با پرواز لوی که نوعی گشت تصادفی است ترکیب می‌کند. هر تخم در لانه نشان‌دهنده‌ی یک جواب برای مسئله و تخم جدید فاخته معادل راه‌حل تازه‌ای برای آن است. استفاده از راه‌حل‌های جدیدتر و به طور بالقوه بهتر، به منظور جایگزین کردن با راه‌حل‌های نه چندان مناسب قبل انجام می‌شود. در نسخه‌ی استاندارد این الگوریتم احتمال کشف تخم به صورت ثابت در نظر گرفته شده است اما در روش پیشنهادی این احتمال به صورت پویا در طول اجرای الگوریتم تغییر می‌کند. با تنظیم پویای این پارامتر، ترکیب صحیحی از قابلیت‌های جست‌وجوی اکتشافی و جست‌وجوی محافظه‌کارانه ایجاد می‌شود و دقت الگوریتم به شکل قابل توجهی بهبود می‌یابد. نتایج به دست آمده از انجام آزمایش‌ها روی چهار مجموعه داده‌ی واقعی و دو مجموعه داده‌ی مصنوعی، عملکرد مناسب الگوریتم پیشنهادی را تأیید می‌کند.

کلید واژه- الگوریتم بهینه‌سازی جست‌وجوی فاخته، جست‌وجوی اکتشافی، جست‌وجوی محافظه‌کارانه

۱- مقدمه

بهینه‌سازی تغییر ورودی‌ها و خصوصیات یک دستگاه، فرآیندی ریاضی یا آزمایشی تجربی است به نحوی که بهترین خروجی به دست بیاید. در فرآیند بهینه‌سازی تغییراتی روی ایده‌ی اولیه انجام می‌شود و با نتایج حاصل از این تغییرات ایده‌ی اولیه بهبود می‌یابد. بهینه‌سازی را می‌توان شامل طیف گسترده‌ای از مسائل دانست که هدف از حل آن‌ها جست‌وجو برای یافتن یک ناحیه‌ی بهینه‌ی معین است. روش‌های زیادی برای دسته‌بندی مسائل بهینه‌سازی وجود دارد که به طور کلی می‌توان آن‌ها را به دو دسته‌ی «الگوریتم‌های دقیق[a]» و «الگوریتم‌های تقریبی[b]» تقسیم کرد. الگوریتم‌های دقیق قادر به یافتن دقیق پاسخ بهینه هستند ولی در مورد مسائل بهینه‌سازی سخت[c] کاربرد ندارند. اما الگوریتم‌های تقریبی قادر به یافتن پاسخ‌های خوب (نزدیک به بهینه) با زمان حل مناسب برای مسائل بهینه‌سازی سخت هستند. الگوریتم‌های تقریبی به دو دسته‌ی الگوریتم‌های اکتشافی[d] و الگوریتم‌های فرا اکتشافی[e] تقسیم می‌شوند [1]. مسئله‌ی خوشه‌بندی یکی از انواع مسائل بهینه‌سازی سخت محسوب می‌شود و برای حل آن از دیدگاه بهینه‌سازی، نیازمند روش‌های بهینه‌سازی احتمالی هستیم [2].

الگوریتم جست‌وجوی فاخته[f] یک تکنیک بهینه‌سازی است که از شیوه‌ی زندگی فاخته الهام گرفته شده است. این الگوریتم توانایی همگرایی بسیار سریعی در یافتن نقاط بهینه‌ی سراسری دارد که به نظر می‌رسد این موضوع به تعداد کم پارامتر در این الگوریتم مرتبط باشد. در نسخه‌ی ابتدایی الگوریتم جست‌وجوی فاخته احتمال لو رفتن یا کشف تخم فاخته‌ی مهاجم برابر با ثابت P_a=۰,۲۵ در نظر گرفته شده است. در الگوریتم پیشنهادی که آن را «جست‌وجوی فاخته با پارامتر P_a پویا[g]» نامیده‌ایم، پارامتر p_a به صورت پویا در طول اجرای الگوریتم تغییر می‌کند. با تنظیم پویای این پارامتر ترکیب صحیحی از قابلیت‌های جست‌وجوی اکتشافی و جست‌وجوی محافظه‌کارانه ایجاد می‌شود. این دو قابلیت عواملی هستند که کارایی و دقت هر الگوریتم بهینه‌سازی را کنترل می‌کنند.

در ادامه، بخش ۲ شامل نسخه‌ی استاندارد الگوریتم جست‌وجوی فاخته و بخش ۳ نسخه‌ی اصلاح شده‌ی آن است. آزمایش‌ها و نتایج در بخش ۴ و نتیجه‌گیری در بخش ۵ آمده است.

۲- الگوریتم جست‌وجوی فاخته (CS)

الگوریتم جست‌وجوی فاخته یکی از الگوریتم‌های فرا اکتشافی است که اساس کار آن بر پایه‌ی رفتار گونه‌ی خاصی از فاخته با تخم‌گذاری در لانه‌ی پرندگان میزبان است. هر تخم در لانه نشان‌دهنده‌ی یک جواب برای مسئله و تخم جدید فاخته معادل راه‌حل تازه‌ای برای آن است. استفاده از راه‌حل‌های جدیدتر و به طور بالقوه بهتر، به منظور جایگزین کردن با راه‌حل‌های نه چندان مناسب قبل انجام می‌شود. در جست‌وجوی فاخته چند قاعده ی اولیه وجود دارد: ۱- هر فاخته در یک زمان مشخص فقط یک تخم می‌گذارد و آن را به صورت تصادفی در لانه‌ی سایر پرندگان رها می‌کند. ۲- بهترین لانه با بهترین راه‌حل‌های ارائه شده بدون تغییر به نسل بعد منتقل می‌شود. ۳- تعداد لانه‌های میزبان ثابت است و تخم گذاشته شده با احتمال $p_a \in [0, 1]$ توسط پرنده‌ی میزبان کشف می‌شود. در این مورد پرنده‌ی میزبان هم می‌تواند تخم را به بیرون پرت کند و هم لانه را رها کند و یک لانه‌ی جدید بسازد. در واقع می‌توان بخش p_a را به عنوان جایگزین لانه‌ی جدید در نظر گرفت (با راه‌حل‌های تصادفی جدید).

تولید پاسخ‌های جدید تصادفی به روش حرکت تصادفی بر پایه‌ی قاعده‌ی پرواز لوی[h] است. طبق رابطه‌ی (۱) وقتی راه‌حل‌های جدید $x(t+1)$ برای هر فاخته i تولید می‌شود، یک پرواز لوی انجام شده است.

$$X_t^{(t+1)} = X_i^{(t)} + \alpha \oplus Levy\ (\lambda) \qquad (1)$$

برای تولید پاسخ جدید تصادفی طبق رابطه‌ی (۲) ابتدا عددی تصادفی از توزیع احتمال لوی تولید می‌شود و سپس در فضای پاسخ‌های ممکن، پاسخی با استفاده از آن عدد تصادفی ایجاد می‌شود.

$$X_t^{(t+1)} = \alpha \times Levy(ß) \times (X^{(t)} - best) \qquad (2)$$

در رابطه‌ی (۲) $\alpha>0$ طول گام است که متناسب با مقیاس مسئله و اندازه‌ی فضای جواب انتخاب می‌شود. این رابطه در اصل یک تساوی تصادفی برای قدم زدن یا پرواز تصادفی است. در ابتدای اجرای این الگوریتم قابلیت جست‌وجوی اکتشافی بالاست. (مانند روال زندگی فاخته در طبیعت که تخم‌های اولیه‌ی فاخته در لانه‌ی پرندگان میزبان شباهت کم‌تری به تخم‌های واقعی دارند و با احتمال بیش‌تری توسط پرنده‌ی میزبان کشف می‌شوند. پرنده یاد می‌گیرد تخم‌هایش را به تخم‌های پرنده‌ی میزبان شبیه کند).

الگوریتم در ابتدا قابلیت ریسک‌پذیری بالایی دارد اما آرام آرام محتاط‌تر عمل می‌کند [3]. شبه کد الگوریتم جست‌وجوی فاخته در جدول ۱ آمده است:

جدول ۱: شبه کد الگوریتم جست‌وجوی فاخته [3]

تعریف تابع هدف f(x)
تولید جمعیت اولیه از n لانه‌ی میزبان
تا زمانی که شرایط خاتمه برآورده نشده است:
برای فاخته‌ی i - ام
یک پاسخ جدید توسط پرواز لوی ایجاد می‌شود.
مقدار تابع هدف پاسخ جدید محاسبه می‌شود (F_i).
یک لانه از بین n لانه (مثلاً j) به صورت تصادفی انتخاب می‌شود.
اگر Fi<Fj:
راه‌حل جدید i جایگزین راه‌حل j می‌شود.
کسری (P_a) از بدترین پاسخ‌ها حذف می‌شوند
و راه‌حل‌های ایجاد شده توسط پرواز لوی جایگزین آن‌ها می‌شوند.
بهترین پاسخ‌ها حفظ می‌شوند.
پاسخ‌ها مرتب می‌شوند و بهترین آن‌ها مشخص می‌شود.
پایان.

۳- نسخه‌ی پیشنهادی الگوریتم جست‌وجوی فاخته (DCS)

در این بخش به منظور بهبود عملکرد و افزایش کارایی الگوریتم، اصلاحاتی روی نسخه‌ی اصلی آن انجام می‌شود. همان‌طور که گفته شد، پارامتر p_a در نسخه‌ی استاندارد الگوریتم ثابت در نظر گرفته شده است. در رویکرد پیشنهادی این مقدار طبق رابطه‌ی (۳) به صورت پویا در طول اجرای الگوریتم تغییر می‌کند.

$$P_a = P_a(initial) - (m_{p_a} - m_{p_a} \times iter) \qquad (3)$$

در رابطه‌ی (۳) p_a نشان‌دهنده‌ی احتمال کشف تخم‌های فاخته‌ی مهاجم توسط میزبان در هر تکرار الگوریتم، $p_a(initial)$ احتمال اولیه‌ی کشف تخم‌های فاخته‌ی مهاجم توسط میزبان، m_{p_a} شیب تغییرات p_a و $iter$ تعداد تکرار است.

تابع هدف در این مقاله با استفاده از الگوریتم میانگین هارمونیک K تعریف شده است. این الگوریتم یک نسخه‌ی بهبود یافته از

الگوریتم خوشه‌بندی K-means است که بر اساس کمینه کردن میانگین هارمونیک تمام نقاط موجود در یک مجموعه داده تا مراکز خوشه‌ها عمل می‌کند [4,5].

رابطه‌ی ۴ تابع هدف الگوریتم پیشنهادی را معرفی می‌کند:

$$KHM(X,C) = \sum_{i=1}^{n} \frac{k}{\sum_{j=1}^{k} \frac{1}{\|x_i - c_j\|}}, p \geq 2 \qquad (4)$$

در ارتباط با نسخه‌ی اصلاح شده‌ی الگوریتم می‌توان گفت با تنظیم پویای پارامتر p_a ترکیب صحیحی از قابلیت‌های جست‌وجوی اکتشافی و جست‌وجوی محافظه‌کارانه ایجاد می‌شود. این تاکید بر پویایی در نسخه‌ی بهبود یافته‌ی الگوریتم جست‌وجوی فاخته به نوعی با مدل زندگی این پرنده در طبیعت تناسب دارد. جمعیت اولیه‌ی فاخته تعدادی تخم را در لانه‌ی پرندگان میزبان می‌گذارد. تعدادی از این تخم‌ها که شباهت بیشتری به تخم‌های پرنده‌ی میزبان دارند شانس بیش‌تری برای رشد و تبدیل شدن به فاخته‌ی بالغ خواهند داشت. سایر تخم‌ها توسط پرنده‌ی میزبان شناسایی شده و از بین می‌روند. فاخته به مرور می‌آموزد از الگوی تخم‌های پرنده‌ی میزبان الگوبرداری کند. این فرآیند به صورت پیوسته در حال تکرار و بهبود است.

الگوریتم در ابتدا قابلیت ریسک‌پذیری بالایی دارد اما آرام آرام محتاط‌تر عمل می‌کند. در ابتدای اجرای الگوریتم فاخته تعداد پاسخ‌های خوب قابل قبول است اما احتمال تصادفی بودنش بالاست. به مرور این الگوریتم به سمت پاسخ‌های بهتر و پایدارتر حرکت می‌کند.

۴- آزمایش‌ها و نتایج

در این بخش آزمایش‌های مربوط به ارزیابی عملکرد دو الگوریتم آمده است. در این آزمایش‌ها مجموعه داده‌های Iris، Wine، CMC و Vowel و دو مجموعه داده‌ی مصنوعی ART Set1 و ART Set 2 برگزیده شده‌اند. در جدول ۲ این مجموعه داده ها به صورت مختصر معرفی شده‌اند.

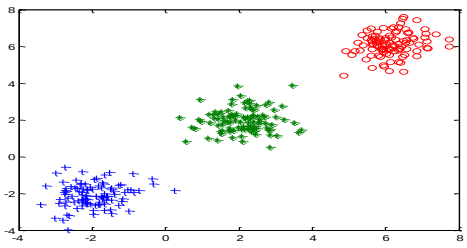
جدول ۲: مجموعه داده‌های Iris, Wine, CMC, Vowel, ArtSet1,ArtSet2 [6]

Data Set	تعداد نمونه	تعداد ویژگی	تعداد دسته
Iris	۱۵۰	۴	۳
Wine	۱۷۸	۱۳	۳
CMC	۱۴۷۳	۱۰	۳
Vowel	۸۷۱	۳	۶
ART1	۳۰۰	۲	۳
Art 2	۳۰۰	۳	۳

Artset1 یک مجموعه داده‌ی مصنوعی با ۳ کلاس و ۳۰۰ نمونه‌ی ۲ بعدی است. کل ۳۰۰ نمونه از سه توزیع نرمال دو متغیره‌ی مستقل تولید شده‌اند. توزیع کلاس‌ها مطابق با رابطه‌ی (۵) محاسبه شده است.

$$N_2\left(\mu = \begin{pmatrix}\mu_{i1}\\ \mu_{i2}\end{pmatrix}, \sum = \begin{bmatrix}0.4 & 0.04\\ 0.04 & 0.4\end{bmatrix}\right), \quad i = 1,2,3 \qquad (5)$$

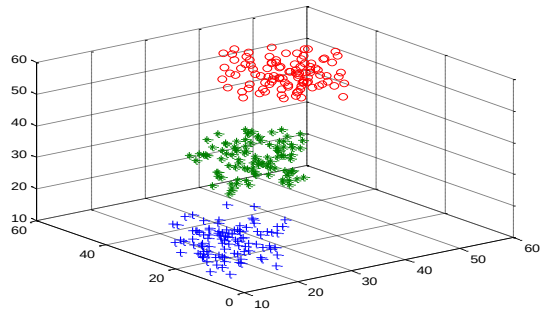
در رابطه بالا μ بردار میانگین است و مقادیر آن برای ۳ توزیع به صورت $\mu_{11}=\mu_{12}= -2$, $\mu_{21}=\mu_{22}= 2$, $\mu_{31}=\mu_{32}= 6$ و $\sum$ ماتریس کواریانس است. خوشه‌بندی مجموعه داده‌ی Art1 در شکل ۱ نشان داده است.



شکل ۱: خوشه‌های مجموعه داده‌ی Art1

Artset2 یک مجموعه داده‌ی مصنوعی با ۳ کلاس و ۳۰۰ نمونه‌ی ۳ بعدی است. ویژگی‌های هر کلاس مطابق با Class1~Uniform(10,25)، Class2~Uniform(25,40) و Class3~Uniform(40,55) توزیع شده است. خوشه‌بندی مجموعه داده‌ی Art2 در شکل ۲ نشان داده شده است.

است.



شکل ۲: خوشه‌های مجموعه داده‌ی Art2

هر آزمایش به ازای هر الگوریتم و هر مجموعه داده ۵۰ بار به صورت مستقل انجام شده است و نتایج نهایی حاصل میانگین‌گیری از این ۵۰ بار اجرای مستقل است. در اینجا معیار مقایسه‌ی دقت الگوریتم‌ها، مقادیر تابع هدف (مجموع انحراف معیار داخلی خوشه‌ها) در نظر گرفته شده است. بدیهی است که هر چه مقدار تابع هدف به دست آمده توسط یک الگوریتم کوچک‌تر باشد، عملکرد آن الگوریتم بهتر خواهد بود. نتایج آزمایش‌های به دست آمده از تابع هدف الگوریتم پیشنهادی DCS در مقایسه با الگوریتم CS به ازای P=2.5,3,3.5 در جداول ۳ تا ۵ نشان داده شده است.

جدول ۳: نتایج به دست آمده از تابع هدف الگوریتم پیشنهادی DCS در مقایسه با الگوریتم CS به ازای P=2.5.

Data Set	CS [3]	DCS
Iris	121.3819	94.8129
Wine	29104390	27938480
CMC	58808.01	57240.64
Vowel	459568224	457368535
ART1	954.00082	569.00445
Art 2	88765.126	78432.163

جدول ۴: نتایج به دست آمده از تابع هدف الگوریتم پیشنهادی DCS در مقایسه با الگوریتم CS به ازای P=3.

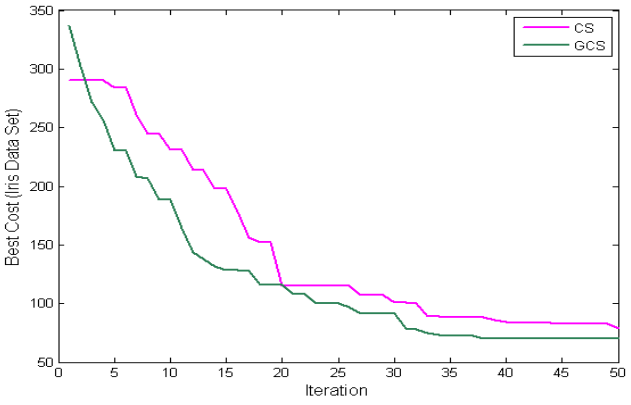
Data Set	CS [3]	DCS
Iris	147.1941	122.717894
Wine	389477890	361103489
CMC	152651.2	134334.8
Vowel	8431840086	8357190532
ART1	731.741501	442.900684
Art 2	332367.778	273371.765

جدول ۵: نتایج به دست آمده از تابع هدف الگوریتم پیشنهادی DCS در مقایسه با الگوریتم CS به ازای P=3.5.

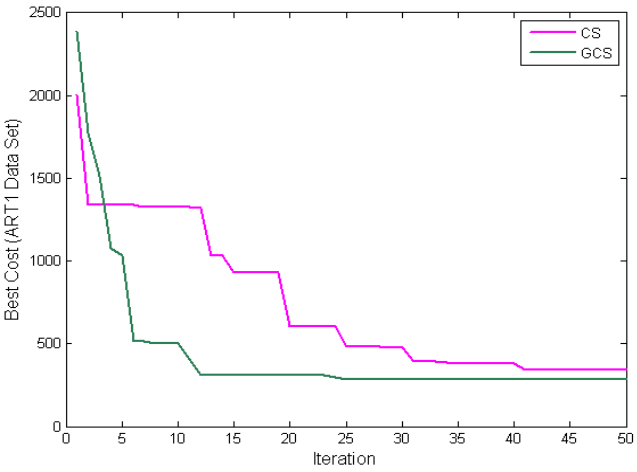
Data Set	CS [3]	DCS
Iris	207.3474	138.6355316
Wine	5480461928	4986011371
CMC	297292.779	244411.371
Vowel	2.28592E+11	1.83683E+11
ART1	2448.744463	889.3060534
Art 2	949293.9878	857326.7475

مشاهده می‌شود الگوریتم DCS در مجموع توانسته است از لحاظ دقت رسیدن به پاسخ بهینه نتایج بهتری نسبت به الگوریتم CS به دست آورد. دلیل این بهبود را می‌توان در نوع عملکرد این الگوریتم جست‌وجو کرد. قابلیت‌های اکتشاف و بهره‌وری که در حالت دینامیک برقرار می‌شوند، عواملی هستند که کارایی و دقت هر الگوریتم بهینه‌سازی را کنترل می‌کنند. کاوش به معنای توانایی الگوریتم برای جست‌وجوی مناطق مختلف فضای جست‌وجوست تا بهینه‌ی مناسب را مکان‌یابی کند. بهره‌وری قابلیت متمرکز کردن جست‌وجو در محدوده‌ی مطلوب است تا جواب مورد نظر موشکافی شود. الگوریتم در ابتدا قابلیت ریسک‌پذیری بالایی دارد اما آرام آرام محتاط‌تر عمل می‌کند. در ابتدای اجرای الگوریتم فاخته تعداد پاسخ‌های خوب قابل قبول است اما احتمال تصادفی بودنش بالاست. به مرور این الگوریتم به سمت پاسخ‌های بهتر و پایدارتر حرکت می‌کند. این تاکید بر پویایی در نسخه‌ی بهبود یافته‌ی فاخته به نوعی با مدل زندگی این پرنده در طبیعت تناسب دارد. نوعی پویایی در شیوه‌ی زندگی.

به عنوان نمونه روند همگرایی دو الگوریتم مورد آزمایش در مجموعه داده‌های Iris و Art1 در شکل‌های ۳و ۴ آمده‌اند.



شکل ۳. روند همگرایی دو الگوریتم CS و DCS در مجموعه داده‌ی Iris



شکل ۴. روند همگرایی دو الگوریتم CS و DCS در مجموعه داده‌ی ART1

با توجه به شکل مشاهده می‌شود که با افزایش مقدار p الگوریتم به سمت نتایج بهتر حرکت می‌کند. می‌توان گفت با تنظیم پویای پارامتر p_a ترکیب صحیحی از قابلیت‌های جست‌وجوی اکتشافی و جست‌وجوی محافظه‌کارانه ایجاد شده است.

۵- نتیجه‌گیری

مسئله‌ی خوشه‌بندی را می‌توان یکی از انواع مسائل بهینه‌سازی سخت در نظر گرفت که برای حل آن از دیدگاه بهینه‌سازی نیازمند روش‌های بهینه‌سازی احتمالی هستیم. در این مقاله یک نسخه‌ی اصلاح شده از الگوریتم جست‌وجوی فاخته با نام DCS ارائه شد. در نسخه‌ی ابتدایی الگوریتم جست‌وجوی فاخته احتمال لو رفتن یا کشف تخم فاخته‌ی مهاجم برابر با ثابت P_a=0.25 در نظر گرفته شده است. در الگوریتم پیشنهادی پارامتر P_a به صورت پویا در طول اجرای الگوریتم تغییر می‌کند. با تنظیم پویای این پارامتر ترکیب صحیحی از قابلیت‌های جست‌وجوی اکتشافی و جست‌وجوی محافظه کارانه ایجاد می‌شود. نتایج آزمایش‌ها روی شش مجموعه داده بهبود نتایج را نشان داده است.

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Exact Algorithms [a]
Approximate Algorithms [b]
NP Hard [c]
Heuristic [d]
Meta-Heuristic [e]
Coockoo Search Algorithm [f]
CS with Dynamic Pa [g]
Levy Flight [h]

بازشناسی چهره تحت شرایط گریم وآرایش با استفاده از الگوریتم کوانتیزاسیون فاز محلی و تجزیه مقدار تکین در صورت وجود یک تصویر مدل از هر شخص

فاطمه جعفری[۱]، حمیدرضا رشیدی کنعان [۲]

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چکیده-دراین مقاله یک رویکرد بازشناسی چهره تحت شرایط گریم و آرایش مبتنی بر الگوریتم کوانتیزه‌ساز فاز محلی (LPQ) و تجزیه مقدار تکین (SVD) تصاویر گالری ارائه شده است. LPQ برای استخراج ویژگی آماری فاز در پنجره‌هایی با اندازه‌های مختلف استفاده شده است. از SVD جهت مقابله با چالش محدود بودن تصاویر گالری استفاده شده که به کمک تصاویر پایه مستخرج از آن، هر تصویر منفرد به سه تصویر بازسازی‌شده تبدیل می‌شود. LPQ به دلیل استفاده از ویژگی آماری فاز تبدیل فوریه، در مقابل محوی موجود در تصاویر مقاومت نشان می‌دهد هم‌چنین استفاده از پنجره‌هایی با اندازه‌های مختلف به جای استفاده از پنجره ثابت در مرحله استخراج ویژگی، باعث افزایش کارایی در روش پیشنهادی شده است. جهت بازشناسی، از دو معیار شباهت‌سنجی فاصله اقلیدسی و منهتن استفاده شده است. کارایی الگوریتم پیشنهادی با سه سری آزمایش بر روی دو پایگاه داده واقعی وساختگی تغییرچهره ارزیابی شده است. آزمایش اول با بررسی تمام ترکیبات ممکن پنجره‌هایی با اندازه‌های مختلف ایجاد شده در مرحله استخراج ویژگی، آزمایش دوم با کاهش تعداد تصاویر گالری وآزمایش سوم با گریم‌های مختلف از هر شخص انجام گرفته است. نتایج پیاده‌سازی‌های انجام شده، برتری شیوه پیشنهادی را در مقایسه با چند الگوریتم مطرح موجود نشان می‌دهد.

کلمات کلیدی–بازشناسی چهره تحت شرایط گریم وآرایش، کوانتیزه‌ساز فاز محلی، تجزیه مقدار تکین، تبدیل فوریه، فاصله اقلیدسی و منهتن،

۱- مقدمه

بازشناسی چهره یکی از مهم‌ترین موضوع‌ها در حوزه بازشناسی الگو و بینایی ماشین است. هدف از بازشناسی چهره، شناسایی و یا تأیید هویت اشخاص با استفاده از پایگاه‌های داده‌ی چهره‌ی آنها است. بازشناسی چهره تحت شرایط گریم وآرایش یک چالش مهم در این حوزه است که کمتر به آن توجه شده است. فناوری بازشناسی چهره به دلیل داشتن مزایایی ازجمله دقت بالا و نفوذپذیری پائین، در مواردی همچون امنیت اطلاعات، نظارت و اجرای قانون، کارت‌های هوشمند و کنترل دسترسی مورد استفاده قرار می‌گیرد. علی‌رغم تحقیقات انجام شده طی چند دهه اخیر، به دلیل پیچیدگی ذاتی مسئله بازشناسی چهره هنوز با مشکل روبه‌رو است که این به سبب تنوع چهره انسان ناشی از تغییرات شرایط نورپردازی، پوشیدگی و تغییرقیافه می‌باشد[۱].

محققین اخیراً با یک چالش بازشناسی چهره روبرو شده‌اند وآن زمانی است که یک نفر هویت خود را به‌عمد با پنهان‌کاری جعل می‌کند؛ بنابراین توانایی شناسایی دقیق یک هویت جعل‌شده هنگامی‌که حداقل مجموعه‌ای از تصاویر یک نفر در اختیار داشته باشیم اهمیت پیدا کرده است[۲]. محققین برای برطرف کردن مشکلات ناشی از تغییرات ساختگی چهره، ژست و روشنایی روشهایی از جمله استفاده از ویژگی‌های هندسی [۳]، ایگن‌فیس [۴]، ویژگی‌های محلی [۵]، شبکه‌های عصبی [۶] و موجک‌ها [۷] را پیشنهاد داده‌اند.

رامانادن وهمکارانش جهت رویارویی با چالش تغییرچهره از شباهت‌های تصویر برای چندین متغیر شامل دو فضای ایگن از دو نیمه صورت (دریکی از نیمه سمت چپ و دیگری نیمه سمت راست) استفاده کرده‌اند و این نیمه‌ها را موردمطالعه قرار داده‌اند. با استفاده از روشنایی بهینه، نیمه صورت انتخاب‌شده در فضای ایگن پیش‌بینی می‌شود[۸]. در مطالعه‌ای توسط سینگ و همکاران، یک الگوریتم بازشناسی چهره تحت شرایط گریم وآرایش ارائه شده که در جهت رفع دو چالش اصلی در این زمینه برآمده است. چالش اول وقتی که شخص عمداً ظاهر و ویژگی‌های

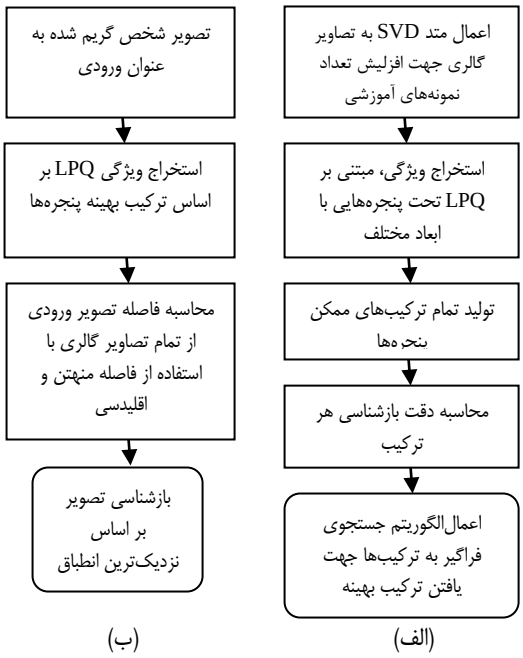
خود را از طریق گریم و آرایش تغییر می‌دهد و چالش دوم زمانی است که تصاویر گالری محدودی برای بازشناسی در دسترس هستند. این الگوریتم از یک معماری شبکه عصبی دینامیکی برای استخراج ویژگی‌های فازی بافت صورت با استفاده از تبدیل لگاریتمی قطبی دوبعدی گابور بهره می‌گیرد[۲] این روش حجم محاسباتی زیادی دارد.

درسیستم بازشناسی چهره تحت شرایط گریم وآرایش، یک تصویر گریم شده موجود است که می بایست هویت واقعی آن تشخیص داده شود. انواع بسیار زیادی از تغییرات گریم و آرایش وجود دارند که یک شخص می‌تواند از آنها برای تغییر چهره خود استفاده کند. هر کدام از این تغییرات به تنهایی می‌تواند ابهامات زیادی تولید کند که سبب تغییرات زیادی در مقادیر پیکسلی در تصویر چهره می‌شود. از آنجا که نوع و دامنه این تغییرات از پیش مشخص نیست، استخراج ویژگی در این سیستم‌ها را با مشکل مواجه کرده است. برای رویارویی با این چالش، در مرحله استخراج ویژگی در روش پیشنهادی، برای هرپیکسل، استفاده از پنجره‌هایی با ابعاد گوناگون، به جای استفاده از پنجره‌ی ثابت مطرح گردید. برای مثال اگر یک پیکسل را در ناحیه چشم فرض کنیم ابعاد مختلف پنجره می‌تواند مقدار پیکسل را به سمت پیشانی یا گونه سوق دهد نواحی که احتمال می‌رود کمتر تحت تأثیر تغییرات قرا گرفته باشند. چالش دیگر در این زمینه محدود بودن تصاویر گالری است که برای مقابله با آن در روش ارائه شده، با استفاده از روش تجزیه مقدار تکین (SVD[۱]) از هر تصویر منفرد، سه تصویر بازسازی‌شده تولید می‌شود.

در بخش (۲) روش پیشنهادی بیان می‌شود. در بخش (۳) نتایج آزمایش‌ها شرح داده خواهد شد که درآن سه نوع آزمایش انجام می‌شود، یکی بررسی تمام ترکیبات ممکن پنجره‌هایی با اندازه‌های مختلف ایجاد شده در مرحله استخراج ویژگی و دوتای دیگری ارزیابی روش با انواع تغییرات در چهره و کاهش تعداد تصاویر گالری می‌باشند. در پایان نیز نتیجه‌گیری ارائه شده است.

۲- روش پیشنهادی

روش پیشنهادی مبتنی بر الگوریتم کوانتیزه‌ساز فاز محلی (LPQ[۲]) و تجزیه مقدار تکین (SVD) تصاویر گالری است که به دو چالش اساسی می‌پردازد. چالش اول زمانی‌که یک نفر به عمد چهره خود را با استفاده از لوازم گریم تغییر می‌دهد و دوم زمانی که از هر نفر تنها یک تصویر موجود است. الگوریتم پیشنهادی دارای دو مرحله آموزش و آزمایش است. در فاز آموزش ابتدا متد SVD به تصاویر گالری منفرد اعمال می‌شود و از هر کدام آنها سه تصویر بازسازی شده تولید می‌شود که ار این طریق تعداد نمونه‌های آموزش افزایش داده شده است. سپس با استفاده از توصیفگر LPQ برای هر تصویر موجود در گالری، چندین بردار ویژگی با پنجره‌های مختلف استخراج و ذخیره می‌شوند. آنگاه دقت بازشناسی به ازای تمام ترکیبات ممکن این پنجره‌ها محاسبه شده و در نهایت با اعمال الگوریتم جستجوی‌فراگیر به این ترکیب‌ها، ترکیبی با بیش‌ترین دقت بازشناسی به عنوان ترکیب بهینه انتخاب می‌شود. در فاز آزمایش برای پیدا کردن صاحب یک تصویر، ابتدا ویژگی‌های تصویر مزبور با توجه به ترکیب بهینه پنجره‌ها استخراج شده و سپس فاصله آن با ویژگی‌های به‌دست‌آمده از تمام تصاویر در مرحله آموزش محاسبه می‌شود و درنهایت نزدیک‌ترین انطباق یافت می‌شود. ساختار کلی روش ارائه شده در شکل ۱ آمده است. در روش پیشنهادی اساس کار استفاده از پنجره‌هایی با ابعاد گوناگون، به جای استفاده از پنجره ثابت و افزایش تعداد نمونه‌های آموزش به کمک متد SVD است که عملکرد روش را تا حد زیادی بهبود بخشیده است. نتایج پیاده‌سازی‌ها مؤید این مسئله است. جهت بازشناسی، فاصله‌های اقلیدسی و منهتن مورد استفاده قرار گرفته‌اند زیرا محاسبه آن‌ها بسیار سریع بوده و سرعت عمل بازشناسی را ارتقا می‌بخشد.



شکل (۱) : ساختار روش پیشنهادی، الف : فاز آموزش، ب : فاز آزمایش

۲-۱- تجزیه مقدار تکین (SVD) تصاویر گالری

برای مقابله با چالش محدود بودن گالری تصاویر (زمانیکه تنها یک تصویر از هر شخص در اختیار داریم) یک راه‌حل مبتنی بر

[۱] Singular Value Decomposition

[۲] Local Phase Quantization

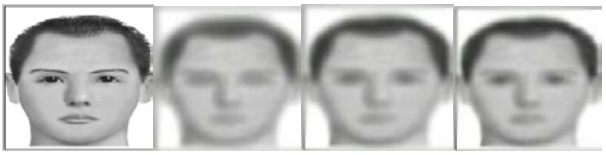
روش تجزیه مقدار تکین در نظر گرفته شده است. با استفاده از این روش، هر تصویر چهره به تصاویر پایه تجزیه شده و از هر کدام از آنها سه تصویر بازسازی شده تولید می‌شود. به طوری که اگر f(x) تصویر چهره باشد معادله (۱) بیانگر روش تجزیه مقدار تکین [۹،۱۰] این تصویر می‌باشد.

$$f(x) = \sum_{i=1}^{n} \sigma_i . u_i . v_i^T \qquad (۱)$$

که در آن u_i و v_i ستون iام u و v به ترتیب می‌باشند. u و v به ترتیب بردارهای ویژه ff^T و f^Tf است. σ_i مقادیر تکین تصویر f(x) است بطوریکه $\sigma_1 \geq \sigma_2 \geq \ldots\ldots \sigma_n$ [۹،۱۰].

در معادله (۱) تصویر f(x) از مجموعه تصاویر پایه i=1,…,n و $F_i = \sigma_i . u_i . v_i^T$ ساخته شده است. شکل ۲ تصویر اصلی و تصاویر بازسازی‌شده با استفاده از تصاویر پایه حاصل از تجزیه مقدار تکین را نشان می‌دهد. در این شکل تصاویر با توجه به معادله (۱) و مقادیر i از یک تا سه، تولید شده‌اند. همانطور که دیده می‌شود با افزایش مقدار n تصاویر بازسازی‌شده به تصویر اصلی نزدیک می‌شوند. آزمایش‌ها نشان داد که اگر $n \geq 4$ شود تفاوت بین تصاویر بازسازی‌شده و تصویر اصلی بسیار کم است.

بر این اساس، از گالری منفرد که تنها شامل یک نمونه آموزشی برای هر نفر است می‌توان یک گالری جدید شامل چهار تصویر برای هر نفر(یکی تصویر اصلی و سه تصویر بازسازی‌شده) تولید کرد. در روش پیشنهادی از این طریق تا حدودی با چالش تصویر گالری منفرد مقابله شده است.



(الف) (ب) (پ) (ت)

شکل (۲) : تصاویر بازسازی‌شده با استفاده از SVD به ترتیب از ب تا ت با مقادیر i از یک تا سه

۲-۲- استخراج ویژگی مبتنی بر LPQ

توصیف‌گر LPQ که توسط اجانسیوو و هیکیلا پیشنهاد شده است، به دلیل عملکرد برجسته خود در تجزیه و تحلیل بافت تصویر مورد توجه محققان زیادی قرار گرفته است [۱۱]. این توصیفگر بر اساس فازهای کوانتیزه شده تبدیل فوریه گسسته (DFT) ویژگی‌های آماری فاز را استخراج می‌کند که به صورت محلی در پنجره‌هایی با اندازه‌های مختلف برای هر پیکسل تصویر محاسبه می‌شود. در نهایت یک هیستوگرام از این ویژگی‌ها تولید می‌شود. کدهای تولید شده به وسیله این عملگر نسبت به محوی متقارن مرکزی از جمله جابجائی‌ها، متمرکز نبودن و تلاطم‌های محیطی مقاوم هستند [۱۱]. اما به دلیل اندازه محدود تصاویر، این مقاومت به طور کامل حاصل نمی‌شود زیرا کانولوشن یک تصویر ایده‌ال با تابع محوی بسیار بیش‌تر از آن چیزی است که ما در تصویر مشاهده می‌کنیم. زمانیکه مرزهای محوی بسیار بزرگتر از اندازه تصویر باشند اطلاعات زیادی در مورد تصویر از بین خواهد رفت.

۲-۲-۱- پایداری LPQ در مقابل محوی با استفاده از فاز تبدیل فوریه

در پردازش رقمی تصاویر، مدل گسسته محوی در تصویر اولیه f(x) منجر به یک تصویر مشاهده شده g(x) می‌شود که توسط معادله (۲) بیان می‌شود:

$$g(x) = (f * h)(x) \qquad (۲)$$

که در آن h(x) تابع گسترش نقطه (PSF) برای محوی تصویر است، * بیانگر کانولوشن دو بعدی و x یک بردار در دستگاه مختصات x-y است. معادله (۲) در دامنه فوریه معادل خواهد بود با:

$$G(u) = F(u).H(u) \qquad (۳)$$

برای مقدار و فاز معادله (۳) خواهیم داشت:

$$|G(u)| = |F(u)||H(u)| \qquad (٤)$$

$$\angle G(u) = \angle F(u) + \angle H(u) \qquad (٥)$$

اگر فرض کنیم که تابع گسترش نقطه محوی h(x) دارای تقارن مرکزی باشد یعنی h(x)=h(-x) تبدیل فوریه همیشه مقدار حقیقی خواهد بود و در نتیجه فاز آن فقط یک تابع با دو مقدار است:

$$\angle H(u) = \begin{cases} 0 & if\ H(u) \geq 0 \\ \pi & if\ H(u) < 0 \end{cases} \qquad (٦)$$

که این به این معنی است که:

$$\angle G(u) = \angle F(u) \quad for\ all\ H(u) \geq 0 \qquad (٧)$$

به بیان دیگر، فاز تصویر مشاهده شده در فرکانس‌هایی که H(u) مثبت است مقدار تابع محوی صفر شده و این یعنی محوی روی فاز تبدیل فوریه بی‌اثر است[۱۱].

۲-۲-۲- تبدیل فوریه کوتاه مدت(STFT)

روش کوانتیزاسیون فاز محلی بر پایه خاصیت پایداری نسبت به محوی طیف فاز فوریه است که در بخش قبل بیان شد. این روش

ویژگی‌های فاز محلی را با استفاده از تبدیل فوریه گسسته دوبعدی یا دقیق‌تر، تبدیل فوریه کوتاه مدت محاسبه شده بر روی یک همسایگی M در M مستطیلی N_x در هر موقعیت پیکسلی x از تصویر f(x) استخراج می‌کند که به صورت زیر تعیین می‌شود:

$$F(u,x)=\sum_{y\in N_x} f(x-y)e^{-j2\pi u^T y}=w_u^T f_x \qquad (۸)$$

که در آن w_u بردار پایه تبدیل فوریه دوبعدی در فرکانس u است و f_x بردار دیگری شامل تمام M^2 پیکسل از همسایگی Nx است. یک راه مناسب برای اجرای این تبدیل، استفاده از کانولوشن دو بعدی $f(x) * e^{-j2\pi u^T y}$ برای کل u است که محاسبه تبدیل فوریه کوتاه مدت، توصیفگر LPQ را در مقابل محوی مقاوم می‌سازد. جرئیات بیشتر در [۱۱] آمده است.

۲-۲-۳- تحلیل آماری ضرایب وکوانتیزاسیون

با فرض اینکه تابع تصویر f(x) نتیجه یک فرآیند مارکوف مرتبه اول باشد که در آن ضریب همبستگی بین مقدار پیکسل‌های مجاور ρ و واریانس هر نمونه σ^2 است. همچنین با فرض $\sigma^2 = 1$ در نتیجه، کوواریانس بین پیکسل‌های x_i و x_j عبارت است از:

$$\sigma_{ij}=\rho^{\left\|x_i-x_j\right\|} \qquad (۹)$$

که در آن ||.|| نشان دهنده نرم L_2 است و ماتریس کوواریانس تمام نمونه‌های M در N_x را می‌توان به صورت معادله (۱۰) بیان نمود. معادله (۱۱) ماتریس کواریانس بردار ضریب تبدیل F_x را نمایش می‌دهد. به راحتی می‌توان دریافت که برای $\rho > 0$، D ماتریس قطری نیست، به این معنی که ضرایب همبسته هستند [۱۱].

$$C=\begin{bmatrix} 1 & \sigma_{12} & . & . & . & \sigma_{1M} \\ \sigma_{21} & 1 & . & . & . & \sigma_{2M} \\ . & . & . & & & . \\ . & . & & . & & . \\ . & . & & & . & . \\ \sigma_{M1} & \sigma_{M2} & . & . & . & 1 \end{bmatrix} \qquad (۱۰)$$

$$D=WCW^T \qquad (۱۱)$$

پیش از کوانتیزاسیون، ضرایب ناهمبسته می‌گردند زیرا اگر نمونه‌های کوانتیزه شده از لحاظ آماری مستقل باشند، اطلاعات در کوانتیزاسیون عددی به طور حداکثر باقی می‌مانند[۱۱] بدین منظور از تبدیل سفیدکردن مطابق معادله (۱۲) استفاده می‌شود:

$$G_x=V^T F_x \qquad (۱۲)$$

که در آن V یک ماتریس متعامد مستخرج از تجزیه مقدار تکین (SVD) ماتریس D است یعنی:

$$D=U\Sigma V^T \qquad (۱۳)$$

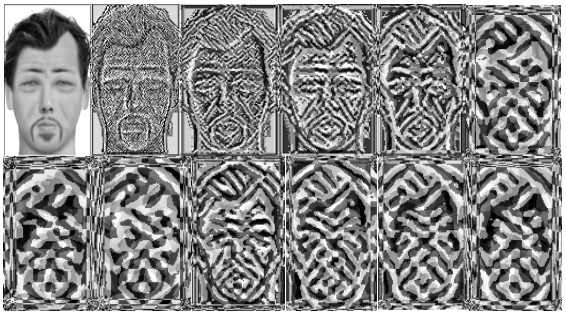
در مرحله بعد بردارهای Gx با معادله (۱۴) کوانتیزه می‌شوند. ضرایب کوانتیزه با استفاده از کدگذاری دوتایی با معادله (۱۵) به صورت مقادیر صحیح بین ۰-۲۵۵ ارائه می‌شوند. در پایان یک هیستوگرام از این مقادیر به عنوان یک بردار ویژگی ۲۵۶ عضوی در بازشناسی استفاده می‌شود.

$$q_j=\begin{cases}1, & if \quad g_j\geq 0\\ 0, & otherwise\end{cases} \qquad (۱٤)$$

$$b=\sum_{j=1}^{8} q_j 2^{j-1} \qquad (۱٥)$$

۲-۲-۴- کوانتیزاسیون فاز محلی در بازشناسی چهره تحت شرایط گریم وآرایش

در این مطالعه تصویر چهره گریم‌شده به عنوان تصویر اصلی به علاوه گریم در نظر گرفته می‌شود و فرض می‌شود که آرایش یا گریم به عنوان تابع h در معادله (۲) به تابع تصویر یا f اضافه شده است و در نهایت تصویر g جهت بازشناسی در اختیار ماست و ما بدون اطلاع دقیق از تابع h قصد داریم مشابه‌ترین تابع f را پیدا کنیم. در شکل ۳ ویژگی‌های هر پیکسل تصویر و فاز کوانتیزه مربوطه به وسیله مقیاس‌های مختلف پنجره‌ی محلی در LPQ نشان داده شده است.



شکل (۳) : تصویر چهره گریم شده و ویژگی‌های فاز کوانتیزه مربوطه حاصل از مقیاس‌های مختلف پنجره محلی در LPQ ، به ترتیب از پنجره کوچک‌تر به بزرگ‌تر.

۲-۳- بازشناسی در الگوریتم پیشنهادی

پس از استخراج ویژگی از تصاویر با استفاده از پنجره‌های مختلف برای هر تصویر، یک ماتریس ویژگی با ابعاد M×N خواهیم داشت که M تعداد پنجره‌ها و N طول هیستوگرام (۲۵۶) است. برای محاسبه فاصله یک تصویر از تصاویر دیگر از فاصله اقلیدسی و منهتن استفاده می‌شود که این فاصله‌ها به ترتیب عباتند از:

$$d(q,p)=\sqrt{(q_1-p_1)^2+(q_2-p_2)^2+\ldots+(q_n-p_n)^2} \quad (۱۶)$$

$$d(q,p)=|q_1-p_1|+|q_2-p_2|+\ldots+|q_n-p_n| \quad (۱۷)$$

که در این دو معادله q_i ویژگی i اُم از تصویر q است.

۳- نتایج عددی

در این بخش سه سری آزمایش انجام شده روی دو پایگاه داده بیان می‌شود. عملکرد الگوریتم پیشنهادی با PCA [۴]، GF [۳]، LFA [۵]، IGF [۱۲]، LBP [۱۳] و 2D-LPGNN [۲] مقایسه شده است.

۳-۱- پایگاه داده

۳-۱-۱- پایگاه داده ساختگی تغییرچهره

در این پژوهش به علت در دسترس نبودن پایگاه داده استاندارد تغییرچهره، ما اقدام به تهیه یک پایگاه داده تغییرچهره ساختگی با استفاده از نرم‌افزار چهره‌ها [۱۴] کرده‌ایم. این پایگاه داده شامل ۳۵۷۰ تصویر از ۸۵ نفر (۶۵ مرد و۲۰ زن) با ۴۲ حالت مختلف همراه با مجموعه‌ای کلی از تغییرات چهره است. همانگونه که در شکل ۴ نشان داده شده است ظاهر و ویژگی‌های چهره به هفت دسته به صورت تغییر در مدل مو، استفاده از عینک، پوشیدن کلاه، بلند کردن ریش وسبیل، ایجاد چین و چروک و ترکیب هریک از این تغییرات مدل شده است و هر کدام از این دسته‌ها حاوی شش حالت مختلف از این تغییرات است.

۳-۱-۲- پایگاه داده AR

پایگاه داده AR شامل حدوداً چهار هزار تصویر از یکصد و بیست و شش نفر است(۷۰ مرد و ۵۶ زن). بیست و شش تصویر رنگی از روبرو از هر شخص با تغییر در حالات چهره همچون اضافه نمودن عینک، شال و ریش و سبیل گرفته شده است[۱۵]. علاوه بر این شامل تغییرات روشنایی نیز می‌باشد. نمونه‌ای از آن در شکل ۵ مشاهده می‌شود.



شکل(۴) : تصاویر یک شخص در پایگاه داده ساختگی تغییرچهره



شکل (۵) : تصاویر یک شخص در پایگاه داده AR [۱۵]

۳-۲- انتخاب بهترین ترکیب پنجره‌ها در LPQ با استفاده از الگوریتم جستجوی‌فراگیر

در روش استخراج ویژگی LPQ، انتخاب پنجره مناسب تأثیر بسزایی در عملکرد الگوریتم پیشنهادی دارد. از اینرو چندین بردار ویژگی از تصاویر پایگاه داده با اندازه‌ی پنجره‌های متفاوت استخراج شدند. نتایج در جدول ۱ نشان داده شده است. آزمایش‌ها بر روی کل تغییرات پایگاه داده ساختگی تغییرچهره انجام شده است. همانگونه که دیده می‌شود فاصله منهتن از دقت بازشناسی بیشتری نسبت به فاصله اقلیدسی برخوردار است با این‌حال دقت در هر دو فاصله پایین است. بنابراین جهت دستیابی به دقت بیشتر، فاصله تصاویر با استفاده از ترکیب چندین پنجره بدست آمده است و سپس با میانگین‌گیری از فاصله‌ها دقت بازشناسی محاسبه شده است. جهت یافتن بهترین ترکیب پنجره‌ها با استفاده از الگوریتم جستجوی فراگیر، تمام ترکیب‌های ممکن پنجره‌ها آزمایش شده‌اند و برای هر دسته از انواع مختلف تغییرچهره، یک ترکیب با بالاترین دقت بازشناسی به عنوان ترکیب بهینه انتخاب شده است. نتایج در جدول ۲ نشان داده شده است.

جدول (۱) : دقت الگوریتم پیشنهادی با پنجره‌های مختلف

اندازه پنجره (پیکسل در پیکسل)	دقت بازشناسی (٪)	
	فاصله منهتن	فاصله اقلیدسی
۳×۳	۵۱/۰۵	۳۲/۳۵
۵×۵	۵۹/۳۸	۴۱/۰۴
۷×۷	۶۴/۲۲	۵۰/۰۰
۹×۹	۶۷/۹۳	۵۸/۱۲
۱۱×۱۱	۶۷/۴۴	۵۷/۷۰
۱۳×۱۳	۶۶/۵۳	۵۸/۶۸
۱۵×۱۵	۶۹/۳۳	۶۲/۲۵
۱۷×۱۷	۶۷/۰۹	۶۰/۹۹
۱۹×۱۹	۶۶/۱۸	۵۷/۱۴
۲۱×۲۱	۶۶/۸۸	۵۸/۵۴
۲۳×۲۳	۶۵/۲۷	۵۷/۹۸
۲۵×۲۵	۶۶/۰۴	۵۷/۹۱
۲۷×۲۷	۶۳/۱۷	۵۵/۱۸
۲۹×۲۹	۶۱/۷۶	۵۶/۷۹
۳۱×۳۱	۶۳/۳۸	۵۵/۸۸

۳-۳- اثر کاهش تعداد تصاویر گالری بر دقت بازشناسی

دقت الگوریتم پیشنهادی با کاهش تعداد تصاویر گالری از سه تصویر به بدترین سناریو (تنها یک تصویر موجود است) مورد بررسی قرار گرفته است. در مورد آزمایش‌هایی با تصویر گالری منفرد، پایگاه تصاویر شامل یک تصویر صورت تمام‌رخ بیرنگ و نورپردازی نشده از هر دسته بوده و مابقی تصاویر به عنوان پایگاه کاوش مورد استفاده قرار می‌گیرند. با اعمال متد SVD به تصویر گالری منفرد، هر تصویر منفرد به سه تصویر بازسازی‌شده تبدیل می‌شود. این رویکرد باعث افزایش دقت بازشناسی در روش پیشنهادی شده است. در مورد آزمایش‌هایی با دو یا سه تصویر، گالری شامل تصاویر نورپردازی‌نشده با حداقل تغییرات و تصاویر باقیمانده پایگاه کاوش را تشکیل می‌دهند. نتایج در جدول ۳ نشان داده شده است. همانطور که دیده می‌شود تحت شرایطی که مجموعه گالری از سه تصویر به یک تصویر کاهش می‌یابد دقت الگوریتم پیشنهادی نیز کاهش می‌یابد. این روند در مورد سایر الگوریتم‌های دیگر هم وجود دارد. روش پیشنهادی بهترین کارایی را در مقایسه با سایر الگوریتم‌های موجود داشته است و این برتری در هر دوی پایگاه داده مورد استفاده دیده می‌شود.

جدول (۲) : دقت الگوریتم پیشنهادی با ترکیب‌های بهینه و فاصله منهتن

#	ترکیب پنجره‌ها	انواع تغییرچهره	دقت بازشناسی (٪)
۱	۵،۲۱،۲۵	مدل مو	۹۲/۶۵
۲	۷،۲۱،۲۳،۲۵،۲۹	عینک	۹۱/۶۷
۳	۱۳،۱۹،۲۵،۳۱	کلاه	۸۵/۷۸
۴	۷،۱۱،۱۳،۲۳	ریش وسبیل	۸۹/۷۱
۵	۳،۲۱،۲۳،۲۷،۲۹	لب، ابرو، بینی	۹۳/۱۴
۶	۹،۱۳،۲۱،۲۳	سالخوردگی	۸۲/۳۱
۷	۷،۱۵	تغییرات چندگانه	۶۹/۷۱

۳-۴- اثر نوع گریم بر دقت بازشناسی

بررسی عملکرد الگوریتم بازشناسی چهره پیشنهادی در تصاویر با انواع تغییرات گریم، موضوع مطالعه بعدی در این پژوهش است. تمام آزمایش‌های انجام شده در این بخش جهت تعیین دقت بازشناسی برای انواع مختلف تغییرچهره تحت شرایطی که تنها یک تصویر از هر شخص موجود است مورد بررسی قرار گرفته است. در این آزمایش‌ها با تصویر گالری منفرد، پایگاه تصاویر شامل یک تصویر صورت تمام‌رخ بیرنگ و نورپردازی نشده از هر دسته بوده و مابقی تصاویر به عنوان پایگاه کاوش مورد استفاده قرار می‌گیرند. با اعمال متد SVD به تصویر گالری منفرد، از هر تصویر سه تصویر بازسازی‌شده تولید می‌شود. این رویکرد باعث افزایش دقت بازشناسی در روش پیشنهادی شده است.

پایگاه‌های داده تصاویر به دسته‌های گوناگونی مطابق با انواع تغییرچهره تقسیم شده است. الگوریتم پیشنهادی به طور خاص برای هر دسته ارزیابی شده است. جدول ۴ نتایج ارزیابی روش پیشنهادی را با انواع تغییرات گریم بر روی این پایگاه داده‌ها و در مقایسه با الگوریتم‌های مطرح موجود نمایش می‌دهد. طبق این نتایج عملکرد الگوریتم پیشنهادی برای هر یک از انواع گریم متفاوت می‌باشد. در موردپایگاه داده AR آن دسته از تصاویر با تغییر حالت چهره، بالاترین دقت را داشته زیرا طی آن تنها ناحیه کوچکی از چهره دستخوش تغییر می‌شود و مابقی قسمت‌ها به تشخیص صحیح کمک می‌کنند. در مورد تصاویر با عینک و شال، پنهان ماندن نواحی مهم از چهره منجر به کاهش دقت می‌شود. در پایگاه داده تغییرچهره ساختگی، دو گروه از انواع تغییرات شامل چشم/ابرو و پیری بالاترین دقت را تولید کرده‌اند. در تمام دسته‌های تغییرات گریم، روش پیشنهادی عملکردی قابل رقابت را نسبت به دیگر الگوریتم‌ها به ارمغان آورد.

۴- نتیجه‌گیری

علی رغم تحقیقات فراوان در زمینه بازشناسی چهره، هنوز چالش‌های متعددی ازجمله جعل هویت با استفاده از لوازم گریم و آرایش و کوچک بودن گالری تصاویر در امر بازشناسی وجود دارند. برای رویارویی با این چالش‌ها، در این مقاله یک رویکرد مبتنی بر الگوریتم کوانتیزه‌ساز فاز محلی وجستجوی فراگیر جهت استخراج ویژگی‌ها (LPQ) و تجزیه مقدار تکین (SVD) ارائه شد. از روش SVD برای رفع چالش محدود بودن گالری تصاویر و افزایش نمونه‌های آموزشی استفاده شد. نتایج آزمایش‌ها مشخص کرد چنانچه در الگوریتم کوانتیزه‌ساز فاز محلی، از ترکیب چند پنجره با اندازه‌های مختلف استفاده شود دقت بازشناسی تا حد زیادی افزایش می‌یابد. به همین منظور با استفاده از الگوریتم جستجوی‌فراگیر ترکیبی که بیش‌ترین دقت بازشناسی را دارا بود به عنوان ترکیب بهینه انتخاب شد. این روند برای انواع تغییرات گریم به صورت مجزا انجام شد و برای هر کدام از آنها ترکیب بهینه‌ی متفاوتی حاصل گردید. با آزمایش‌های انجام‌گرفته بر روی دو پایگاه داده AR و تغییرچهره ساختگی، توانایی روش نشان داده شد. به دلیل در دسترس نبودن پایگاه‌داده تغییرچهره استاندارد، ما یک پایگاه داده متشکل از ۳۵۷۰ تصویر چهره از ۸۵ نفر در ۴۲ حالت مختلف با استفاده از نرم‌افزار شبیه‌ساز چهره‌ها فراهم کردیم. الگوریتم پیشنهادی با چند الگوریتم مطرح مورد مقایسه وارزیابی قرار گرفت. نتایج پیاده‌سازی‌های انجام شده، برتری روش پیشنهادی را در مقایسه با روش‌های دیگر نشان داد. همچنین کارائی آن در برخورد با چالش مجموعه گالری منفرد نشان داده شده است.

جدول (۳) : دقت بازشناسی الگوریتم پیشنهادی با کاهش تعداد تصاویر گالری

پایگاه داده	تعداد تصاویر گالری	دقت بازشناسی (٪)						
		PCA*	GF*	LFA*	IGF*	LBP*	2D-LPGNN*	روش پیشنهادی
AR	سه	۵۰/۶	۴۹/۸	۶۸/۵	۹۲/۰	۹۳/۲	۹۴/۵	۹۶/۵۳
	دو	۳۸/۷	۴۱/۷	۵۱/۵	۸۶/۶	۸۷/۹	۹۰/۰	۹۳/۶۶
	یک	۲۸/۴	۳۶/۴	۴۰/۶	۷۷/۱	۷۸/۷	۸۱/۲	۸۳/۵۲
تغییرچهره ساختگی	سه	۸۶/۵	۹۰/۱	۹۲/۹	۹۳/۴	۹۴/۱	۹۵/۶	۹۶/۵۱
	دو	۷۷/۲	۸۲/۲	۸۵/۵	۸۶/۸	۸۸/۳	۹۱/۸	۹۲/۲۸
	یک	۶۹/۶	۷۹/۰	۸۰/۲	۸۰/۶	۸۱/۴	۸۳/۲	۸۴/۷۲

جدول (۴) : دقت بازشناسی الگوریتم پیشنهادی با انواع تغییرات گریم ومقایسه آن با سایر الگوریتم‌ها

پایگاه داده	انواع تغییرات گریم	دقت بازشناسی (٪)						
		PCA*	GF*	LFA*	IGF*	LBP*	2D-LPGNN*	روش پیشنهادی
AR	حالت‌چهره و نورپردازی	۳۱/۵	۳۸/۲	۴۸/۸	۸۵/۵	۸۶/۵	۸۹/۷	۸۹/۴۹
	عینک با نورپردازی	۲۸/۶	۳۱/۹	۳۳/۴	۶۶/۹	۶۹/۲	۷۱/۷	۷۱/۵۴
	شال با نورپردازی	۱۱/۷	۳۱/۹	۳۰/۹	۵۴/۱	۵۵/۴	۷۲/۹	۷۰/۲۳
تغییرچهره ساختگی	مدل مو	۸۵/۷	۹۴/۱	۹۴/۸	۹۴/۸	۹۴/۸	۹۴/۹	۹۴/۶۵
	عینک	۷۰/۹	۵۵/۱	۸۴/۴	۸۴/۶	۸۴/۹	۸۵/۲	۹۱/۶۷
	کلاه	۸۲/۶	۹۰/۹	۹۱/۷	۹۲/۸	۹۳/۱	۹۴/۷	۹۴/۷۸
	ریش و سبیل	۵۹/۱	۸۵/۲	۸۱/۳	۸۲/۸	۸۳/۵	۸۴/۶	۸۹/۷۱
	چشم و ابرو	۸۷/۴	۷۸/۶	۹۶/۳	۹۶/۷	۹۶/۸	۹۷/۱	۹۷/۱۴
	پیری	۷۷/۵	۸۱/۸	۹۲/۹	۹۴/۰	۹۴/۴	۹۵/۴	۹۴/۸۱
	ترکیبی	۱۹/۷	۴۹/۱	۶۱/۳	۶۳/۳	۶۳/۵	۷۱/۲	۶۹/۷۱

* نتایج از [۲] آورده شده است.

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به کارگیری رویکرد سیستم‌های چندعامله در الگوریتم جهش قورباغه

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چکیده – بهینه‌سازی بدین مفهوم است که در بین پارامترهای یک تابع، به دنبال مقادیری باشیم که مقدار تابع را بیشینه یا کمینه می‌کند. کلیه مقادیر مناسب جهت این امر را، راه‌حل‌های ممکن و بهترین مقدار از این مقادیر را، راه‌حل بهینه می‌نامند. از الگوریتم‌های مبتنی بر هوش جمعی می‌توان برای حل مسائل پیچیده همانند مسائل بهینه‌سازی بهره برد. تاکنون الگوریتم‌های مختلفی در این زمینه ارائه شده که الگوریتم جهش قورباغه، گونه‌ای از این الگوریتم‌ها می‌باشد. الگوریتم جهش ترکیبیِ قورباغه (*SFLA*) یک الگوریتم مبتنی بر ممتیک فرامکاشفه‌ای است. این الگوریتم در سال ۲۰۰۳ توسط یوسف و لنزی ایجاد شد. الگوریتم *SFLA* از نحوه‌ی جستجوی غذای گروه‌های قورباغه سرچشمه می‌گیرد. الگوریتم جهش ترکیبیِ قورباغه، یک الگوریتم بهینه‌سازیِ مبتنی بر کولونی است. *SFLA* قابلیت بالایی برای جستجوی سراسری دارد و می‌تواند بسیاری از مسائل غیرخطی، غیرقابل‌تشخیص و چندحالته را حل کند. اما این الگوریتم دارای نقاط ضعفی از جمله گیرافتادن در بهینه محلی و عدم توانایی برهم‌زدن توازن بین جستجوی محلی و سراسری است. در این مقاله نسخه بهبود یافته‌ای از *SFLA* ارائه گردیده است که شامل ترکیب این الگوریتم با سیستم‌های چندعامله می‌باشد.

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۱- مقدمه

در سال‌های اخیر، استفاده از الگوریتم‌های تکاملی و دیگر فرامکاشفه‌ای‌های زیستی، برای حل مسائل گوناگون جستجو و بهینه‌سازی، به طور شگفت‌آوری رشد فزاینده‌ای داشته است. مهمترین عاملی که سبب شده است استفاده از این الگوریتم‌ها به این اندازه مورد توجه جوامع علمی مختلف قرار گیرد، سادگی اعمال‌شدن و کاربرد آنها برای حل مسائل با ماهیت بسیار متفاوت است و همچنین این الگوریتم‌ها قادر به ارائه جواب‌هایی با کیفیت بالا و در زمان قابل قبول برای مسئله جستجوی بسیار پیچیده می‌باشند. الگوریتم جهش‌قورباغه (SFLA) یکی از الگوریتم‌های فرامکاشفه‌ای مبتنی بر هوش‌جمعی است که در این مقاله به کار گرفته شده است. این الگوریتم ترکیب روش قطعی و تصادفی می‌باشد. روش قطعی به الگوریتم امکان می‌دهد تا پیام-ها را به صورت کارایی مبادله کند. روش تصادفی، انعطاف‌پذیری و مقاومت الگوریتم را تضمین می‌کند[۱]. الگوریتم جهش قورباغه جستجوی سراسری و محلی را در حد قابل قبول انجام می‌دهد، اما نمی‌تواند با توجه به شرایط دسته در فضای مسئله یکی از این دو توانایی را تقویت یا تضعیف کند. برای مثال ممکن است شرایط مسئله به گونه‌ای باشد که انجام یک جستجوی محلی قوی برای رسیدن به نتایج بهتر لازم باشد در حالی که برخی از قورباغه‌ها به دنبال بهترین قورباغه دسته خودشان بروند و به نوعی جستجوی سراسری را انجام دهند. در واقع در چنین حالتی بخشی از پتانسیل الگوریتم تلف می‌شود. یکی دیگر از مشکلات اساسی قورباغه، تابعیت تمام اعضای دسته از بهترین عضو دسته می‌باشد. این امر باعث می‌شود بهترین قورباغه دسته شانس کمتری برای یادگیری داشته باشد و الگوریتم در بهینه محلی بیفتد[۲].

از طرفی عامل‌ها به عنوان یک جامعه جهت رسیدن به اهداف شخصی خود و اهداف مشترک رقابت و همکاری می‌کنند. به عبارتی یک عامل، سیستمی است که با شناخت محیط اطراف خود، شانس موفقیت خود را پس از تحلیل و بررسی افزایش می‌دهد. هدف از این تحقیق استفاده از رویکرد سیستم‌های چندعامله علاوه بر تکنیک‌های الگوریتم‌های بهینه‌سازی فرامکاشفه‌ای در الگوریتم جهش قورباغه می‌باشد که در جهت همکاری مناسب‌تر جمعیت قورباغه‌ها با یکدیگر و جلوگیری از همگرایی سریع آنها به نقاط بهینه محلی می‌باشد. مسلما این امر باعث جستجوی گسترده‌تر در فضای مسئله می‌شود که در نهایت احتمال یافتن پاسخ بهینه بالا رفته و عملکرد الگوریتم بهبود می‌یابد.

ادامهٔ این مقاله به صورت زیر سازماندهی شده است: بخش دوم به معرفی الگوریتم SFLA استاندارد می‌پردازد، در بخش سوم سیستم‌های چندعامله به اختصار معرفی شده است، در بخش چهارم الگوریتم پیشنهادی MSFLA شرح داده می‌شود، بخش پنجم نتایج آزمایشات را ارائه می‌کند و بخش پایانی به

نتیجه‌گیری می‌پردازد.

۲- الگوریتم جهش قورباغه‌ها(SFLA)

الگوریتم جهش قورباغه‌ها در سال ۲۰۰۳ توسط یوسف و لنزی ارائه گردید. این الگوریتم بر اساس قوانین احتمالی، جستجوی تصادفی و جمعیت کار می‌کند. روند اجرای این الگوریتم برگرفته شده از رفتار قورباغه‌ها در تالاب‌ها برای یافتن غذا می‌باشد. در مسائل بهینه‌سازی، موقعیت‌هایی که دارای شایستگی بیشتری هستند از مقدار غذای بیشتری برخوردارند و هدف قورباغه‌ها یافتن غذای بیشتر است. بدین ترتیب قورباغه‌ها با اجرای روند SFLA سعی می‌کنند به غذای بیشتری دست یابند[۲].

در ابتدای اجرای SFLA، یک جمعیت از قورباغه ها وجود دارد که به صورت تصادفی در فضای مسئله پخش می‌شوند. در SFLA هر قورباغه نشان‌دهندهٔ یک راه‌حل شدنی در فضای مسئله می‌باشد. پس از تعیین موقعیت قورباغه‌ها، مقدار شایستگی آن‌ها سنجیده می‌شود. موقعیت قورباغهٔ iام در فضای Dبُعدی برابر $x_i=(x_{i,1}, x_{i,2},\dots, x_{i,D})$ می‌باشد و مقدار غذای موجود در موقعیت این قورباغه که همان مقدار شایستگی آن می باشد برابر $f(x_i)$ می‌باشد.

مطابق با سایر الگوریتم‌های هوش جمعی، SFLA نیز به صورت تکرارشونده کار می‌کند و در هر تکرار مراحل زیر انجام می‌شوند: ابتدا اعضای جمعیت بر اساس مقدار شایستگی‌شان، مرتب می شوند (بهترین قورباغه در اندیس یک قرار می‌گیرد).

قورباغه‌ها به m گروه که ممپلکس نام دارند تقسیم می‌شوند. هر ممپلکس شامل n قورباغه خواهد بود. نحوهٔ تقسیم‌بندی جمعیت به m ممپلکس بدین ترتیب است که اولین قورباغه به اولین ممپلکس، دومین قورباغه به دومین ممپلکس و mامین قورباغه به mامین ممپلکس داده خواهد شد. سپس (m+1)امین قورباغه به ۱امین ممپلکس داده می‌شود و به همین ترتیب فرآیند دسته بندی ادامه می‌یابد تا در هر ممپلکس n قورباغه قرار بگیرند.

پس از دسته‌بندی قورباغه‌ها در m ممپلکس، هر ممپلکس روند زیر را itr بار تکرار می‌کند. در هر ممپلکس موقعیت بهترین و بدترین قورباغه از نظر مقدار شایستگی پیدا می‌شود که به ترتیب برابر با X_b و X_w می‌باشد. سپس یک موقعیت کاندید با استفاده از روابط زیر بدست می‌آید:

$$D = Rand.(X_b - X_W) \quad (۱)$$

$$X'_W = X_W + D, \qquad D_{\min} \le D \le D_{\max} \quad (۲)$$

که در روابط ۱و۲، rand یک تابع تولید عدد تصادفی با توزیع یکنواخت در بازهٔ [0,1] می‌باشد و برابر با طول گام جابه‌جایی است که مقدار آن در هر یک از ابعاد مسئله باید در محدودهٔ $[D_{min},D_{max}]$ باشد. پس از بدست آوردن موقعیت X'_W، مقدار شایستگی آن سنجیده می‌شود و در صورتی که مقدار شایستگی آن بهتر از موقعیت قبلی باشد، X_w به موقعیت جدید خود حرکت می‌کند در غیر این صورت روابط ۱ و ۲ مجدداً اجرا می‌شوند با این تفاوت که به جای موقعیت X_b، از موقعیت بهترین قورباغه در میان تمام ممپلکس‌ها یعنی X_g استفاده می‌شود. اگر پس از این مرحله نیز مقدار شایستگی موقعیت بدست آمده از رابطهٔ۲ بهتر از موقعیت قبلی X_w نبود، این قورباغه مقداردهی اولیه می‌شود یعنی موقعیت جدید آن در فضای مسئله به صورت تصادفی تعیین می‌شود. پس از انجام مرحلهٔ ۳ توسط تمام ممپلکس‌ها (به تعداد itr بار)، شرط پایان الگوریتم سنجیده می شود و در صورتی که این شرط برقرار نشود، مجدداً تمام قورباغه ها بدون در نظر گرفتن اینکه عضو کدام ممپلکس بوده اند در یک دسته قرار می‌گیرند (shuffling) و مراحل ۱ تا ۳ را اجرا می کنند[۳].

۳- سیستم‌های چندعامله

سیستم‌های چندعامله (MAS) یک سیستم نرم‌افزاری است که شامل مجموعه‌ای از عامل‌های نرم‌افزاری می‌باشد و عامل‌ها جهت حل یک مسئله و رسیدن به هدف مورد نظر در کنار یکدیگر به وظایف خود عمل می‌کنند. عامل‌ها در سیستم‌های چندعامله از طریق برقراری ارتباط با یکدیگر تعامل می‌کنند و این توانایی را دارند که در یک محیط درکنار یکدیگر درحال کار بوده و سعی در انجام کاری خاص و رسیدن به هدفی مشخص را داشته باشند.

سیستم‌های چندعامله فرصتی را جهت محاسبه و بهینه‌سازی بسیاری از مشکلات پیچیده فراهم می‌کنند. عامل‌ها در MAS، به عنوان یک جامعه برای رسیدن به اهداف شخصی و اهداف مشترک رقابت و همکاری می‌کنند. این رقابت و همکاری منطبق بر ماهیت اصلی یک ذره در الگویتم‌های هوش‌جمعی می‌باشد. از این رو، در بکارگیری رویکرد سیستم‌های چندعامله در الگوریتم-های هوش‌جمعی، می‌بایست چهار مفهوم زیر بررسی شود [۴]:

- معنا و هدف هر عامل در MAS.
- محیطی که همه عامل‌ها در آن زندگی می‌کنند.
- تعریف محیط محلی.
- مجموعه‌ای از قوانین رفتاری، مربوط به تعامل بین عامل-

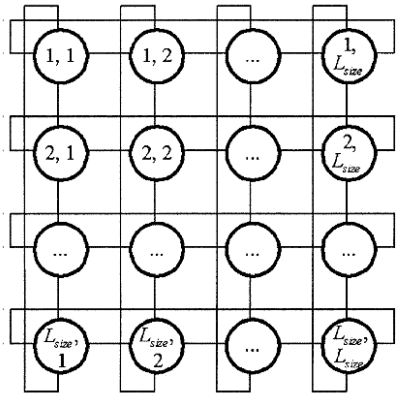
ها و محیط خود.

در بخش بعد که مربوط به الگوریتم پیشنهادی می‌باشد، این مفاهیم با جزئیات شرح داده می‌شوند.

۴- الگوریتم پیشنهادی

همان‌طور که در بحث مشکلات الگوریتم جهش قورباغه استاندارد در فصل دوم گفته شد، یکی از مشکلات اساسی الگوریتم قورباغه، تابعیت تمام اعضای دسته از بهترین عضو دسته می‌باشد. این امر باعث می‌شود بهترین قورباغه دسته شانس کمتری برای یادگیری داشته باشد و الگوریتم در بهینه محلی بیفتد.

در این حالت الگوریتم تنوع خود را از دست داده و قادر به یافتن نقاط جدید نمی‌باشد و به ندرت رفتاری را انجام خواهد داد که بتواند از بهینه محلی جدا شده و در فضای گسترده‌ای جستجوی خود را ادامه دهد. از این رو در این فصل یک الگوریتم جهش قورباغه بهبود یافته با توجه به رویکرد سیستم‌های چندعامله ارائه شده است. در الگوریتم پیشنهادی قورباغه مبتنی بر سیستم‌های چندعامله (MSFLA)، علاوه بر تکنیک‌های الگوریتم‌های بهینه‌سازی از ویژگی‌های سیستم‌های چندعامله در جهت بهبود عملکرد الگوریتم جهش قورباغه استاندارد استفاده شده است. در الگوریتم پیشنهادی MSFLA، هرقورباغه به عنوان یک عامل در نظر گرفته می‌شود و هر عامل نیز نشان دهنده یک راه‌حل پیشنهادی برای مسائل بهینه‌سازی می‌باشد. در ابتدا یک محیط شبکه‌ای مانند شکل ۱ ایجاد کرده و هر عامل را در یک نقطه از این محیط شبکه‌ای قرار می‌دهیم.



شکل ۱: مدلی از محیط شبکه‌ای عامل‌ها.

پس از ایجاد محیط شبکه‌ای عامل‌ها، هر عامل با همسایه‌های خود، محیط محلی کوچکی را می‌سازند که تنها قادر به حس آن محیط می‌باشند. سپس جهت بدست آوردن راه‌حل مطلوب، عامل‌ها با هم رقابت و همکاری می‌کنند. در بکارگیری رویکرد سیستم‌های چندعامله در الگوریتم جهش قورباغه، می‌بایست چهار مفهوم مورد بررسی قرار گیرد.

۴-۱- هدف هر عامل در MSFLA

در MSFLA، هر عامل α نشان دهنده یک راه‌حل پیشنهادی برای مسائل بهینه‌سازی و نماینده یک قورباغه در الگوریتم جهش قورباغه می‌باشد. از این رو عامل α دارای یک مقدار شایستگی بوده و هدف به حداقل رساندن مقدار آن در مسائل بهینه‌سازی می‌باشد.

۴-۲- تعریف عامل

در MSFLA تمام عامل‌ها در یک محیط شبکه‌ای (L) زندگی می‌کنند، مانند شکل ۱. هر عامل در یک نقطه از این محیط شبکه قرار گرفته است و هر دایره نشان دهنده یک عامل می‌باشد. اطلاعات درون دایره حاوی موقعیت عامل در محیط شبکه ای است. با توجه به اینکه هر عامل در این محیط نماینده یک قورباغه در SFLA می‌باشد پس اطلاعات مربوط به موقعیت و مقدار تابع هزینه خود را در فضای جستجوی واقعی نیز دارد. اندازه محیط شبکه L به صورت Lsize * Lsize می‌باشد که Lsize یک عدد صحیح است (برابر با اندازه جمعیت).

۴-۳- تعریف محیط محلی

از آنجا که هر عامل در MAS فقط قادر به درک محیط محلی خودش می‌باشد، تعریف محیط محلی بسیار مهم است، در الگوریتم MSFLA موقعیت هر عامل در محیط L به صورت $\alpha_{i,j}, i,j = 1,2,\dots L_{size}$ می‌باشد و همسایه‌های عامل $\alpha_{i,j}$، به صورت زیر تعریف می‌شوند.

$$N_{i,j} = \{\alpha_{i^1,j}, \alpha_{i,j^1}, \alpha_{i^2,j}, \alpha_{i,j^2}\} \quad (۳)$$

بنابراین همسایگان عامل $\alpha_{i,j}$، طبق رابطه (۴) بدست می‌آید.

$$i^1 \begin{cases} i-1 & i \neq 1 \\ L_{size} & i = 1 \end{cases}, \quad j^1 \begin{cases} j-1 & j \neq 1 \\ L_{size} & j = 1 \end{cases} \quad (۴)$$
$$i^2 \begin{cases} i+1 & i \neq L_{size} \\ 1 & i = L_{size} \end{cases}, \quad j^2 \begin{cases} j+1 & j \neq L_{size} \\ 1 & j = L_{size} \end{cases}$$

باتوجه به رابطه (۳) و (۴)، هر عامل چهار همسایه دارد. عامل‌ها با همسایه‌های خود، محیط محلی کوچکی را می‌سازند که هر عامل تنها قادر به حس آن محیط می‌باشد.

۴-۴- استراتژی رفتارهای بین عامل‌ها

عامل‌ها برای اینکه سریعتر و با دقت بیشتری به هدف برسند

دارای یکسری خصوصیات رفتاری می‌باشند. در الگوریتم پیشنهادی، ابتدا عامل‌ها جهت بهبود مقدار شایستگی‌یشان با همسایگان خود به رقابت و همکاری می‌پردازند، سپس جهت اینکه اطلاعات مفید و مناسب در کل محیط پخش شود از الگوریتم SFLA استفاده می‌کنند. با توجه به این مفاهیم سه عملگر در الگوریتم MSFLA طراحی شده است.

- عملگر رقابت و همکاری

عملگر رقابت و همکاری بر روی عامل α که در موقعیت i,j شبکه L قرار دارد انجام می‌شود و $\alpha_{i,j} = (\alpha_1, \alpha_1, \dots, \alpha_n)$ نیز یک بردار حقیقی در فضای جستجو می‌باشد. فرض کنید $m = MinN_{i,j} = (m_1, m_2, \dots, m_n)$ که m عاملی است با کمترین مقدار تابع هزینه (مسئله کمینه‌سازی) در میان همسایه‌های عامل $\alpha_{i,j}$، به عبارتی $m \in N_{i,j}$ ، $\forall_\varepsilon \in N_{i,j}$ ، انگاه $f(\varepsilon) \geq f(m)$.

اگرشرط $f(\alpha_{i,j}) \leq f(m)$ برقرار باشد، عامل $\alpha_{i,j}$ برنده شده زیرا مقدار تابع هزینه‌اش از کمترین مقدار تابع هزینه همسایگان خود کمتر بوده، پس در شبکه عامل‌ها می‌ماند و موقعیتش در فضای جستجو تغییر نمی‌کند. در غیر این صورت عامل $\alpha_{i,j}$ بازنده شناخته می‌شود و می‌بایست موقعیت عامل $\alpha_{i,j}$ در شبکه عامل‌ها توسط عامل جدید New_{ij} اشغال شود. در الگوریتم پیشنهادی عامل جدید $New_{ij} = (\alpha'_1, \alpha'_2, \dots, \alpha'_n)$ توسط دو استراتژی زیر تعیین می‌شوند.

- استراتژی اول

این استراتژی نوعی بازترکیب می‌باشد که از اطلاعات بازنده نیز استفاده می‌کند [۴]. در این استراتژی عامل جدید New_{ij} طبق رابطه (۵) تعیین می‌شود.

$$\alpha'_k = m_k + rand(0,1) \cdot (m_k - a_k)\ k = 1,2, \dots, n \quad (۵)$$

که $rand(0,1)$ یک عدد تصادفی در بازه [0,1] می‌باشد. فرض کنید X_{min} و X_{max}، دو برداری هستند که محدوده پایین و بالای فضای جستجو را مشخص می‌کنند.

- استراتژی دوم

این استراتژی نوعی جهش است که همانند تابعی از جستجوی تصادفی می‌باشد با این تفاوت که از اطلاعات عامل برنده نیز در جهت تعیین موقعیت عامل جدید استفاده می‌کند [۵]. ابتدا بهترین همسایه $(MinN_{i,j})$ با توجه به رابطه (۶) به بازه [0,1]نگاشت می‌دهیم.

$$m'_k = \frac{m_k - x_{\min k}}{x_{\max k} - x_{\min k}}, k = 1,2, \dots, n \quad (۶)$$

سپس عامل جدید $New'_{ij} = (\beta'_1, \beta'_2, \dots, \beta'_n)$ را با رابطه ۷ تخمین می‌زنیم.

(۷)

$$New'_{ij} = (m'_1, m'_2, \dots, m'_{i1-1}, m'_{i2}, m'_{i2-1}, \dots, m'_{i1+1}, m'_{i1}, m'_{i2+1}, m'_{i2+2}, \dots, m'_n)$$

که $1 < i_1 < n$ ، $1 < i_2 < n$ و $i1 < i2$. در انتها عامل جدید را با توجه به رابطه (۸) به بازه $[X_{min}, X_{Max}]$ باز می‌گردانیم.

$$\alpha'_k = x_{\min k} + \beta'_k \cdot (x_{\max k} - x_{\min k})\ k = 1,2, \dots, n \quad (۸)$$

(

با توجه به توضیحات داده شده، استراتژی اول بهره برداری و استراتژی دوم اکتشاف را افزایش می‌دهد. در این مقاله جهت برقراری توازن بین این دو استراتژی و یا احتمال رخ دادن بیشتر یکی از آنها، از دو پارامتر احتمال pc (احتمال رخ دادن استراتژی اول) و pm (احتمال رخ دادن استراتژی دوم) استفاده شده است.

- عملگر SFLA

از آنجا که هر عامل تنها محیط محلی خود را حس می‌کند، رقابت و همکاری نیز تنها میان آن و همسایه‌گانش صورت می‌پذیرد. این ارتباط محدود باعث شده اطلاعات به آرامی از شبکه محلی به کل شبکه منتقل شود. به منظور سرعت بخشیدن به انتشار اطلاعات مفید به کل شبکه عامل‌ها، افزایش بهره‌بری محاسباتی و بدست آوردن راه‌حل بهینه مناسب، از الگوریتم جهش قورباغه استفاده شده است. از طرفی الگوریتم جهش قورباغه استاندارد زمانی که در یک بهینه محلی گیر می‌افتد به ندرت رفتاری را انجام خواهد داد تا بتواند از یک بهینه محلی جدا شده و در فضای گسترده‌ای جستجوی خود را ادامه دهد. در الگوریتم پیشنهادی سعی بر آن است تا بتوان با به کارگیری ویژگی‌های سیستم‌های چندعامله و الگوریتم SFLA، عملکرد الگوریتم را بهبود بخشید. در الگوریتم MSFLA هر عامل موقعیت خود را در فضای جستجو با توجه به رابطه‌های (۱) و(۲) بروزرسانی می‌کند.

- عملگر خود یادگیر

با استفاده از عملگر خودیادگیری هر عامل می‌تواند از دانش خود در جهت بهبود توانایی‌هایش استفاده کند. در [۴] از الگوریتم ژنتیک در یک مقیاس خیلی کوچک، به عنوان جستجوگر محلی استفاده شده که عملکرد روش آنها را بهبود بخشده است. در این قسمت یک عملگر خودیادگیر با استفاده از الگوریتم MSFLA (در یک مقیاس‌کوچک) و دانش هر عامل ارائه می‌شود. جهت جلوگیری از افزایش بار محاسباتی، عملگر

خودیادگیر تنها بر روی بهترین عامل انجام می‌دهیم. در ابتدا محیط شبکه‌ای SL ساخته می‌شود که اندازه SL ، SLsize * SLsize می‌باشد و SLsize یک عدد صحیح کوچک است. عامل-های جدید $New\alpha_{i',j'} = (e_{i',j',1}, e_{i',j',2}, \dots, e_{i',j',n})$ طبق رابطه (۹) و (۱۰) ایجاد شده و در محیط شبکه‌ای SL قرار می-گیرد.

$$\alpha_{i',j'} = \begin{cases} \alpha_{i,j}, & i'=1, j'=1 \\ New\alpha_{i',j'}, & otherwise \end{cases} \quad i',j' = 1,2,\dots SL_{size} \qquad (۹)$$

$$e_{i',j',k} = \begin{cases} x_{k\,min}, & \alpha_k * \mathrm{rand}(1-sR, 1+sR) < x_{k\,max} \\ x_{k\,max}, & \alpha_k * \mathrm{rand}(1-sR, 1+sR) > x_{k\,max} \\ \alpha_k * \mathrm{rand}(1-sR, 1+sR), & otherwisee \end{cases} \qquad (۱۰)$$

sR شعاع جستجو می‌باشد که $sR \in [0,1]$. بعد از ایجاد محیط شبکه‌ای SL برای بهترین عامل (Gbest)، عملگر رقابت و همکاری و عملگرSFLA به تعداد r بار انجام می‌شوند. در انتها عاملی که دارای کمترین مقدار تابع هزینه هست جایگزین Gbest می‌شود. در شکل ۲ شبه‌کد الگوریتم پیشنهادی نشان داده شده است.

1. Generate Initial Population of Shuffle Frog x_i (i=1,2,…,n)
2. t=0 , Initialize p_m ,p_c and SFLA Parameters , Creat table L, Initialize L^t using the Values Generated by the Step 1 , Update Gbest .
3. Perform The Neighborhood Competition Operator on Each Agent in L^t
   - For Each Loser Agent in L^t , IF Rand(0,1) ≤ p_c Perform Strategy 1 According to Equation (۷) ; and , IF Rand(0,1) ≤ p_m Perform Strategy 2 According to Equation (۹)
   - Update L^t
4. Perform SFLA Operator (Input = L^t);Update L^t
5. Find Ibest^t in L^t and then Perform the Self-learning Operator (Input = Ibest^t), Ibest^t= Self-learning Operator Output.
6. IF Cost (Ibest^t) < Cost (Gbest) Then Gbest= Ibest^t and Update L^t.
7. IF Termination Criteria are Reached, Output Gbest and Stop; Otherwise t=t+1, $L^t = L^{t-1}$ and Increase P_c, Decrease P_m, Go to Step 3.

شکل ۲: شبه کد الگوریتم پیشنهادی MSFLA.

در این شبه کد L_t نشان دهنده محیط شبکه‌ای ایجاد شده در تکرار tام می‌باشد، Gbest بهترین عامل در میان $L_0, L_1, \dots, L_t$ و $Ibest_t$ بهترین عامل در تکرار tام است. P_c و P_m به ترتیب احتمال رخ دادن استراتژی اول و دوم در عملگر رقابت و همکاری بوده و t نیز تعداد تکرار الگوریتم می‌باشد.

۵- نتایج آزمایشات

در این بخش به مقایسه و بررسی نتایج الگوریتم پیشنهادی MSFLA، الگوریتم SFLA استاندارد و دو الگوریتم شناخته شده‌ی دیگر در این زمینه، که شامل LPSO [۶]، GPSO [۶] می‌باشند، می‌پردازیم. آزمایشات بر روی پنج تابع بنچمارک که عموماً برای سنجش کارایی الگوریتم‌های بهینه سازی مورد استفاده قرار می‌گیرند، انجام شده است. رابطه‌ی مربوط به این توابع به همراه مقادیر بهینه، ابعاد و محدوده‌ی فضای مسئله در جدول ۱ نشان داده شده است. تنظیمات مربوط به دو الگوریتم PSO بدین شرح است: c1=c2=2، اندازه‌ی جمعیت برابر۴۰ و مقدار w در بازه [0.4,0.9] تغییر می‌کند بر اساس آزمایشات بسیار زیادی که بر روی الگوریتم SFLA و الگوریتم پیشنهادی انجام داده‌ایم به این نتیجه رسیده‌ایم که تنظیم پارامترهای این دو الگوریتم بر اساس مقادیر آورده شده در ادامه، در مجموع بهترین نتایج را تولید می‌کنند.

تعداد جمعیت اولیه در هر دو الگوریتم جهش قورباغه برابر ۴۰ درنظر گرفته‌ایم و تعداد دسته‌ها ۱۰ و تعداد قورباغه‌ها در هر دسته را ۴ درنظر گرفتیم. مقدار پارامتر sR را در الگوریتم پیشنهادی برابر ۰,۲۵ در نظر گرفته‌ایم.

جدول ۱: توابع بنچمارک به کار رفته در این بخش.

Test Function	Search Space	Global f_{min}	Name of Function
$f1(x) = 20 + e - 20e^{-0.2\sqrt{\frac{1}{n}\sum_{i=1}^{n} x_i^2}} - e^{\frac{1}{n}\sum_{i=1}^{n}\cos(2\pi x_i)}$	$[-32,32]^D$	0	Ackly
$f2(x) = \sum_{i=1}^{n}\left(\frac{x_i^2}{4000}\right) - \prod_{i=1}^{n}\cos\left(\frac{x_i}{\sqrt{i}}\right) + 1$	$[-600,600]^D$	0	Griewank
$f3(x) = \sum_{i=1}^{D} x_i^2$	$[-100,100]^D$	0	Sphere
$f_4(x) = \sum_{i=1}^{D} x_i^2 + \left(\sum_{i=1}^{D} 0.5 x_i\right)^2 + \left(\sum_{i=1}^{D} 0.5 x_i\right)^4$	$[-5,10]^D$	0	Zakharov
$f_5(x) = 10d + \sum_{i}^{D}\left[x_i^2 - 10\cos(2\pi x_i)\right]$	[-5.12,-5,12]	0	Rastrigin

آزمایشات برای تمامی الگوریتم‌ها ۳۰ بار انجام شده است و متوسط نتایج، بهترین و انحراف استاندارد آنها در جدول ۲ نشان داده شده است. جهت برقراری عدالت در اجرای الگوریتم‌های مختلف، شرط پایان را به جای اینکه مبتنی بر تعداد تکرار (نسل) در نظر بگیریم، بر اساس تعداد ارزیابی شایستگی در نظر می-گیریم. شرط پایان اجرای الگوریتم‌ها انجام۲۰۰۰۰۰ ارزیابی شایستگی می‌باشد.

همانطور که نتایج جدول۲ نشان می‌دهد، الگوریتم پیشنهادی در مجموع در سه تابع از پنج تابع تست شده نسبت به دیگر الگوریتم‌ها به نتایج بهتری دست یافته است و در دو تابع دیگر

نیز به نتایج قابل قبولی رسیده است. نتایج بدست آمده از الگوریتم پیشنهادی نشان می‌دهد که مکانیزم به کار رفته در آنها توانسته باعث افزایش کارایی الگوریتم SFLA شود. بهبود کارایی الگوریتم پیشنهادی نسبت به SFLA استاندارد را می‌تواند به دلایلی همچون نحوه تعیین همسایگی، ایجاد ارتباط مناسب بین عامل‌ها، استفاده از استراتژی‌های مناسب جهت همکاری و رقابت بین عامل‌ها و همچنین بکارگیری عملگر خود یادگیر برای بهبود بهترین عامل در هر تکرار دانست.

جدول۲ : نتایج ارزیابی در فضای ۳۰ بعدی.

Function	Criteria	GPSO	LPSO	SFLA	MSFLA
Ackly	Best	7.92e-15	2.29e-04	19.17	4.34e-06
	Mean	1.34e-14	1.51e-03	19.68	6.43e-05
	Std-Dev	4.81e-15	1.65e-03	0.58	4.26e-05
Griwank	Best	1.13e-16	1.46e-06	1.14	3.96e-10
	Mean	0.013	1.23e-03	1.17	4.35e-07
	Std-Dev	0.016	3.42e-03	0.011	6.47e-07
Sphere	Best	2.86e-34	6.39e-08	17.61	7.13e-11
	Mean	8.63e-32	6.58e-07	19.38	2.80e-10
	Std-Dev	2.73e-31	6.10e-007	1.41	2.45e-10
Rastrigin	Best	18.90	21.89	128.85	13.04
	Mean	38.05	29.48	211.89	22.65
	Std-Dev	12.57	4.24	35.38	7.92
Zakharov	Best	1.33e-04	4.54	0.44	4.30e-05
	Mean	9.19e-04	11.32	8.31	4.71e-04
	Std-Dev	7.85e-04	2.97	10.91	3.15e-04

۶- نتیجه‌گیری

در این مقاله، یک الگوریتم پیشنهادی بر پایه الگوریتم جهش قورباغه استاندارد و سیستم‌های چند عامله ارائه گردید و کارایی آن با چندین الگوریتم شناخته شده مورد مقایسه قرار گرفت. در الگوریتم پیشنهاد شده هرقورباغه به عنوان یک عامل در نظر گرفته می‌شد و در جهت بدست آوردن راه‌حل مطلوب‌تر با دیگر عامل‌ها رقابت و همکاری می‌کردند. نتایج آزمایشات نشان دادند که الگوریتم پیشنهادی بهبود قابل توجهی نسبت به الگوریتم جهش قورباغه استاندارد داشته است و می‌تواند با روش‌های معروف بهینه‌سازی مقایسه شود.

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بهبود الگوریتم مبتنی برجمعیت سیاه چاله با استفاده از اتوماتای یادگیر

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چکیده-تکنیک سیاهچاله یکی از جدیدترین تکنیک های برگرفته از طبیعت می باشد که نتایج بهتری نسبت به سایر الگوریتم های تکاملی بدست آورده است اما همچنان مشکل همگرایی به بهینه های محلی در آن وجود دارد.این مقاله یک الگوریتم جدید ترکیبی برای حل مشکل بهینه های محلی ارائه می نماید. الگوریتم پیشنهادی، ترکیبی از الگوریتم تکاملی سیاه چاله و اتوماتای یادگیر است که با عنوان BH–LA ارائه شده است. در الگوریتم پیشنهادی اتوماتای یادگیر با استفاده از بازخورد دریافتی از محیط جهت حرکت جمعیت الگوریتم سیاهچالهرا کنترل می نماید. این الگوریتم ترکیبی با کارایی بالاتر از هر دو الگوریتم ذکر شده توانایی افراز خوشه ها را دارا می باشد. کارایی الگوریتم ارائه شده توسط چندین مجموعه داده واقعی ارزیابی شده است. نتایج آزمایش های انجام شده برروی مجموعه داده های استاندارد نشان می دهند که کارایی الگوریتم ارائه شده از نظر دقت خوشه بندی بهتر از سایر الگوریتم ها نظیر K- means, Black hole, pso می باشد.

کلید واژه- *Learning Automata,Black hole,data clustering,Nature-inspired algorithm*

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۱-مقدمه

هدف از خوشه بندی ایجاد زیرمجموعه های جدا از هم, از داده های اولیه می باشد به طوری که فاصله نقاط قرار گرفته در یک خوشه از مرکز همان خوشه کمینه و فاصله مراکز خوشه ها تا یکدیگر بیشینه باشد[۱].

یکی از روشهای های محبوب و پر کاربرد درخوشه بندی استفاده از هوش جمعی است که از چند دهه گذشته تحقیقات زیادی جهت توسعه و بهبود کارایی آن انجام پذیرفته است.[۱].

الگوریتم سیاه چاله یکی از جدیترین روش های تکاملی مبتنی بر جمعیت الهام گرفته شده ازطبیعت است که در حل مسائل بهینه سازی خصوصا خوشه بندی داده ها نتایج بهتری از الگوریتم های تکاملی دیگر نظیر pso بدست آورده است[۲].

از طرف دیگر در الگوریتم تکاملی سیاهچاله ذرات بدون هیچگونه یادگیری و بازخوردی از محیط، تنها به سمتیکه بهترین تجربه گروهی در آن نقطه روی داده است با سرعت ثابت در حال حرکت هستند. حرکت تنها به سمت بهینه سراسری روشی بسیار ساده است که توانایی به کارگیری کامل دانش اولیه راجع به مساله و نیز استفاده از بازخورد سیستم را ندارد بنابراین احتمال گیر افتادن در بهینه های محلی به خصوص در مسائل چند قله ای وجود دارد.

اکتشاف فضای جدید و بهره برداری از اطلاعات بدست آمده دو هدف اصلی جستجو می باشد. بنابراین در بسیاری از روشهای جستجو از ترکیب روشهای جستجوی سراسری و روشهای جستجوی محلی برای رسیدن به این هدف استفاده نموده اند[۳].

در این مقاله یک الگوریتم خوشه بندی جدید با استفاده از ترکیب روشتکاملی سیاهچاله و اتوماتای یادگیربه نام BH-LAارائه میگردد. در این الگوریتم نیز همانند الگوریتم سیاهچاله یک جمعیتاز ستاره ها وجود دارد و هر یک از ستاره ها دارای یکموقعیت است و یک سرعت اولیه هستند. تفاوت الگوریتم پیشنهادی با الگوریتم استاندارد این است کهالگوریتم پیشنهادی از یک اتوماتای یادگیر برای کنترل رفتار ستاره ها و برقراری موازنه بین جستجوی سراسری و جستجوی محلی استفاده میکند.

نتایج آزمایشات روی مجموعه داده های واقعی نشان می دهد که الگوریتم BH-LA عملکرد بهتری در یافتن مراکز خوشه ها نسبت به روش های موجود دیگر در مساله خوشه بندی دارد.

۱- اتوماتای یادگیر

اتوماتای یادگیر[۴]یک واحد تصمیم گیری خودتطبیق است. اتوماتای یادگیر را می توان به عنوان تعیین کنندهیک عمل

بهینه از میان مجموعه ای از عمل ها که از طریق تعاملات مکرر با یک محیط تصادفی ناشناخته بدست می آید توصیف نمود. هر بار یک عمل بر اساس توزیع احتمال آن لحظه انتخاب نموده و روی محیط تصادفی اعمال می نماید. سپس محیط یک سیگنال تقویتی به محیط می فرستند تا عمل انتخاب شده را ارزیابی نماید. اتوماتای یادگیر پاسخ محیط را پردازش نموده و بردار احتمال عمل را به روز می نماید. با تکرار این فرایند اتوماتا یاد می گیرد چگونه عمل بهینه را انتخاب نماید و جریمه دریافتی از محیط را به حداقل برساند.

محیط توسط سه تایی $E \equiv \{\alpha, \beta, c\}$ توصیف می گردد که $\alpha \equiv \{\alpha_1, \alpha_2, ..., \alpha_r\}$ مجموعه متناهی از ورودی ها است، $\beta \equiv \{\beta_1, \beta_2, ..., \beta_m\}$ مجموعه خروجی ها است که توسط سیگنال تقویتی دریافت می گردد، $c \equiv \{c_1, c_2, ..., c_r\}$ مجموعه احتمال های جریمه است که در آن c_i مربوط به عمل α_i می باشد. ورودی $\alpha(n)$ متعلق به مجموعه α در زمانهای گسسته t=n(n=0,1,2,…) به محیط اعمال می گردد. $\beta(n)$ خروجی دریافتی متعلق به مجموعه β در محیط از نوع Q می تواند شامل مقادیر ۰ و ۱ باشد. $\beta(n) = 1$ نشان دهنده شکست یا پاسخ نامطلوب محیط است و $\beta(n) = 0$ نشان دهنده موفقیت یا پاسخ مطلوب محیط است و در محیط از نوع S، $\beta(n)$ متغیر تصادفی در فاصله [۰,۱] است. c_i احتمال اینکه عمل α_i نتیجه نامطلوبداشته باشد میباشد. c_i متعلق به مجموعه C توسط

$$\Pr(\beta(n) \equiv 1 \mid \alpha(n) = \alpha_i) = c_i (i = 1,2,...,r)$$

نمایش داده می شود.در محیط ایستا، مقادیر c_i بدون تغییر میمانند، حال آنکه در محیط غیر ایستا این مقادیر در طی زمان تغییر میکنند. در شکل زیر ارتباط میان اتوماتای یادگیر با محیط تصادفی نمایش داده شده است.



اتوماتاها به دو گروه اصلی اتوماتای یادگیر با ساختار ثابت و اتوماتای یادگیر با ساختار متغیرتقسیم می شوند[۶]. اتوماتای یادگیر با ساختار ثابت توسط پنج تایی $\{\alpha, \beta, F, G, \phi\}$ نشان داده میشود که در آن $\alpha \equiv \{\alpha_1, \alpha_2, \cdots, \alpha_r\}$ مجموعه عملهایی که اتوماتا از میان آن ها انتخاب می نماید, $\beta \equiv \{\beta_1, \beta_2, \cdots, \beta_m\}$ مجموعه ورودیها که مقدار یک نشان دهنده جریمه و صفر نشان دهنده پاداش است, $\phi \equiv \{\phi_1, \phi_2, \cdots, \phi_s\}$ مجموعه وضعیتهای داخلی، $F : \phi \times \beta \to \phi$ تابع نگاشت وضعیت فعلی و ورودی به وضعیت جدید اتوماتا است و $G : \phi \to \alpha$ تابع نگاشت وضعیت فعلی به ورودی فعلی است به عبارت دیگر G عمل انتخاب شده توسط اتوماتا را معین می نماید[۵].

اتوماتای یادگیر با ساختار متغیر با چهارتایی $\{\alpha, \beta, p, T\}$ نشان داد می شود که $\alpha = \{\alpha_1, ..., \alpha_r\}$ مجموعه عملهای قابل انتخاب توسط اتوماتا، $\beta = \{\beta_1, ..., \beta_m\}$ مجموعه ورودی ها، $p = \{p_1, ..., p_r\}$ بردار احتمال انتخاب هریک از عملها و $p(n+1) = T[\alpha(n), \beta(n), p(n)]$ الگوریتم یادگیری میباشد.اگر پارامتر پاداش و جریمه با هم برابر باشند، الگوریتم را L_{RP}، هنگامی که جریمه از پاداش خیلی کوچکتر باشد، الگوریتم را $L_{R\varepsilon P}$ و اگر جریمه مساوی صفر باشد آن را L_{RI} مینامیم[۶].

۲- الگوریتم سیاه چاله

در چند دهه اخیر تعداد زیادی الگوریتم از طبیعت برگرفته شده است برای مثال می توان به چند الگوریتم زیر اشاره نمود. الگوریتم های ژنتیک از عمل پراکندگی گونه های ژنتیکی برگرفته شده است [۷] و بهینه سازی کلونی مورچه ها از رفتار واقعی کلونی مورچه ها الهام گرفته شده است که کوتاهترین مسیر را میان غذا و لانه پیدا می کنند [۸]. یا الگوریتم حرکت جمعی ذرات که بر اساس رفتار جمعی مانند ماهی ها و پرندگان توسعه یافته اند[۹][۱۰]. الگوریتم قطره های آب که الهام گرفته شده از رفتار جریان رودخانه ها است که بهترین مسیر را به مقصد از میان سست ترین خاک پیدا می کند[۱۱].یا الگوریتم کرم های شب تاب [۱۲] و رفتار زنبورهای عسل که بر اساس رفتار واقعی کلونی زنبورها می باشد[۱۳][۱۴]. همچنین روش بهینه سازی جستجوی هارمونی که عمل پیدا نمودن هارمونی قطعات موسیقی همانند عمل یافتن راه حل بهینه است[۱۵]. الگوریتم سیاه چاله ها نیز از پدیده سیاه چاله در فضا برگرفته

شده است. جرم بسیار زیاد سیاه چاله سبب جاذبه بالای آن شده است که هیچ چیز حتی نور نمی تواند از آن فرار کند و هر چیزی را که در شعاع خاصی از آن قرار گیرد را می بلعد.در الگوریتم سیاه چاله همانند سایر الگوریتم های مبتنی بر جمعیت,مقادیر اولیه جواب های کاندید به صورت تصادفی انتخابشده و در فضای جستجو توزیع می گردند.در ادامه تابع هدف برای جواب های کاندید محاسبه می گردد و بهترین کاندید به عنوان سیاه چاله انتخاب می شود سپس سیاه چاله شروع به جذب جواب های کاندید اطراف خود که ستاره نامیده می شوند می نماید. درصورتی که یک ستاره بیش از اندازه به سیاه چاله نزدیک شود برای همیشه بلعیده خواهد شد. در چنین مواردی یک ستاره جدید(جواب کاندید جدید) تولید شده و به طور تصادفی در فضای جستجو قرار می گیرد و این کار تا رسیدن به میزان خطای کمتر از یک حد آستانه تکرار می گردد. بر اساس توصیف ذکر شده در بالا گام های اصلی الگوریتم سیاه چاله به صورت زیر خلاصه می گردد[۲]:

شروع حلقه

۱- تابع هدف برای هر ستاره تعریف می گردد.

۲- ستاره ای که بهترین مقدار تطبیق را دارا می باشد به عنوان سیاه چاله انتخاب می گردد.

۳- مکان ستاره ها با توجه به فرمول زیر تغییر می یابد.

$$x_i(t+1) = x_i(t) + rand \times (x_{BH} -, x_i(t)) \quad i = 1,2,\ldots,N$$

که در اینجا $x_i(t)$ و $x_i(t+1)$ به ترتیب مکان های ستاره i ام در تکرارهای t و t+1 می باشد. X_{BH} مکان سیاه چاله در فضای جستجو است.rand یک عدد تصادفی بین صفر و یک است و N تعداد ستاره ها و راه حل های کاندید است.

۴- درصورتی که مکان ستاره ای در شعاع سیاه چاله که در فرمول زیر به آن اشاره گردیده است قرار گیرد با یک ستاره جدید که به طور تصادفی مکان آن تعیین می گردد جایگزین می گردد.

$$R = \frac{f_{BH}}{\sum_{i=1}^{N} f_i}$$

که f_{BH} مقدار fitness برای سایه چاله است و f_i همان مقدار برای ستاره i ام است و N تعداد ستاره ها (راه حل های کاندید) است.

۵- در صورتی که تعداد تکرار لازم با مقادیر تطبیق مناسب بدست آید حلقه خاتمه می یابد.

پایان حلقه.

۳- الگوریتم پیشنهادی BH- LA

در این بخش الگوریتم سیاهچاله بهبودیافته برپایه اتوماتای یادگیر با نام BH-LAارائه گردیده است. در الگوریتم پیشنهادی همانند الگوریتم سیاهچاله یک جمعیت از ستاره ها که هر کدام دارای موقعیت اولیه ای هستند ایجاد می نماییم. در الگوریتم

Initialize a population of stars with random locations in the search space

Initialize Automaton Probability vector
Loop

For each star, evaluate the objective function and define the state of each star
Select the best star that has the best fitness value as the black hole

For each star, Automaton chooses one of its actions According to Probability vector
Change the location of each star according to Choosed action.
If a star reaches a location with lower cost than the black hole, exchange their locations

If a star crosses the event horizon of the black hole, replace it with a new star in a random location in the search space

The action probability vector is updated based on the reinforcement feedback from the environment.
If a termination criterion (a maximum number of iterations or a sufficiently good fitness) is met, exit the loop
End loop

شبه کد الگوریتم پیشنهادی BH +LA

سیاهچاله استاندارد ستاره ها بدون دریافت هیچگونه بازخوردی

از محیط تنها به سمت بهینه سراسری(سیاهچاله) حرکت می نمایند اما در الگوریتم پیشنهادی در هر بار تکرار بر اساس تجربه کل جمعیت مقادیر مربوط به جدول اتوماتای یادگیر به روز رسانی می شود و همچنین بر اساس تجربه شخصی هر ستاره از جمعیت وضعیت آنستاره تعیین می گردد سپس در تکرار بعدی اتوماتای یادگیر بر اساس وضعیت هر ستاره جهت حرکت آن را مشخص می نماید.

شده است که در مجموعه داده های یادگیری ماشین موجود می باشند[۱۶].

در جدول شماره یک خصوصیات مجموعه داده های آزمایشی استفاده شده در این مقاله آورده شده است. بر اساس [۱۷] در زمانی که تعداد خوشه ها فراتر از سه می شود مساله خوشه بندی تبدیل به یک مساله NP-hard می گردد.

کارایی الگوریتم پیشنهادی در مقایسه با الگوریتم های مشهور

Dataset	Number of clusters	Number of features	Number of data objects
Iris	3	4	150 (50,50,50)
Glass B	6	9	214 (70, 76,17, 13, 9,29)
Vowel	6	3	871 (72, 89,172,151,207,180)
CMC	3	9	1473 (629,334,510)

جدول ۱ : خصوصیات اصلی مجموعه داده های آزمایشی.

در واقع وظیفه اتوماتای یادگیر، یادگیری بردار احتمال مطلوب وبرقراری تعادل بین جستجوی سراسری و جستجوی محلی در فرایندجستجو میباشد که انتخاب عمل حرکت به سمت سیاهچاله،جستجوی محلیرا در پی خواهد داشت و حرکت تصادفی در فضای جستجو، موجب جستجوی سراسری در قسمتهایی ناشناخته فضای جستجومیگردد.شکل فوقشبه کد الگوریتم پیشنهادی را نشان می دهد.

۴- ارزیابی الگوریتم پیشنهادی

برای ارزیابی الگوریتم پیشنهای آزمایش های مختلفی برروی

مجموعه داده های استاندارد IrisGlass, Vowel , و CMCانجام

نظیر الگوریتم Kmeans [۱۸] و الگوریتم Pso[۱۹] ارزیابی شده است. خلاصه ای از فاصله میان خوشه ای در جدول شماره دو آورده شده است که مقادیر در حالتهای بهترین , بدترین , میانگین و انحراف استاندارد راه حل ها با استفاده از شبیه سازی الگوریتم ها در نرم افزار مطلب گزارش شده است.همانطور که درجدول شماره دو مشاهده می شود الگوریتم پیشنهادی نتایج بهتری در مقایسه با سایر الگوریتم ها بدست آورده است و در حالتهای بهترین و بدترین و میانگین خروجی های مناسب تری در مقایسه با سایر الگوریتم ها داده است.

کارایی الگوریتم پیشنهادی توسط دو شرط زیر ارزیابی و مقایسه شده است.

Dataset	Criteria	K-means	PSO	BH	BH-LA
Iris	Best	97.32592	96.87935	96.65589	78.940
	Average	105.72902	98.14236	96.65681	80.267
	Worst	128.40420	99.76952	96.66306	145.279
	Std	12.38759	0.84207	0.00173	0.381
Glass	Best	215.67753	223.90546	210.51549	164.742
	Average	227.97785	230.49328	211.49860	173.469
	Worst	260.83849	246.08915	213.95689	207.115
	Std	14.13889	4.79320	1.18230	1.176
Vowel	Best	149,394.80398	152,461.56473	148,985.61373	112,457.461
	Average	153,660.80712	153,218.23418	149,848.18144	118,924.263
	Worst	168,474.26593	158,987.08231	153,058.98663	151,462.198
	Std	4123.04203	2945.23167	1306.95375	1075.992
CMC	Best	5542.18214	5539.17452	5532.88323	4012.542
	Average	5543.42344	5547.89320	5533.63122	2986.152
	Worst	5545.33338	5561.65492	5534.77738	5418.904
	Std	1.52384	7.35617	0.59940	0.39855

جدول ۲ : مجموع فاصله های میان خوشه ای بدست آمده توسط الگوریتم های مختلف بر روی مجموعه داده های آزمایشی

۱-مجموع فاصله های میان خوشه ای intra-cluster به عنوان اندازه گیری کیفیت درونی محاسبه شده : فاصله میان هر داده تامرکزخوشه نظیر به نظیر توسط فرمول زیر محاسبه و جمع زده شده است.

$$F(O,Z)=\sum_{i=1}^{N}\sum_{j=1}^{K}w_{ij}\|(O_i-Z_j)\|^2$$

که ||Oi _ Zj|| فاصله اقلیدوسی میان داده Oi و خوشه Zj است. N تعداد داده ها وK تعداد خوشه ها است. Wij وزن داده Oi در خوشه j است که می تواند ۰ و ۱ تلقی شده یا به صورت فازی میان بازه ۰ و ۱ قرار گیرد.

هر چه جمع فاصله ها کوتاه تر باشد کیفیت خوشه بندی بالاتر است.

الگوریتم سیاه چاله ها که یکی از جدیدترین الگوریتم های بر گرفته از طبیعت است و توانسته نتایج خوبی در مقایسه با سایر الگوریتم های مشابه بدهد دارای دو مزیت می باشد. اول اینکه دارای ساختاری ساده است و به راحتی پیاده سازی می شود و دوم اینکه به تنظیم پارامترها وابسته نمی باشد. الگوریتم سیاه چاله عملکرد بسیار خوب و پایدار در بهینه های سراسری با پیچیدگی زمانی پایین تر دارد. امااین الگوریتم نیز همانند سایر الگوریتم های تکاملی برگرفته شده از طبیعت مشکل بهینه های محلی را دارد.

در الگوریتم پیشنهادی با استفاده از اتوماتای یادگیر توانسته با به کارگیری کامل دانش اولیه راجع به مساله و نیز استفاده از بازخورد

Dataset	K-means(%)	PSO (%)	BH(%)	BH-LA(%)
Iris	13.42	10.06	10.02	09.72
Glass	38.44	41.20	36.51	31.02
Vowel	43.57	42.39	41.65	41.15
CMC	54.48	54.50	54.39	51.97

جدول ۳ : نرخ خطا الگوریتم های خوشه بندی بر روی مجموعه داده های آزمایشی

۲- نرخ خطا (ER) برای اندازه گیری کیفیت بیرونی : شامل درصد داده های به اشتباه خوشه بندی شده است که در فرمول زیر آمده است.

$$ER=\frac{\text{number of misplaced objects}}{\text{total umber of objects within dataset}}\times 100$$

در جدول شماره ۲ جمع فاصله میان خوشه ها از الگوریتم های مختلف در مجموعه داده های مختلف بدست آمده است.

جدول شماره ۳ نرخ خطای بدست آمده از اجـرای الگـوریتم ها بر روی مجموعـه داده هـا را نشـان مـی دهـد. همانگونـه کـه مشاهده می شود الگوریتم پیشنهادی در مقایسه با الگـوریتم هـا ی K-means و PSO و سیاه چاله ها که به تنهایی و بدون ادغام با سایر الگوریتم ها اجرا شده اند دارای نرخ خطای کمتـری مـی باشد.

۵- نتیجه‌گیری

استفاده از مدل ها و شبیه سازی پدیده های طبیعی برای حل مسائل پیچیده در چند دهه اخیر مورد توجه بسیاری از محققان جهت حل مسائل خوشه بندی بوده است.

سیستم عملکرد بهتری در یافتن مراکز خوشه ها نسبت به روش های موجود دیگر و هر کدام از این روشها به تنهایی دارد.

۶- فعالیتهای آتی

برای توسعه الگوریتم پیشنهادی می توان با بهبود عمل ها سرعت حرکت جمعیت را نیز با استفاده از بازخورد دریافتی از محیط به صورت هوشمند کنترل نمود.

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خلاصه‌سازی ویدئو مبتنی بر ماتریس هم‌رخدادی بافت تصویر

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چکیده – خلاصه‌سازی ویدئو به صورت بالقوه مرور سریعتر مجموعه‌های ویدئویی بزرگ و همچنین دسترسی و نمایه‌سازی کارآمدتر محتوا را قادر می‌سازد. اساساً این حوزه پژوهش شامل تولید خلاصه خودکار از یک ویدئو است که عموما با خوشه‌بندی همراه بوده و به دو صورت خلاصه ایستا ویدئو یا خلاصه پویا ویدئو می‌باشد. از جمله چالش‌های خلاصه‌سازی ویدئو مبتنی بر خوشه‌بندی می‌توان به اندازه بردار ویژگی‌ها، انتخاب زیر مجموعه‌ای از فریم‌ها و انتخاب فریم کلیدی اشاره کرد. در این مقاله برای حل چالش‌های فوق یک روش جدید برای تولید خلاصه ایستای ویدئو با استفاده از استخراج ویژگی بافت مبتنی بر ماتریس هم‌رخدادی ارائه شده است. در روش پیشنهادی پس از استخراج ویژگی بافت تمام فریم‌ها توسط ماتریس هم‌رخدادی فریم‌های بی‌معنا حذف می‌شوند، و مابقی فریم‌ها خوشه‌بندی می‌شوند. پس‌از آن فریم‌های کلیدی از هر خوشه انتخاب شده و در آخر فریم‌های کلیدی مشابه از خلاصه به دست آمده نیز حذف می‌شوند. برای محاسبه کیفیت خلاصه‌های تولید شده از دو معیار نرخ دقت و نرخ خطا استفاده شده است و خلاصه‌های به دست آمده با چند کار پیشین بر روی پروژه ویدئوی باز مقایسه شده‌اند. نتایج بدست آمده از نرخ دقت و خطا به ترتیب ۸۷% و ۲۵% نشان می‌دهد که راهکار پیشنهادی نسبت به روش‌های پیشین برتری داشته است.

کلید واژه- خلاصه‌سازی ویدئو، خلاصه ایستا، ویژگی بافت تصویر، ماتریس هم‌رخدادی.

۱- مقدمه

امروزه رسانه‌های دیداری-شنیداری مهمترین رسانه تاثیرگذار بر جوامع بشری می‌باشند. با ورود سامانه‌های تولید، ضبط و پخش دیجیتال، سرعت رشد این رسانه‌ها بسیار زیاد شده است. این رشد مدیون فناوری های کامپیوتر، مخابرات و الکترونیک می‌باشد. یکی از جدیدترین و جذاب‌ترین کاربردهای این فناوری‌ها تحلیل محتوا و استخراج مفاهیم درونی ویدئو است. تحلیل محتوا و ا ستخراج مفاهیم درونی ویدئو از دو جنبه اهمیت دارد. اول اینکه می‌توان به طور خود کار یک تحلیل آ ماری از رویدادهای اتفاق افتاده در ویدئو داشت و دوم اینکه می‌توان خلاصه‌ای از ویدئو که شامل رویدادها و مفاهیم رخداده در آن است را استخراج و در غالب یک فایل ویدئویی با مدت زمان کوتاه ارائه نمود. اصطلاحاً به ساختن یک خلاصه ویدئویی خلاصه‌سازی ویدئو[۱] گفته می‌شود که به عنوان یکی از کاربردهای تحلیل ویدئو مطرح است [۱]. اساساً دو نوع سیستم خلاصه‌سازی ویدئو وجود دارد: (الف) خلا صه سازی ایستا (ب) رونو شت‌برداری پویا. در این مقاله خلا صه سازی ایستای ویدئو مدنظر می‌با شد. خلا صه سازی ایستای ویدئو فرآیندی است که در آن یک مجموعه از تصاویر مهم به نام فریم های کلیدی برای نمایش محتوای یک و یدئو انتخاب می‌شوند. خلاصه‌سازی محتوای بصری ویدئوهای دیجیتال با فریم‌های کلیدی یکی از مهمترین تکنیک‌ها برای اندیس‌گذاری، مرور و جستجوی محتوای ویدئو است. با استفاده از فریم‌های کلیدی می‌توان حجم داده مورد نیاز برای اندیس‌گذاری ویدئو را کاهش داد و یک چارچوب مناسب برای کار با داده‌های ویدئویی

[۱] Video summarization

فراهم آورد [۲].

در سال ۲۰۱۰ فیورینی و همکاران [۳] یک تکنیک خلاصه‌سازی ویدئو به نام "STIMO" را که مبتنی بر خوشه‌بندی هیستوگرام رنگ HSV است، پیشنهاد دادند. بحث اصلی این مقاله در مورد STIMO (خلاصه ثابت و متحرک) است که یک تکنیک خلاصه سازی برای تولید خلاصه‌های متحرک و در پرواز می‌باشد. این تکنیک در نهایت به دقت ٪۷۲ و خطای ٪۵۸ دست یافت.

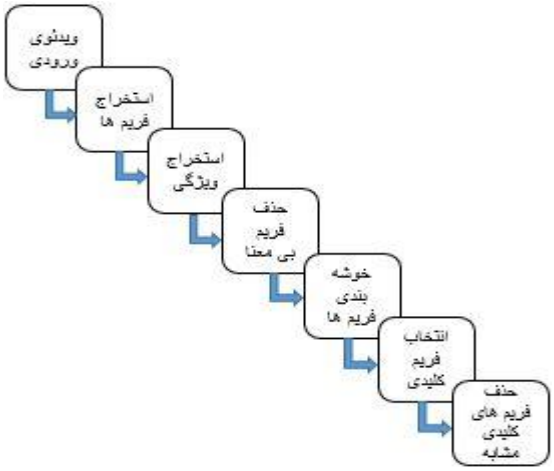
در سال ۲۰۱۱ اویلا و همکاران[۴] روشی به نام "VSUMM" پیشنهاد کردند که ویژگی‌های رنگی را از فریم‌ها بعد از مرحله پیش نمونه‌برداری از فریم‌های ویدئویی، استخراج می‌کند. بعد از حذف فریم‌های بی‌معنا، فریم‌های باقیمانده بر اساس الگوریتم خوشه‌بندی K-Means خوشه‌بندی می‌شوند. برای ارزیابی این روش، خلاصه‌های دیگری که توسط انسان ساخته شده بود، با تکنیک VSUMM و چندین روش دیگر موجود در این حوزه مقایسه شدند. مزیت اصلی این روش ارزیابی که مرور خلاصه کاربران (CUS) نامیده می‌شود و در این مقاله پیشنهاد داده شده، این است که ارزیابی ذهنی را برای انجام ارزیابی عملکرد تکنیک پیشنهادی کاهش می‌دهد، کیفیت خلاصه را به صورت کمی بیان می‌کند و امکان مقایسه عینی‌تری بین تکنیک‌های مختلف را فراهم می‌کند. این تکنیک برای معیارهای دقت و خطا به ترتیب به ۸۵٪ و ۳۵٪ دست یافته است.

در سال ۲۰۱۲ اسدی و مقدم[۵] یک روش جدید برای استخراج فریم کلیدی با استفاده از خوشه‌بندی C-Means فازی ارائه دادند؛ به این صورت که فریم‌های با بیشترین درجه عضویت از هر خوشه را به عنوان فریم کلیدی معرفی می‌کنند. تعداد خوشه‌ها با استفاده از یک روش ساده تخمین زده می‌شود. خلاصه‌هایی که به وسیله افراد تولید شده‌اند، برای ارزیابی این تکنیک استفاده شده و نهایاتاً به دقت ۷۵٪ و خطای ۳۰٪ رسیده است.

در این مقاله یک روش جدید برای خلاصه‌سازی ایستای ویدئو ارائه شده است. در ادامه در بخش ۲ به بررسی روش پیشنهادی خواهی پرداخت، در بخش ۳ آزمایش‌ها و نتایج به دست آمده مورد ارزیابی قرار خواهد گرفت و نهایتاً در بخش ۴ جمع‌آوری مطالب را خواهیم داشت.

۲- روش پیشنهادی

در شکل ۱ دیاگرام روش پیشنهادی نشان داده شده است. در این روش ابتدا ویدئوی ورودی به فریم‌هایی شکسته شده، پس از آن با استفاده از ماتریس هم‌رخدادی ویژگی بافت فریم‌ها استخراج می شود و بعد از حذف فریم‌های بی‌معنا، مابقی فریم‌ها خوشه بندی می‌شوند. سپس از هر خوشه یک فریم به عنوان فریم کلیدی انتخاب شده و در آخر فریم‌های کلیدی مشابه از خلاصه نهایی حذف می‌شوند.



شکل ۱: دیاگرام روش پیشنهادی.

۲-۱- استخراج فریم‌های ویدئو

در برخی از تکنیک‌ها مانند اویلا و همکاران[۴] و اسدی و مقدم [۵] تمام فریم های ویدئو را در نظر نمی‌گیرند، بلکه زیرمجموعه‌ای از فریم‌ها را در نظر می‌گیرند که از نرخ نمونه‌برداری از پیش تعیین شده به دست می‌آیند و ویژگی فریم‌های نمونه‌برداری شده را، استخراج می‌کنند. نرخ نمونه‌برداری اهمیت اساسی دارد زیرا نرخ نمونه‌برداری خیلی کم می‌تواند موجب کیفیت پایین خلاصه‌سازی شود که فاقد اطلاعات مهم است. ما در اینجا برای انتخاب فریم‌هایی از ویدئوی اولیه به منظور استخراج ویژگی و عملیات خوشه‌بندی، از تمام فریم‌های ویدئو استفاده می‌کنیم تا اشکالی را که بر روش‌هایی که از فریم نمونه برداری شده استفاده می‌کنند را برطرف کنیم. اشکال وارد به این روش‌ها، این است که فریم انتخابی (نمونه برداری شده) ممکن است دارای نویز باشد مانند دو فریمی که محتوای یکسان دارند اما در بعضی از قسمت‌های فریم، پیکسل‌ها بر اثر فلاش یا انواع گذارهایی که در جریان ویدئو رخ می‌دهد، دچار خرابی شده باشند. در شکل ۲ نمونه‌ای از موارد ذکر شده را می‌توان مشاهده

کرد. چنانکه یکی از فریم‌ها جز فریم‌های نمونه‌برداری باشد و بعد از انجام عملیات خوشه‌بندی به عنوان فریم کلیدی از خوشه‌ای خاص در نظر گرفته شود، در مرحله مقایسه فریم‌های کلیدی کاربران و تکنیک مورد نظر، چون این فریم دارای نویز، فلاش یا گذار است در خلاصه کاربران وجود ندارد و سبب افزایش خطای روش پیشنهادی در تشکیل خوشه‌های درست می‌شود.



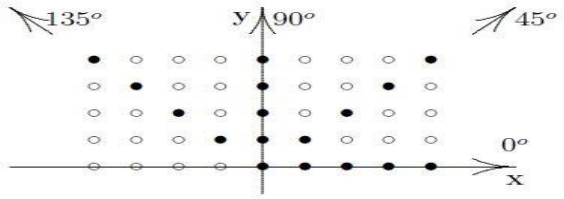
شکل ۲: نمونه‌ای از گذارها و تغییراتی که ممکن است در فریم‌های متوالی رخ دهد. برگرفته از کتلاس و ویکولادیس[۱۲].

۲-۲- استخراج ویژگی بافت مبتنی بر ماتریس هم-رخدادی

در روش پیشنهادی این مقاله ویژگی استخراج شده برای فریم های ویدئو، ویژگی بافت مبتنی بر ماتریس هم‌رخدادی می‌باشد. با توجه به اینکه در بیشتر روش‌های خلاصه‌سازی مبتنی بر طبقه‌بندی از روشنایی تصویر بعنوان ویژگی استخراجی استفاده شده است، که این کار می‌تواند وجود نویز و اثر مخرب آنرا در پی داشته باشد، بنابراین در این مقاله برای کاهش نویز و اثر مخرب آن بر روی تصویر، از اطلاعات مکانی پیکسل‌ها در قالب ویژگی بافت استفاده شده است.

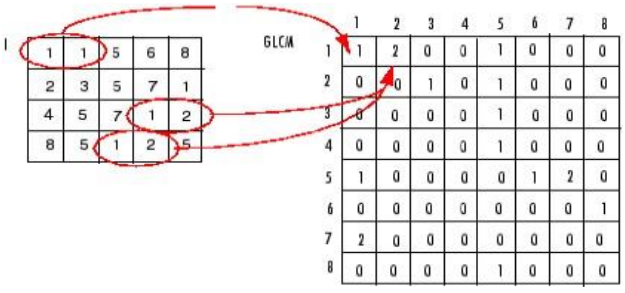
ماتریس هم‌رخدادی یک ابزار قدرتمند برای استخراج ویژگی بافت تصویر می‌باشد که با نقشه‌برداری از سطح خاکستری تصویر، ماتریس هم‌رخداد احتمالات، براساس روابط فضایی از پیکسل‌های مختلف در مسیرهای زاویه‌ای متفاوت ایجاد می‌شود.

یک ماتریس هم‌رخداد نرخ رخداد مقادیر خاکستری دو پیکسل وابسته از تصویر را که در فاصله و جهت بخصوصی از یکدیگر، قرار گرفته‌اند، را بیان می‌کند [۶]. بعبارت دیگر می‌توان گفت ماتریس هم‌رخداد، ماتریس مربعی است که عناصر آن نشان دهنده فرکانس نسبی رخداد یک جفت از مقادیر خاکستری در فاصله خاص و در یک جهت تعیین شده، می‌باشند. ماتریس هم‌رخداد در واقع همان توصیف فرکانس های مربوط به P_{ij} می‌باشد که دو پیکسل هم سایه جدا از هم با فاصله ثابت d که یکی با شدت خاکستری i و دیگری با شدت خاکستری j روی تصویر اتفاق می‌افتند. بنابراین ماتریس هم‌رخداد از یک ماتریس مربعی که اندازه آن منوط به بیشینه شدت خاکستری پیکسل‌های موجود در تصویر می‌باشد، تشکیل خواهد شد. هر المان P_{ij} بیانگر تعداد اتفاقات ساختار فوق می‌باشد؛ پیکسلی با اندازه i در فاصله مشخص d از پیکسلی با اندازه j. اگر فاصله d=۱ باشد چهار جهت ممکن مقدور می‌باشد که زاویه‌های ممکن بین دو پیکسل می‌توانند با ۰، ۴۵، ۹۰ و ۱۳۵ درجه بیان شوند [۷].



شکل ۳: اندازه‌گیری سطح خاکستری ماتریس هم‌رخدادی در چهار زاویه ۰، ۴۵، ۹۰ و ۱۳۵ درجه [۷].

بعبارت دقیق‌تر در این شیوه تصویر تبدیل به یک ماتریس دو بعدی می‌شود که هر درایه آن احتمال قرار گرفتن شدت رنگ i و j را در همسایگی به فاصله d و زاویه‌ای به اندازه θ بیان می‌کند. در نهایت با استفاده از تابعی که بر این ماتریس تعریف شده است مشخصه‌هایی استخراج شده و با مقایسه آن‌ها کلاس‌بندی انجام می شود [۷]. در شکل ۴ برای ماتریس ۵ × ۵ یک تصویر، ماتریس هم‌رخدادی آن تشکیل شده است. M و N در ماتریس هم‌رخدای با هم یکسان و برابر با تعداد سطوح رنگ در تصویر می‌باشد و در این مثال تصویر ما دارای هشت سطح رنگ مختلف است. مقدار درایه (i و j) در ماتریس هم‌رخدادی بدین مفهوم است که در ماتریس تصویر، چند پیکسل با رنگ i وجود دارد که رنگ پیکسل سمت راست آن مقدار j باشد. برای مثال مقادیر [۴و۴] ماتریس هم‌رخدادی به ما می‌گوید، که در ماتریس تصویر چند پیکسل با رنگ چهار داریم که مقدار پیکسل مجاور آن نیز چهار باشد.



شکل ۴: تشکیل ماتریس هم‌رخدادی [help matlab].

از ماتریس هم‌رخدادی اولین بار هارلیک [۸] برای استخراج ویژگی بافت از تصویر بمنظور عیب‌یابی میوه گریپ فروت استفاده کرد. هریک از ویژگی‌های بافت تصویر که هارلیک و همکارانش از ماتریس هم‌رخدادی استخراج کردند نماینده یک مشخصه تصویر

مانند درشتی، کنتراست، همگنی، پیچیدگی و ... بودند.

مزیت استفاده از این ماتریس بر هیستوگرام تصویر این است که در مقایسه با هیستوگرام که در آن اطلاعات مکانی پیکسل‌ها از بین رفته و فقط فراوانی مقادیر خاکستری پیکسل‌ها حساب می‌شود، در این ماتریس اطلاعات و موقعیت مکانی پیکسل‌ها نیز در نظر گرفته می‌شود؛ به طوری که هرچه توزیع مقادیر خاکستری تصویر گسترده‌تر باشد، واریانس بیشتری در ماتریس دیده خواهد شد. در این مقاله ویژگی‌های استخراج شده براساس بافت از تصاویر مبتنی بر ماتریس هم‌رخدادی به ترتیب زیر می‌باشند:

۱. وضوح

$$Contrast = -\sum_{i=1}^{n}\sum_{j=1}^{m} |i-j|\, C_{ij} \qquad (۱)$$

۲. انرژی

$$Energy = \sum_{i=1}^{n}\sum_{j=1}^{m} C_{ij}^{2} \qquad (۲)$$

۳. همشکلی

$$Homogeneity = \sum_{i=0}^{j-1}\sum_{j=0}^{i-1} \frac{C(i,j)}{1+|i-j|} \qquad (۳)$$

۴. همبستگی

$$Correlation = \frac{\sum_{ij}^{mn} (i-\mu)(j-\mu)C_{ij}}{\sqrt{var(i)var(j)}} \qquad (۴)$$

۵. مجموع مربعات (واریانس)

$$Variance = \sum_{i=1}^{G}\sum_{j=1}^{G} (i-\mu)^{2} c(i,j) \qquad (۵)$$

۲-۳- حذف فریم بی‌معنا

فریم بی‌معنا که به دلیل اثرات محو و آشکار شدن تدریجی [۳،۴] یا استفاده از فلاش‌ها در ویدئوهای ورزشی یا اخبار [۳] ایجاد می‌شود، فریمی غالبا تک رنگ است. در شکل ۵ نمونه‌ای از این فریم‌ها را می‌توان مشاهده کرد. اویلا وهمکاران [۴] برای حذف فریم بی‌معنا انحراف معیار فریم را محاسبه می‌کنند. انحراف معیار فریم‌های بی‌معنا برابر با صفر یا نزدیک به صفر است. پس از محاسبه انحراف معیار فریم‌ها، فریم‌هایی که انحراف معیارشان صفر یا نزدیک به صفر است حذف می شوند. بنابراین برای حذف فریم‌های بی‌معنا مانند [۴] از ورود این فریم‌ها به مرحله خوشه‌بندی جلوگیری شده است. همچنین در تابع زیر میزان نزدیک بودن انحراف معیار فریم‌های بی‌معنا به صفر مشخص شده است.

$$\text{meaningless}\begin{cases} 1 & \text{if } |std-avrg| \text{ between } 0.1 \text{ and } -0.1 \\ 0 & \text{otherwise} \end{cases} \qquad (۶)$$



(ب) (الف)

شکل ۵: نمونه‌هایی از فریم‌های بی‌معنا، انحراف معیار در (الف) برابر با صفر و در (ب) برابر با ۰،۰۵ می‌باشد [۴].

۲-۴- خوشه‌بندی

به تعداد خوشه‌ها نقاطی بعنوان مراکز اولیه $c_1 c_2 c_3 \dots c_n$ در فضای جستجوی مساله مشخص می شوند. سپس با استفاده از الگوریتم C-Means فازی عضویت تک تک فریم‌ها را با این نقاط مشخص می‌کنیم، روابط (۷) و (۸). بعد از مشخص کردن اینکه کدام فریم به کدام مرکز خوشه تعلق دارد، فاصله درون خوشه‌ای هر مرکز را با فریم‌هایی که بیشترین درجه عضویت را به این مرکز دارند، با استفاده از رابطه (۹) مشخص می‌شود [۹].

$$m_{ik} = \frac{1}{\sum_{j=1}^{c}\left(\frac{d_{ik}}{d_{jk}}\right)^{2/(q-1)}} \qquad (۷)$$

$$d_{ik} = \|u_k - c_i\| \qquad (۸)$$

$$J(M, c_1, c_2, c_3) = \sum_{i=1}^{C} J_i \sum_{i=1}^{c}\left(\sum_{k=1}^{k} m_{ik}^{q} \|u_k - c_k\|^{2}\right) \qquad (۹)$$

۲-۵- استخراج فریم‌های کلیدی

برای انتخاب فریم کلیدی، از تمام فریم‌های وارد شده به هر خوشه استفاده می شود؛ به این صورت که فریمی به عنوان فریم کلیدی انتخاب می‌شود که کمترین فاصله اقلیدسی با مرکز

خوشه را داشته باشد یعنی از لحاظ فاصله اقلیدسی با تمام فریم‌های آن خوشه نسبت به مرکز خوشه، دارای کمترین اختلاف باشد. در این صورت احتمال اینکه محتوای این فریم به تمام فریم‌های آن خوشه شبیه‌تر باشد، بیشتر است و می‌تواند نماینده بهتری برای نشان دادن محتوای آن خوشه باشد.

۲-۶- حذف فریم‌های کلیدی مشابه

برای حذف فریم‌های کلیدی مشابه، شباهت دو فریم کلیدی براساس آستانه T سنجیده می‌شود. حد مطلوب آستانه استفاده شده در کارهای قبلی که به صورت تجربی و براساس محاسبه معیارهای دقت و خطا برای مقادیر مختلف آستانه به دست آمده، برابر با ۰٫۵ بوده است. در این مقاله نیز مقدار حد مطلوب آستانه با استناد به کارهای پیشین و آزمایشات تجربی انجام شده در راستای محاسبه نرخ دقت و خطا به ازای مقادیر مختلف آستانه، برابر با ۰٫۵ در نظر گرفته شده است.

چنانچه شباهت دو فریم کلیدی اندازه‌گیری شده کمتر از آستانه T باشد، یکی از دو فریم کلیدی از خلاصه نهایی حذف می‌شود. در شکل ۶ می‌توان مثالی از فریم‌های کلیدی مشابه ($T < ۰.۵$) و غیرمشابه ($T \geq ۰.۵$) را مشاهده کرد.



(الف) (ب) (ج) (د)

شکل ۶: فریم‌های کلیدی مشابه (الف و ب) و غیر مشابه (ج و د) [۴].

۳- آزمایش و نتایج

۳-۱- روش ارزیابی

برای ارزیابی روش‌پیشنهادی جستوهای زیادی انجام دادیم که از یک روش عینی استفاده کنیم، به طوری که قضاوت انسانی را در مورد خلاصه‌های نهایی کاهش دهیم. در این مقاله از روش ارزیابی که اویلا و همکاران [۴] برای ارزیابی خلاصه سازی ویدئو پیشنهاد کردند، استفاده شده است. در این روش ارزیابی که "مقایسه خلاصه‌های کاربر" (CUS) نامیده می‌شود، چندین کاربر ویدئو را از فریم‌های نمونه به طور دستی خلاصه می‌کنند. خلاصه‌های کاربر به عنوان مرجعی برای مقایسه خلاصه‌های به دست آمده از روش‌های مختلف به کار می‌رود. بدین صورت، خلاصه‌های کاربران خلاصه‌های مرجع هستند، یعنی حقایق. چنین مقایسه‌هایی براساس معیارهای متری خاص است. در روش ارزیابی CUS، خلاصه هر کاربر که به صورت دستی ایجاد شده مستقیماً با خلاصه خودکار روش پیشنهادی مقایسه می‌شود و به این صورت نظر اصلی هرکاربر را در نظر می‌گیریم. اگر فاصله بین دو فریم کلیدی کمتر از آستانه T از پیش تعیین شده باشد، آن دو فریم، فریم کلیدی مشابه هستند. وقتی دو فریم بر هم منطبق شدند از تکرار بعدی روند مقایسه حذف می‌شوند. در ادامه مراحل روش ارزیابی توضیح داده می‌شود:

مرحله اول: روش کار به این صورت است که در ابتدا از کاربران خواسته می‌شود تا ویدئو را ببینند و سپس به روش دستی آن را خلاصه کنند. برای خلاصه‌سازی ویدئو توسط کاربران، فریم‌های نمونه به کاربران نمایش داده می‌شود نه تمام ویدئو.

مرحله دوم: کاربران تمایل دارند مجموعه فریم هایی را انتخاب کنند که به نظرشان قادر به خلاصه سازی محتوای اصلی ویدئو می‌باشد. کاربران هر تعداد فریم را که مایل باشند می‌توانند در خلاصه‌شان قرار دهند.

مرحله سوم: سپس خلاصه‌های کاربران با خلاصه‌هایی که به طور خودکار تولید شده مقایسه می‌شوند. کیفیت خلاصه‌ای که به طور خودکار تولید شده با دو معیار متری ارزیابی می‌شود:

$$CUS_A = \frac{n_{mAS}}{n_{us}} \qquad (۱۰)$$

$$CUS_E = \frac{n_{\dot{m}AS}}{n_{us}} \qquad (۱۱)$$

که میزان درستی با رابطه (۱۰) و میزان خطا با رابطه (۱۱) به دست می‌آید.

n_{mAS} تعداد فریم‌های کلیدی منطبق در خلاصه خودکار (AS)، $n_{\dot{m}AS}$ تعداد فریم‌های کلیدی غیر منطبق در خلاصه خودکار و n_{us} تعداد فریم‌های کلیدی در خلاصه کاربر (US) است.

محدوده مقادیر CUS_A از ۰ (در بدترین وضعیت، وقتی هیچکدام از فریم‌های کلیدی در خلاصه خودکار بر فریم‌های کلیدی در خلاصه کاربر منطبق نیستند یا برعکس) تا ۱ (در

بهترین و ضعیت، وقتی تمام فریم‌های کلیدی در خلا صه کاربر بر فریم‌های کلیدی در خلاصه خودکار منطبق است) می‌باشد.

محدوده مقادیر CUS_E از ۰ (در بهترین وضعیت، وقتی تمام فریم های کلیدی در خلاصـــه خود کار بر فریم های کلیدی در خلاصـــه کاربر منطبق اســـت) تا ۱ (در بدترین وضـــعیت، وقتی هیچکدام از فریم های کلیدی در خلاصـــه خودکار بر فریم های کلیدی در خلاصـــه کاربر منطبق نیســـتند و برعکس) می‌باشـــد. بالاترین کیفیت خلاصـــه‌ســـازی زمانی اســـت که $CUS_A = ۱$ و $CUS_E = ۰$ با شد و به این معنی ا ست که تمام فریم‌های کلیدی در خلاصه خودکار و خلاصه کاربر دقیقا برهم منطبق‌اند.

۳-۲- مشخصات مجموعه داده مورد ارزیابی

رو شی که ما برای ارزیابی ا ستفاده کردیم [۴] تمام مجموعه داده اســـتفاده شـــده، خلاصـــه‌های کاربران و دیگر نتایج مورد نیاز برای مقایســـه تکنیک‌های مختلف بر روی بســـتر یکســـان را در اختیار همگان قرار داده ا ست. ما روش پیشنهادی خود را بر روی بســـتر یکســـان با معیارهای عینی ذکر شـــده مورد مقایســـه قرار می‌دهیم. به این منظور بر روی ۵۰ و یدئوی انتخاب شـــده از "پروژه و یدئو باز" (OVP) تمرکز می‌کنیم. این و یدئو ها همان و یدئو هایی هســـتند که ماندر و همکاران [۱۰] و فیورینی و همکاران [۳] و اویلا و همکاران [۴] و اسدی و مقدم [۵] استفاده کردند. بنابراین اســـتفاده از مجموعه "پروژه ویدئو باز" ارزیابی مقایسه‌ای را امکان‌پذیر می‌سازد. تمام ویدئوها در فرمت MPEG-۱ دارای رزولوشن ۴۰ × ۳۵۲ و سرعت ۳۰ فریم در ثانیه هستند. ویدئوهای انتخاب شـده به دسـته‌های مختلف تقسـیم می‌شـوند (مستند، آموزشی، روزانه، تاریخی، سخنرانی) و مدتشان از ۱ تا ۴ دقیقه متغییر ا ست. خلا صه‌های کاربران را ۵۰ کاربر تولید کردند که هر کدام از آن‌ها با پنج ویدئو سروکار دا شتند، یعنی هر ویدئو دارای ۵ خلاصـــه اســـت که پنج کاربر مختلف تولید کرده‌اند. به عبارت دیگر ۲۵۰ خلا صه ویدئو بطور د ستی تولید شده‌اند. تمام خلاصـــه‌های دســـتی تولید شـــده توســـط کاربران و خلاصـــه‌های اتوماتیک دیگر روش‌های مقایســـه شـــده را می‌توان در ســـایت Vsummsite [۱۳] مشاهده نمود.

۳-۳- نتایج آزمایشات

به منظور ارزیابی کارایی روش پیشـــنهاد شـــده در این مقاله، روش پیشـــنهادی با تکنیک‌های دیگر مقایســـه شـــده اســـت. برای مقایسه خلاصه به دست آمده از تکنیک‌های گوناگون، از دو معیار "نرخ دقت" و "نرخ خطا" اســـتفاده کرده‌ایم و می‌خواهیم مقادیر دو معیار ذکر شده را برروی خلا صه‌های گوناگون م شاهده کنیم. بنابراین روش پی شنهادی با تکنیک‌های ارائه شده تو سط ماندر و همکاران [۱۰] و فیورینی و همکاران [۳] و اویلا و همکاران [۴]، همچنین با خلا صه تولید شده تو سط دیمنتون و همکاران [۱۱] نیز مقایسه شده است.



الف) کاربر شماره ۱

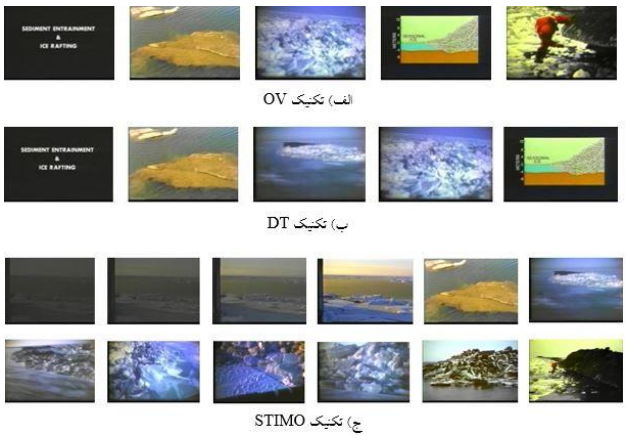
ب) کاربر شماره ۲

ج) کاربر شماره ۳

د) کاربر شماره ٤

ه) کاربر شماره ۵

شکل ۷: خلاصه کاربران از ویدئوی رانش یخ به عنوان یک عامل زمین‌شناسی، بخش هشتم (موجود در پروژه ویدئوی باز) [۱۳].



الف) تکنیک OV

ب) تکنیک DT

ج) تکنیک STIMO



شکل ۸: خلاصه تکنیک‌های مختلف از ویدئوی رانش یخ به عنوان یک عامل زمین‌شناسی، بخش هشتم (موجود در پروژه ویدئوی باز) [۱۳].



شکل ۹: خلاصه روش پیشنهادی از ویدئوی رانش یخ به عنوان یک عامل زمین‌شناسی، بخش هشتم (موجود در پروژه ویدئوی باز)

نتایج به دســـت آمده دو معیار "نرخ دقت" و "نرخ خطا" تکنیک‌های مختلف و روش پیشنهادی در جدول ۱ قابل مشاهده می‌باشند.

جدول ۱: مقایسه "نرخ دقت" و "نرخ خطا" به دست آمده روش پیشنهادی با سایر روش‌ها.

روش پیشنهادی	VSUMM۲ [٤]	VSUMM۱ [٤]	STIMO [۳]	DT [۱۰]	OV [۱۱]	
٪۸۹	٪۷۰	٪۸۵	٪۷۲	٪۵۳	٪۷۰	CUS_A
٪۱۸	٪۲۷	٪۳۸	٪۵۸	٪۲۹	٪۵۷	CUS_E

نتایج ارائه شـــده در جدول ۱ تایید می‌کند که روش پیشنهادی به نرخ دقت بالاتر و نرخ خطای پایین‌تری در مقایسه با ۵ تکنیک دیگر دســت یافته اســت، که به این معنی اســت که روش پیشـــنهادی به خلاصـــه‌های تولید شـــده توســـط کاربران نزدیک‌تر است.

۴- نتیجه‌گیری

در این مقاله یک روش جدید برای خلاصه‌سازی ویدئو با هدف بهبود عملکرد خلاصه‌سازی ارائه شد. به طوری که دقت عملیات خوشه‌بندی برای قرار گرفتن فریم‌های کلیدی در خوشه‌ها افزایش پیدا کرد. در روش پیشنهادی سعی بر مرتفع نمودن برخی اشکالات وارد بر روش‌های پیشین شد. برای مقایسه روش پیشنهادی با سایر روش‌ها از یک روش عینی ارزیابی بر مبنای دو معیار "نرخ دقت" و "نرخ خطا" بر روی بستر آزمایشی "پروژه ویدئوی باز" استفاده شد. با توجه به اینکه در روش پیشنهادی در استخراج ویژگی، از توصیف‌گرهای آماری موقعیت مکانی پیکسل‌ها مبتنی بر ویژگی بافت تصویر با استفاده از ماتریس هم‌رخدادی استفاده شده، این امر سبب بهبود کارایی شده و به نرخ دقت بالا و خطای پایینی نسبت به سایر روش‌ها دست یافته شد.

این پژوهش را می‌توان با انجام خوشه‌بندی سلسله‌مراتبی و استفاده از الگوریتم‌های فرا اکتشافی جهت افزایش سرعت و بهینه-سازی ادامه داد. همچنین جهت مقایسه نتایج بیشتر آزمایش‌ها با مجموعه تصاویر دوربین‌های مدار بسته تکرار شوند.

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ارایه یک استراتژی یادگیری جدید برای بهبود الگوریتم بهینه سازی هوش جمعی گربه‌ها در محیط‌های ایستا

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چکیده - الگوریتم‌های مبتنی بر الگوریتم بهینه سازی هوش جمعی گربه‌ها که تا کنون پیشنهاد شده‌اند استراتژی یادگیری جایگزین برای گربه‌ها در زمان بهبود برازندگیشان در طول فرایند جستجو ارایه نکرده اند. بمنظور ارایه استراتژی یادگیری جدید، در این مقاله، ابتدا الگوریتم بهینه سازی مبتنی بر تدریس-یادگیری (*TLBO*) بهبود داده شده و سپس الگوریتم ترکیبی جدیدی پیشنهاد می‌شود. الگوریتم پیشنهادی از ترکیب الگوریتم بهینه سازی مبتنی بر تدریس-یادگیری (*TLBO*) بهبود یافته و الگوریتم *CSO* برای بهینه سازی در محیط‌های ایستا بدست می‌آید. به همین دلیل، الگوریتم پیشنهادی را *ETeachCSO* می‌نامیم. عملکرد الگوریتم *ETeachCSO* به همراه چندین الگوریتم *PSO* شناخته شده ، نسخه باینری الگوریتم بهینه سازی هوش جمعی گربه‌ها و الگوریتم *TLBO* در فضای ۳۰ بعدی بر روی پنج تابع محک آزمایش شده اند. نتایج آزمایشات نشان می‌دهند که الگوریتم *ETeachCSO* از کارایی بسیار مناسبی برخوردار است.

کلید واژه- الگوریتم بهینه سازی هوش جمعی گربه‌ها،الگوریتم بهینه سازی مبتنی بر تدریس-یادگیری،بهینه سازی

۱- مقدمه

بهینه سازی تقریبا در تمام زمینه‌های علمی و مهندسی رایج است. در سال های اخیر چندین روش بهینه سازی مانند الگوریتم ژنتیک (GA) ، الگوریتم بهینه سازی ازدحام ذرات (PSO)، الگوریتم بهینه سازی ازدحام گربه (CSO) و غیره برای حل مسائل بهینه سازی مختلف پیشنهاد شده و مورد استفاده قرار گرفته است[۱].

الگوریتم CSO در سال ۲۰۰۶ توسط چو و همکاران [۲] معرفی شد. این الگوریتم از نحوه جستجوی گربه‌ها برای یافتن غذا الهام گرفته شده است. براساس تحقیقات آن‌ها، گربه‌ها دارای دو حالت جستجو و ردیابی هستند. حالت جستجو برای مدل سازی وضعیتی است که گربه در حال سکون و تماشای اطراف و جستجوی موقعیت بعدی برای حرکت به آن موقعیت می‌باشد. حالت ردیابی برای مدلسازی رفتار گربه در زمان ردیابی برخی اهداف است. در بخش (۲) الگوریتم CSO بطور کامل توضیح داده می‌شود.

رائو و همکاران [۳] یک روش بهینه سازی موثر تحت عنوان TLBO برای مسایل بهینه سازی غیر خطی بزرگ مقیاس پیشنهاد کردند.TLBO مبتنی بر تاثیر توانایی یک معلم روی خروجی یادگیرندگان در یک کلاس است.این الگوریتم براساس فلسفه تدریس و یادگیری می باشد. خروجی در اینجا می تواند در اصطلاحاتی از نتایج یا نمرات بیان شود.معلم به عنوان یک شخص با دانش بالا در نظر گرفته می شود کسی که دانش خود را با دیگران به اشتراک می گذارد. همچنین کیفیت یک معلم از خروجی یادگیرندگان تاثیر می پذیرد.مشخص است که یک معلم خوب یادگیرندگان را به گونه ای آموزش می دهد که آنها بتوانند نتایج خوبی را بدست آورند. علاوه بر این یادگیرندگان از تعامل با دیگر یادگیرندگان نیز آموزش می بینند و بدین وسیله نتایجشان را بهبود می بخشند.

رائو و پاتال [۴] الگوریتم TLBO پایه را بمنظور بهبود قابلیت های جستجو و بهره برداری توسط معرفی مفاهیم تعداد

معلمان ، فاکتور تدریس خود انطباق، آموزش فردی و یادگیری خود انگیزشی توسعه داده اند.

لیم و ایسه [۵] الگوریتم پایه TLBO را بهبود بخشیدند و این چارچوب بهبود یافته را به PSO وفق دادند. نتیجه الگوریتم پیشنهادی TPLPSO است.در این الگوریتم دو فاز یادگیری تحت عنوان فاز یادگیری جفتی و فاز تدریس مطرح شده است.ذرات ابتدا وارد مرحله تدریس می شوند و سرعتشان را براساس بهترین اطلاعات فردی و بهترین سراسری بروز رسانی می کنند. ذره ای که در بهبود برازندگی اش در فاز تدریس شکست می خورد وارد فاز یادگیری جفتی می شود جاییکه یک نمونه به عنوان ذره راهنما انتخاب می گردد .

راجاسکهار و همکاران [۶] نوع جدیدی از TLBO تحت عنوان TLBO نجبه گرا برای بهینه سازی تابع عددی پیشنهاد دادند. روش پیشنهادی با دو مکانیزم برای رسیدن به بهینه سراسری دقیق با پیچیدگی زمانی کمتر تقویت می شود.یکی از آنها نخبه گرایی است چیزی که قابلیت روش بیهنه سازی را به وسیله نگهداری بهترین راه حل بدست آمده تا کنون تقویت می کند، از طرف دیگر روش تضاد در بهتر کردن توانایی جستجو کمک می کند. از آنجا که ETLBO مزیت هر دو یادگیری مبتنی بر نخبه گرایی و تضاد را دارد از این رو این الگوریتم سعی می کند راه حل بهینه را با تضمین همگرایی بدست آورد.

زو و همکاران [۷] یک الگوریتم بهبود یافته مبتنی بر TLBO با استراتژی گروهبندی پویا پیشنهاد دادند.در این الگوریتم برخلاف TLBO ، هر یادگیرنده قادر به یادگیری از میانگین گروه متناظرش به جای میانگین کلاس در فاز تدریس است. علاوه بر این هر یادگیرنده استراتژی یادگیری تصادفی که در TLBO معرفی شده است و استراتژی یادگیری با رفتار کوانتومی[۸] در گروه متناظرش در فاز یادگیری را بکار می گیرد.گروهبندی دوباره بطور پویا بعد از یک تعداد تکرار رخ می دهد تا به نگهداری تنوع جمعیت و حذف همگرایی زودرس کمک کند.

در اکثر الگوریتم‌های پیشنهادی مبتنی بر الگوریتم بهینه سازی هوش جمعی گربه‌ها استراتژی یادگیری جایگزین در زمان شکست خوردن گربه‌ها در بهبود برازندگیشان در طول فرایند جستجو ارایه نکرده اند. با توجه به این امر، در این مقاله، ابتدا الگوریتم بهینه سازی مبتنی بر تدریس-یادگیری (TLBO) بهبود داده شده و سپس الگوریتم ترکیبی جدیدی پیشنهاد می-شود. الگوریتم پیشنهادی از ترکیب الگوریتم بهینه سازی مبتنی بر تدریس-یادگیری (TLBO) بهبود یافته و الگوریتم CSO برای بهینه سازی در محیط‌های ایستا بدست می‌آید. به همین دلیل، الگوریتم پیشنهادی را ETeachCSO می‌نامیم.

ادامه این مقاله بدین صورت سازماندهی شده است: بخش ۲ الگوریتم بهینه سازی هوش جمعی گربه‌ها را به طور مختصر شرح می‌دهد، بخش ۳ مدل بهینه سازی مبتنی بر یادگیر – معلم و سپس در بخش ۴ الگوریتم پیشنهادی را توضیح می‌دهد. در بخش ۵ نتایج آزمایشات مورد بررسی قرار می‌گیرد و بخش ۶ به بیان نتیجه‌گیری می‌پردازد.

۲- الگوریتم بهینه سازی هوش جمعی گربه‌ها

براساس الگوریتم CSO، گربه‌ها دارای دو حالت رفتاری جستجو و ردیابی هستند. گربه‌ها در سرتاسر فضای جستجو از طریق جذب به بهترین راه حل یافت شده توسط کل گروه حرکت می‌کنند. گربه i براساس موقعیت C_i ، سرعت V_i و یک پرچم تعریف می‌شود. پرچم بمنظور تشخیص حالت کنونی گربه بکار می‌رود. برای ترکیب کردن این دو حالت درون الگوریتم CSO، یک نرخ ترکیب از الحاق حالت جستجو و حالت ردیابی به یکدیگر تعریف می‌شود. در شروع الگوریتم CSO براساس مقدار نرخ ترکیب تعدادی از گربه‌ها در حالت ردیابی و بقیه در حالت جستجو قرار داده می‌شوند.

۲-۱- حالت جستجو

چهار فاکتور اصلی در حالت جستجو وجود دارد[۱۵] : ائتلاف حافظه جستجو (SMP) ، دامنه جستجوی بعد انتخاب شده (SRD) ، تعداد ابعاد برای تغییر (CDC) و (SPC) که یک پرچم بولین است. SPC مشخص می‌کند که آیا موقعیت کنونی گربه یکی از موقعیت‌های کاندید برای حرکت بعدی گربه خواهد بود (SPC=۱) یا نه (SPC=۰). از آنجا که در روش پیشنهادی عمل جهش فقط بر روی بهترین موقعیت یافت شده گروه انجام خواهد شد همیشه این موقعیت یکی از موقعیت‌های کاندید برای حرکت بعدی گربه است. بنابراین در الگوریتم پیشنهادی پارامتر (SPC) همیشه برابر ۱ است.SMP برای تعریف اندازه حافظه جستجو برای هر گربه استفاده می‌شود و به نقاط جستجو شده توسط گربه اشاره دارد. گربه تمایل به انتخاب یک نقطه از حافظه ائتلافی مطابق با قوانین تعریف شده دارد. SRD نرخ جهش برای هر بعد انتخاب شده را تعیین می‌کند. در حالت جستجو، اگر یک بعد برای تغییر انتخاب شود ،تفاضل بین مقدار جدید و مقدار قبلی، خارج از دامنه مجاز نخواهد شد. CDC تعیین می‌کند چه تعداد از ابعاد موقعیت گربه توسط عمل جهش تغییر داده خواهد

شد. این فاکتورها نقش‌های مهمی در حالت جستجو ایفا می‌کنند. چگونگی اجرای حالت جستجو را می‌توان در پنج گام زیر بیان کرد:

- j کپی از موقعیت کنونی Cat_k ایجاد کن ،بطوریکه j=SMP باشد. اگر مقدار SPC برابر ۱ است ،j=SMP-1 قرار بده ، سپس موقعیت کنونی گربه را به عنوان یکی از موقعیت‌های کاندید حفظ کن.
- برای هر کپی، به تعداد CDC بعد از ابعاد هر موقعیت کپی شده را در نظر بگیر، اگر SRD از یک مقدار تصادفی کمتر باشد، مقادیر موجود را بطور تصادفی جمع یا کسر کن و ابعاد قبلی را که تغییر کرده اند در مکان اولیه آن جایگزین کن.
- مقادیر برازندگی (FS) را برای همه نقاط کاندید محاسبه کن.
- اگر همه FS ها دقیقا برابر نیستند، احتمال انتخاب هر نقطه کاندید را از طریق معادله (۱) محاسبه کن ،در غیر اینصورت احتمال انتخاب هر نقطه کاندید را ۱ قرار بده .

$$p_i = \frac{|FS_i - FS_b|}{FS_{\max} - FS_{\min}} \qquad (۱)$$

در این معادله FS_i برازندگی گربه iام است و اگر هدف تابع برازندگی یافتن راه حل کمینه باشد $FS_b=FS_{max}$ در غیر اینصورت $FS_b=FS_{max}$ خواهد بود.

- از روش چرخ گردان برای انتخاب نقطه حرکت به / از نقطه کاندید استفاده کن و موقعیت کنونی را با موقعیت کاندید انتخاب شده جایگزین کن.

۲-۲- حالت ردیابی

در حالت ردیابی، حرکت بعدی هر گربه مبتنی بر سرعت گربه و بهترین موقعیت یافت شده توسط اعضای گروه تعیین می‌شود. حالت ردیابی می تواند در سه گام زیر توصیف شود:

۱.سرعت هر گربه V_k براساس معادله (۲) بروز رسانی کن:

$$V_k(t+1) = V_k(t) + r_1 \times c_1 \times (C_{gbest} - C_k(t)) \qquad (۲)$$

که در این معادله C_{gbest} موقعیت گربه‌ای است که بهترین مقدار برازندگی را دارد، C_k موقعیت کنونی Cat_k است، c_1 یک مقدار ثابت است که از بازه [۰،۲] انتخاب می‌شود،r_1 یک مقدار تصادفی یکنواخت در بازه [۰،۱] است.

۲.بررسی کن سرعت هر گربه درون بازه مجاز باشد. در مورد سرعت جدید که خارج از بازه قرار می گیرد، آن را برابر با محدودیت تعریف شده قرار بده.

۳.موقعیت Cat_k را براساس معادله (۳) بروز رسانی کن :

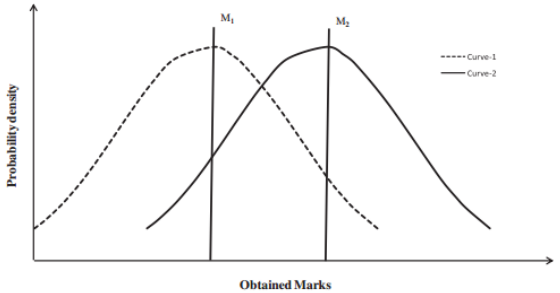
$$C_k(t+1) = C_k(t) + V_k(t+1) \qquad (۳)$$

۳- مدل بهینه سازی مبتنی بر یادگیر-معلم

فرض کنید دو معلم مختلف، T_1 و T_2، یک موضوع با محتوای یکسان را به دانش آموزان دارای سطح شایستگی یکسان در دو کلاس مختلف تدریس می‌کنند. شکل ۱ توزیع نمرات دانش آموزان دو کلاس مختلف توسط ارزیابی معلمان را نشان می دهد. منحنی های ۱ و ۲ نشان دهنده نمرات به دست آمده توسط دانش آموزان آموزش داده شده توسط T1 و T2 می‌باشد. توزیع نرمال برای نمرات به دست آمده در نظر گرفته شده است، اما در عمل آن می تواند چولگی داشته باشد. توزیع نرمال بصورت رابطه (۱) تعریف می شود،

$$f(X) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{-(x-\mu)^2}{2\sigma^2}} \qquad (۱)$$

σ^2 واریانس، μ میانگین و x هر مقداری است که در تابع توزیع نرمال موردنیاز می‌باشد. از شکل ۱ دیده می شود که منحنی ۲ نشان دهنده نتایج بهتری نسبت به منحنی ۱ است پس می توان گفت معلم T_2 در تدریس بهتر از معلم T_2 است. تفاوت اصلی بین هر دو نتایج در میانگینشان (M_2 برای منحنی ۲ و M_1 برای منحنی ۱) است،یعنی یک معلم خوب میانگین بهتری برای نتایج حاصل از دانش آموزان تولید می‌کند. تعامل بین دانش آموزان و یاد بگیرندگان کلاس نیز در نتایج بدست آمده کمک می کند.



شکل۱: مدل توزیع نمرات بدست آمده توسط دانش آموزان در دو گروه مختلف[۳].

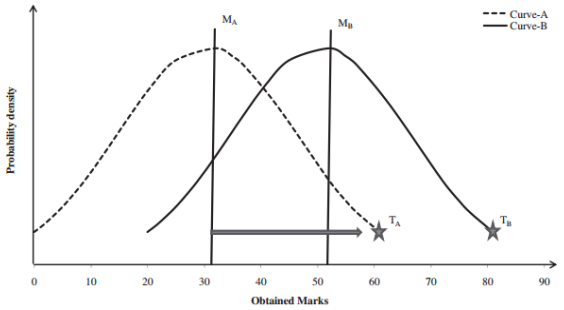
۴- الگوریتم پیشنهادی ETeachCSO

پس از مقداردهی اولیه موقعیت بصورت تصادفی، برازندگی هر کدام از اعضا محاسبه می‌شود و به دلیل اینکه معلم در کلاس درس بیشترین دانش را دارد بنابراین عضو با بهترین برازندگی به عنوان معلم در نظر گرفته می‌شود. سپس اعضای دیگر، گروه‌های اولیه را بمنظور افزایش تنوع جمعیت تشکیل می‌دهند. هر گروه از اعضای خود بمنظور جستجو برای مناطق امیدبخش در فضای جستجو استفاده می کند. برای پیاده سازی گروه بندی، فواصل متصل مختلفی ممکن است استفاده شود. در این مقاله، ما از فاصله اقلیدسی به خاطر سادگی آن برای گروهبندی استفاده می کنیم. در الگوریتم پیشنهادی همه اعضا به گروه های با تعداد مساوی (در این مقاله، هر گروه دارای پنج عضو است) بر اساس فاصله اقلیدسی بین جفت اعضا تقسیم می شوند. اول، اعضا به ترتیب صعودی نتایجشان (برای مسائل کمینه سازی) مرتب می‌شوند. سپس، فاصله اقلیدسی اولین عضو و هر یادگیرنده دیگر ارزیابی شده و همه اعضا بصورت صعودی با توجه به این فاصله اقلیدسی مرتب می‌شوند. سوم، اولین ε دانش آموز انتخاب شده و به عنوان یک گروه در نظر گرفته می‌شود. در نهایت، ε دانش آموز انتخاب شده از این لیست صعودی حذف می‌شوند. در گروه‌ها یادگیرنده با بهترین برازندگی به عنوان عضو نمونه (exemplar) یا یادگیرنده قوی در نظر گرفته می‌شود. گروهبندی زمانی که همه یادگیرنده ها به چندین گروه اولیه تقسیم شدند خاتمه می‌یابد.

باتوجه به اینکه براساس روش تدریس پیشنهادی، تیم‌های اولیه بمنظور استفاده از دانش گروه‌های دیگر، تشکیل گروه‌های موقت را می‌دهند، بنابراین اعضای هر گروه اولیه به صورت تصادفی یا ترتیبی انتخاب شده و در گروه‌های موقت قرار می‌گیرند. برای ایجاد گروه‌ها ، باید یادگیرندگان قوی و متوسط و ضعیف در یک گروه وجود داشته باشند. در اینصورت گروه ها مخلوطی از مهارت های گوناگون یادگیرندگان خواهد بود و بدین ترتیب گروهی ناهمگن بدست می آید. در گروه غیرهمگن تفاوت های افراد گروه باعث کارآمدشدن یادگیری از طریق همیاری می شود. در گروهها یادگیرنده با بهترین برازندگی به عنوان عضو نمونه (exemplar) یا یادگیرنده قوی در نظر گرفته می‌شود.

پس از تشکیل گروه های موقت، عضو نمونه و اعضای دیگر هر گروه براساس روش های متفاوت در گروههای موقت آموزش می‌بینند و از این طریق از دانش گروههای دیگر بمنظور بهبود میانگین گروه اولیه اشان استفاده می‌کنند.به همین منظور پس از پایان مرحله قبل گروههای موقت حذف شده و گروههای اولیه تشکیل می‌شود و سپس اعضای گروه از همدیگر آموزش می-بینند. به این ترتیب دانش کسب شده توسط اعضا در گروه‌های موقت، به اعضای گروه اولیه انتقال می‌یابد.

شکل ۲ را در نظر بگیرید که یک مدل برای نمرات به دست آمده توسط دانش آموزان در یک گروه اولیه با منحنی A و دارای میانگین M_A نشان می‌دهد. عضو نمونه به عنوان بهترین عضو در گروه اولیه در نظر گرفته شده است، بنابراین بهترین یادگیرنده توسط T_A در شکل نشان داده شده است. عضو نمونه تلاش می کند دانش خود را تا نزدیکی سطح دانش معلم بهبود بخشد و از طرفی با انتشار دانش خود در میان فراگیران به نوبه خود باعث افزایش سطح دانش یادگیرندگان در گروه شود و به بهبود نمرات دانش آموزان کمک کند. بنابراین عضو نمونه سعی می کند میانگین گروه را افزایش دهد. همچنین سایر اعضای گروه نیز در بهبود میانگین گروه شرکت دارند. پس از تشکیل گروه های موقت، عضو نمونه و اعضای دیگر گروه براساس روش های متفاوت در گروههای موقت آموزش می‌بینند و از این طریق از دانش گروههای دیگر بمنظور بهبود میانگین گروه اولیه اشان استفاده می‌کنند. به همین منظور پس از پایان آموزش در گروههای موقت ، گروههای اولیه تشکیل می‌شود و سپس اعضای گروه از همدیگر آموزش می‌بینند. به این ترتیب دانش کسب شده توسط اعضا در گروههای موقت، به اعضای گروه اولیه انتقال می‌یابد. بنابراین گروه اولیه از این طریق باعث جابجایی میانگین گروه به میانگین جدید M_B خواهد شد. با اینکار کیفیت نمرات اعضای گروه بالا می‌رود و در نتیجه نیاز به عضو نمونه جدید دارند. در این مورد عضو نمونه بصورت T_B نشان داده شده است. بنابراین نمودار جدید B با میانگین M_B و عضو نمونه بصورت T_B ایجاد خواهد شد.



شکل ۲:مدل توزیع نمرات بدست آمده برای یک گروه دانش آموز[۳]

۴-۱- روش‌های یادگیری اعضای گروه

همانطور که در بخش قبل اشاره شد هر گروه موقت شامل اعضای نمونه ، متوسط و ضعیف می‌باشد که هر نوع به روش

متفاوتی برای بهبود نمرات خود نیاز دارنـد. دانـش آمـوزان قـوی تلاش دارند دانش خود را تا نزدیکـی سـطح دانـش معلـم بهبـود بخشـند بنـابراین بایـد جسـتجوی خـوبی در پیرامـون بهتـرین موقعیت(P_g) انجام دهند بنابراین یک روش جستجوی سـاده امـا موثر برای بهره برداری توسط دانش آموزان قـوی(exemplar) بـا استفاده از معادله (۲) انجام می شود.

$$C_{exem}(t) = C_{exem}(t-1) + r_1 \times (C_{Teacher}(t) - C_{exem}(t-1)) \quad (۲)$$

در معادله (۲) عبارت $C_{exem}(t)$ موقعیت جدید عضو نمونه است. r_1 یک مقدار تصادفی در بازه [۱و۰] می‌باشد. $C_{Teacher}$ موقعیت معلم است.

از طرف دیگر شاگردان ضعیف بایـد در جسـتجوی راه حـل های بهتر برای بهبود عملکردشان باشند بنابراین باید جسـتجوی بیشتری در فضای مسئله انجام دهند و به آنها مهلت داده شود تا عملکردشان را بهبود بخشند. اعضای ضعیف گـروه از سـه طریـق سعی می‌کند دانش خود را بهبود دهند:

- بهبود دانش خود با استفاده از یک جستجوی تصادفی پیرامون موقعیت خودش(آموزش فردی)

$$C_{i,1} = C_{i,SMP}(t-1) \quad (۳)$$

در معادله (۳) عبارت $C_{i,1}$ موقعیت جدید عضو i بعد از انجام عمل جهش می‌باشد. بمنظور انجام عمل جهش ابتدا SMP کپی از موقعیت فعلی عضو i ایجاد شده و از این تعداد بر روی CDC بعد از ابعاد (SMP-1) موقعیت با نرخ جهش SRD عمل جهش انجام می‌شود. در اینصورت موقعیت فعلی نیز به عنوان یکی از SMP موقعیت کاندید برای حرکت بعدی در نظر گرفته خواهد شد .سپس مقدار شایستگی همه موقعیت‌های کاندید محاسبه می‌شود. اگر همه مقادیر شایستگی‌ها برابر نباشند، احتمال انتخاب هر نقطه کاندید بوسیله معادله (۱) محاسبه می‌شود در غیراینصورت احتمال انتخاب هر نقطه کاندید ۱ در نظر گرفته می‌شود. سپس با استفاده از روش چرخ گردان یکی از موقعیت-های کاندید انتخاب شده و به عنوان $C_{i,SMP}$ در نظر گرفته می-شود.

- یادگیری از عضو نمونه گروهی که عضو i در آن قرار دارد.

$$C_{i,2} = r_2 \times (C_{exem}(t) - C_i(t-1)) \quad (۵)$$

در معادله (۵) عبارت r_2 یک عدد تصادفی در بازه [۱و۰] است. C_{exem} موقعیت ذره exemplar می‌باشد.

- یادگیری از اعضای دیگر گروه که بهتر از خود یادگیرنده می‌باشد.

$$C_{i,3} = r_3 \times (C_{j,rnd}(t-1) - C_i(t-1)) \quad (۶)$$

در رابطه (۶) عبارت $C_{j,rnd}$ موقعیت عضو j است که یک عضو همگروه عضو i می‌باشد و بصورت تصادفی از بین اعضای همگروه عضو i که بهتر از خود i می باشند انتخاب می‌شود. r_3 یک عدد تصادفی از بازه [۱و۰] می‌باشد.

- در انتها موقعیت عضو i بصورت معادله (۷) بروز رسانی می‌شود:

$$C_i(t) = C_{i,1} + C_{i,2} + C_{i,3} \quad (۷)$$

بعد از انجـام مراحـل بـالا و بـروز رسـانی موقعیـت ذرات در گروههای موقت، مرحله بازگشت بـه گروههـای اولیـه و آمـوزش اعضای گروه اولیه توسط دیگر اعضا انجام خواهد شد. بـرای انجـا اینکار هر عضو از عضو هم تیمی اش که بهتر از خودش می‌باشـد بصـورت تصـادفی انتخـاب کـرده و از رابطـه (۸) مـوقعیتش را بروزرسانی می‌کند. در رابطه (۸) عبارت r_4 یـک عـدد تصـادفی از بازه [۱و۰] است.

$$C_i(t) = C_i(t) + r_4 \times (C_{j,rnd}(t) - C_i(t)) \quad (۸)$$

- سپس میانگین و عضو نمونه جدید گروه محاسبه می-شود.

$$C_{exem,i}(t) = \underset{c_i \in PrimaryGroupi}{\arg\max} (f(c_i)) \quad (۹)$$

- سپس مرحله بروز رسانی معلم انجام می‌شود. این مرحله از این حقیقت در کلاس درس الهام گرفته شده است که یک عضو می‌تواند دانش خود را آنقدر بهبود دهد که سطح برازندگی آن بالاتر از عضو معلم شود. باید توجه شود که برای بروز رسانی معلم کل اعضای کلاس در نظر گرفته می‌شود .

$$C_{Teacher}(t) = \arg\max_{c} (f(c)) \quad (۱۰)$$

مراحل بالا تا رسیدن به معیار اتمام اجرای الگوریتم ادامه می‌یابد.

۵- آزمایشات

عملکرد الگوریتم RCSO بر روی ۵ تابع محک آزمایش شده است. این توابع شامل Rastrigin، Sphere،Rosenbrock، Ackley و Griewank می‌باشد. که بترتیب با F_1،F_2،F_3،F_4 و F_5 مشخص شده است. جدول ۱ مقادیری که برای ابعاد تابع ، محدوده مجاز، بازه مجاز برای مقداردهی اولیه موقعیت گربه‌ها و هدف هر تابع که باید توسط الگوریتم‌ها بدست آید، نشان داده شده است.

جدول۱:توابع محک و پارامترهای آنها

معادله تابع	ابعاد	بازه مجاز	هدف
$F_1=\sum_{i=1}^{n-1}\left(100\left(x_{i+1}-x_i^2\right)^2+\left(x_i-1\right)^2\right)$	30	$[-30,30]^n$	100
$F_2=\sum_{i=1}^{n}x_i^2$	30	$[-5.12,5.12]^n$	0.01
$F_3=10n+\sum_{i=1}^{n}(x_i^2-10\cos(2\pi x_i))$	30	$[-5.12,5.12]^n$	100
$F_4=20+e-20\exp\left(-0.2\sqrt{\frac{1}{n}\sum_{i=1}^{n}x_i^2}\right)-\exp\left(\frac{1}{n}\sum_{i=1}^{n}\cos\left(2\pi x_i\right)\right)$	30	$[-32,32]^n$	0.1
$F_5=1+\sum_{i=1}^{n}\frac{x_i^2}{4000}-\prod_{i=1}^{n}\cos\left(\frac{x_i}{\sqrt{i}}\right)$	30	$[-600,600]^n$	0.1

الگوریتم پیشنهادی با الگوریتم‌های BCSO[۱]، SPSO[۱۰]، PSOIW[۹]، PSO-TVAC[۱۱]، PSOLP[۱۲]، $UAPSO_{Con}$، $IAPSO_{Adv}$ و $IAPSO_{Con}$ [۱۳] مقایسه شده است. همه آزمایشات ۱۰۰۰۰ بار اجرا شده اند. معیار اتمام یک اجرای الگوریتم رسیدن به تعداد تکرار از پیش تعریف شده است که این مقدار برای همه آزمایشات ۱۰۰۰می‌باشد. برای همه الگوریتم‌ها میانگین بهترین برازندگی در جدول ۱ گزارش شده است. این نتایج با فاصله اطمینان ۹۵٪ گزارش شده است. در هر آزمایش بهترین نتیجه بدست آمده بولد شده است. سپس نتایج الگوریتم-ها براساس موفقیت و سرعت همگرایی در رسیدن به یک هدف خاص برای هر تابع ارایه شده و مقایسه شده است. در این آزمایش نخست نرخ موفقیت هر الگوریتم در رسیدن به هدف خاص برای هر تابع مطالعه شده است. نرخ موفیت یک الگوریتم بصورت درصد اجراهای موفق آن است. یک اجرای موفق اجراییست که در آن الگوریتم به هدف خاص تابع می‌رسد[۱۹]. سپس، ما سرعت همگرایی به هدف را برای اجراهای موفق هر تابع اندازه می گیریم که برابر با تعداد تکرارهای مورد نیاز برای رسیدن به هدف خاص است[۱۴]. نتایج ارایه شده در این بخش متوسط ۱۰۰۰ اجرا الگوریتم با ۵۰۰۰ تکرار در هر اجرا می باشد.نرخ موفقیت الگوریتم پیشنهادی و سایر الگوریتم‌ها در جدول های ۲ و ۳ و در شکل‌های ۳ و ۴ ارایه شده است.

جدول(۴):میانگین بهترین برازندگی الگوریتم‌های مختلف و رتبه آنها

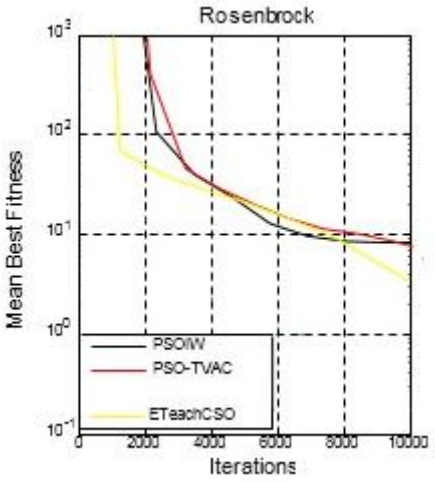
Function / Algorithm	Mean Fitness				
	F_1	F_2	F_3	F_4	F_5
$IAPSO_{Con}$	3.50 ±0.30	2.3E-84 ±2.8E-84	2.2E+00 ±8.3E-02	**1.11E-2 ±1.9E-2**	2.81E-2 ±1.4E-3
BCSO	978.645 ±1.39	9.559E-06 ±5.3E-30	62.926 ±7.9E-01	**2.520E-2 ±1.4E-4**	1.81E-2 ±1.0E-3
$UAPSO_{Con}$	5.82 ±0.71	4.9E-52 ±9.3E-52	3.1E+00 ±2.0E-01	8.51E-2 ±7.1E-2	2.62E-2 ±1.9E-3
TLBO	25.30 ±1.66	2.1E-44 ±1.6E-44	6.4E+00 ±1.5E-01	6.40E-5 **±1.3E-4**	2.35E-2 ±1.4E-3
ETeachCSO	3.35 ±0.30	2.4E-84 ±2.8E-84	2.2E+00 ±8.3E-02	**1.01E-2 ±1.9E-2**	2.81E-2 ±1.4E-3
PSOIW	8.19 ±0.83	2.5E-243 ±0.0E+00	3.2E+01 ±4.9E-01	1.65E+0 ±2.9E-1	**1.57E-2 ±9.6E-4**
PSO-TVAC	7.89 ±0.81	2.0E-190 ±0.0E+00	2.9E+01 ±3.8E-01	6.96E-2 ±4.9E-2	1.99E-2 ±1.1E-3
DCPSO	70.72 ±6.72	1.1E-05 ±1.8E-06	2.5E+01 ±1.0E+00	4.78E+0 ±9.6E-1	3.19E-2 ±3.8E-3
PSO-LP	1.32 ±0.47	**7.3E-292 ±0.0E+00**	1.1E+02 ±3.4E+00	1.98E+1 ±7.8E-3	4.76E-2 ±6.8E-3
DAPSO	714.42 ±49.13	5.0E+00 ±1.9E-01	5.1E+01 ±9.6E-01	4.26E+0 ±3.8E-1	1.03E+0 ±3.0E-3

جدول(۲):میانگین نرخ موفقیت

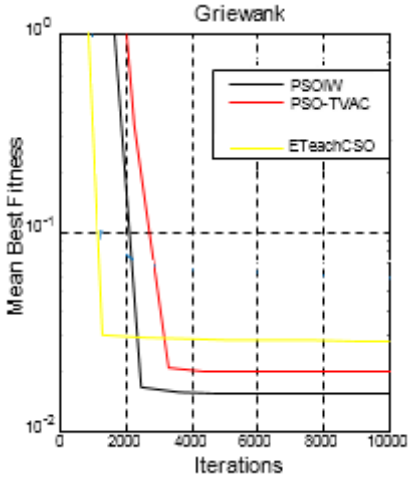
Function / Algorithm	F_1	F_2	F_3	F_4	F_5
BCSO	95.1%	**100.0%**	94.9%	95.0%	96.4%
$UAPSO_{Con}$	99.5%	**100.0%**	**100.0%**	21.2%	97.0%
TLBO	90.0%	**100.0%**	**100.0%**	98.0%	98.0%
ETeachCSO	99.0%	**100.0%**	**100.0%**	79.9%	98.5%
PSOIW	99.8%	**100.0%**	**100.0%**	75.8%	**99.8%**
PSO-TVAC	99.9%	**100.0%**	**100.0%**	78.1%	99.2%

جدول(۳):میانکین تعداد تکرارهای رسیدن به هدف در اجراهای مختلف

Function / Algorithm	F_1	F_2	F_3	F_4	F_5
BCSO	59,703 ±2,326	32,907±1 ,014	32,369±1 ,298	45,283±9 21	39,261±8 50
$UAPSO_{Con}$	39,077 ±1,498	28,033±3 09	28,462±6 82	99,448±7 ,357	24,230±3 55
TLBO	47,838 ±1,815	22,931±1 47	20,947±7 13	43,285±5 27	22,779±5 02
ETeachCSO	**27,856 ±1,747**	**10,964±1 05**	18,850±4 85	95,158±5 ,375	**19,157±3 71**
PSOIW	42,792 ±1,307	38,187±1 43	14,571±2 42	33,535±3 67	36,385±1 56
PSO-TVAC	28,736 ±988	22,193±1 00	**11,433±2 06**	**22,249±2 21**	21,177±1 56



شکل ۳:میانگین بهترین برازندگی در ۱۰۰۰۰تکرار



شکل ۴:میانگین بهترین برازندگی در ۱۰۰۰۰تکرار

۶- نتیجه‌گیری

در این مقاله بمنظور بهبود الگوریتم CSO در محیط ایستا روش نوینی معرفی شد. روش پیشنهادی بطور خاص بمنظور بهبود رفتار گربه‌ها زمانی‌که در حالت دنبال کردن قرار دارند پیشنهاد شد. براساس این روش، گربه‌ها در حالت دنبال کردن رفتار متفاوتی نسبت به رویکرد موجود در الگوریتم CSO اصلی داشتند. تفاوت روش پیشنهادی در استفاده از بهترین موقعیت یافت شده توسط گروه برای بروز رسانی موقعیت گربه‌ها در حالت دنبال کردن است.

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همزمان‌سازی سیستم‌های آشوبناک مرتبه کسری اقتصادی با استفاده از کنترل مد لغزشی ترمینال مرتبه‌کسری- ژنتیک

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چکیده - در این مقاله، یک روش مبتنی بر مد لغزشی به منظور همزمان‌سازی سیستم‌های آشوبناک مرتبه کسری اقتصادی معرفی شده است. پارامترهای این کنترل‌کننده توسط الگوریتم ژنتیک به منظور کاهش هزینه کنترلی و زمان عملکرد تعیین می‌گردند. سیستم‌های شبیه‌سازی شده در این مقاله ساختارهای متفاوتی دارند. روش ارائه شده در این پژوهش قادر به حذف عواملی همچون اغتشاش و عدم قطعیت در سیستم‌ها با دامنه محدود می‌باشد. نتایج شبیه‌سازی‌های انجام شده گویای عملکرد مناسب کنترل‌کننده می‌باشد.

کلید واژه - سیستم آشوبناک اقتصادی، سیستم‌های پایه و پیرو، سیستم مرتبه کسری، کنترل‌کننده مد لغزشی ترمینال، همزمان‌سازی.

۱- مقدمه

محاسبات مرتبه کسری نقش بسیار مهمی در زمینه‌های گوناگون علمی دارد، به خصوص در دهه اخیر کاربرد کنترل مرتبه کسری در مهندسی کنترل به عنوان یک موضوع مهم در عرصه تحقیقات بین‌المللی مطرح شده است[1,2]. اخیرا دانشمندان نشان داده‌اند که معادلات مرتبه کسری قادرند پدیده‌های گوناگون را مناسب‌تر از مرتبه صحیح آن مدل کنند و یک ابزار قدرتمند جهت توصیف ساختارهای یک سیستم با دینامیک پیچیده می‌باشند. اکثر سیستم‌های موجود در طبیعت با دینامیک کسری بوده و با تقریب، مرتبه‌ی آنها صحیح در نظر گرفته می‌شود. تئوری الکترومغناطیس [3]، حرکت براونی کسری [4]، دینامیک محیط متخلخل [5]، تئوری راه رفتن تصادفی با پیوستگی زمان [6] و تئوری آشوب جزو این دسته از سیستم‌ها هستند. رفتار آشوبی در زمینه‌های مختلف علوم و مهندسی مانند مکانیک، برق، فیزیک، پزشکی، زیست‌شناسی، اقتصاد و.... مشاهده شده است. آشوب در بسیاری از سیستم‌های کسری وجود دارد و کنترل سیستم آشوبی و همچنین همزمان‌سازی دو سیستم آشوبی در سیستم‌های با دینامیک کسری بسیار حائز اهمیت و پرکاربرد است. از عمده کاربردهای آن می‌توان به همزمان‌سازی سیستم‌های آشوبی در مخابرات امن اشاره نمود. یک هدف مهم در کنترل آشوب متوقف نمودن نوسان‌های آشوبی و یا کاهش آنها به نوسان‌های معمول است. سیستم‌های مرتبه کسری برای کنترل موثرشان معمولا به کنترل‌کننده‌های مرتبه کسری نیاز دارند. بعد از اولین روش همزمان‌سازی توسط پکورا و کارول، روش‌های مختلف کنترل برای همزمان‌سازی سیستم‌های آشوبی شامل روش خطی‌سازی فیدبک [7]، روش‌های کنترل فازی [8,9]، روش ضربه‌ای [10]، روش گام به عقب [11]، کنترل مد لغزشی [12]، کنترل مد لغزشی فعال [13,14]، کنترل تطبیقی ارائه شده است[15]. در زمینه همزمان‌سازی از عملگر کسری جهت معرفی کنترل‌کننده‌های کسری و ایجاد یک قانون کنترل جدید و مناسب برای همزمان‌سازی سیستم‌های آشوبی با دینامیک کسری استفاده می‌گردد [16-21].

در این مقاله بر مبنای روش مد لغزشی یک کنترل‌کننده مد لغزشی ترمینال جهت همزمان‌سازی سیستم‌هایی با وجود عدم قطعیت و اغتشاش معرفی شده است. این روش با فرض کراندار بودن محدوده عدم قطعیت و اغتشاش معرفی شده است که فرضی منطقی می‌باشد. از الگوریتم ژنتیک نیز به منظور بهینه‌سازی ضرایب کنترلی برای کاهش هزینه کنترلی و حداقل کردن زمان استفاده شده است.

ساماندهی مقاله به صورت زیر می‌باشد. در بخش دوم به معرفی عملگر کسری مربوط به محاسبات کسری پرداخته شده است. روش پیشنهادی در فصل سوم ارائه می‌شود. بخش چهارم به معرفی سیستم آشوبناک اقتصادی اختصاص دارد. نتایج شبیه‌سازی در بخش پنجم نشان داده می‌شود. جمع‌بندی کارهای انجام شده نیز در بخش ششم آورده شده است.

۲- مشتقات کسری و روش‌های تقریب آن‌ها

عملگر ${}_{\alpha}D_t^q$ یک ترکیبی از عملگر انتگرال و مشتق است که در محاسبات مرتبه کسری به طور معمول استفاده می‌شود که انتگرال و مشتق مرتبه کسری را در یک عبارت واحد نمایش می‌دهد[۲۲]. و تعریف آن :

$$ {}_{\alpha}D_t^q = \begin{cases} \frac{d^q}{dt^q} & q > 0 \\ 1 & q = 0 \\ \int_{\alpha}^{t} (d\tau)^{-q} & q < 0 \end{cases} \qquad (۱) $$

همچنین چندین تعریف برای معادلات مرتبه کسری وجود دارد[22-24]. سه تعریف متداول از این معادلات ریمان-لیوویل[1] گرانوالد-لتنیکو[2] و کاپوتو[3] می‌باشند.

۲-۱ – تعریف Grunwald-Letnikov

عملگر معادله دیفرانسیل مرتبه کسری Grunwald-Letnikov از مرتبه q [22]:

$$ {}_{\alpha}D_t^q f(t) = \frac{d^q f(t)}{d(t-a)^q} = \lim_{N\to\infty} \left[\frac{t-a}{N}\right]^{-q} \sum_{j=0}^{N-1} (-1)^j f\left(t - j\left[\frac{t-a}{N}\right]\right) \qquad (۲) $$

۲-۲- تعریف Riemann-Liouvill

معمول‌ترین تعریف انتگرال مرتبه کسری، انتگرال کسری RL (Riemann-Liouville) نامیده می‌شود:

$$ D^{-q}x(t) = \frac{1}{\Gamma(q)} \int_{t_0}^{t} (t-\tau)^{q-1} x(\tau) d\tau \qquad (۳) $$

که Γ تابع گاما بوده و $q \epsilon R^+$ مرتبه انتگرال است. سپس از معادله بالا برای تعریف مشتق مرتبه کسری استفاده می‌کنیم. مشتق مرتبه کسری تابع $x(t)$ از مرتبه q برابر است با :

$$ D^q x(t) = \frac{d^m}{dt^m}\left[D^{-(m-q)}x(t)\right] = \frac{1}{\Gamma(m-q)} \frac{d^m}{dt^m} \int_{t_0}^{t} (t-\tau)^{m-q-1} x(\tau) d\tau \qquad (۴) $$

که m یک عدد صحیح است که در $m-1 < q < m$ صدق می‌کند. تبدیل لاپلاس مشتق- انتگرال مرتبه کسری معادله (۳) و (۴) تحت شرایط اولیه صفر برای مرتبه q برابر است با :

$$ L\{D^{\pm q}x(t)\} = S^{\pm q}X(s) \qquad (۵) $$

۲-۳-تعریف Caputo

اگر $m \in N$، در نتیجه معادله دیفرانسیل کسری Caputo از تابع $f(x)$ به صورت زیر تعریف می‌شود[22] .

$$ {}_{\alpha}D_t^q = \begin{cases} \frac{1}{\Gamma(m-q)} \int_{a}^{t} (t-\tau)^{m-q-1} \frac{d^m f(\tau)}{d\tau^m} d\tau & m-1 < q < m \\ \frac{d^m u(x,t)}{dt^m} & q = m \in N \end{cases} \qquad (۶) $$

که m کوچکترین عدد صحیح بزرگتر از q می‌باشد. معادله دیفرانسیل کسری Caputo اجازه می‌دهد شرایط مرزی در فرمول‌بندی مسئله گنجانده شوند، اما برای فرض شرایط اولیه همگن این دو عملگر بر یکدیگر منطبق می‌شوند. برای جزئیات بیشتر در مورد معادلات دیفرانسیل کسری RL و Caputo به [22] مراجعه شود.

۳- همزمان‌سازی با استفاده از کنترل مودلغزشی ترمینال مرتبه‌کسری برای سیستم‌هایی با ساختار متفاوت

در این بخش از روش کنترل مودلغزشی جهت همزمان‌سازی سیستم‌هایی با ساختار متفاوت استفاده شده‌است. این سیستم‌ها علاوه بر شرایط اولیه، از لحاظ ساختاری نیز با یکدیگر متفاوت می‌باشند. سیستم‌های پایه و پیرو به صورت (۷) و (۸) مفروض می‌باشند.

[1] Riemann-Liouville(RL)
[2] Grunwald-Letnikov
[3] Caputo

$$\frac{d^q x_m}{dt^q} = f(x_m) = A_1 x_m + F(x_m) \quad (۷)$$

$$\frac{d^q x_s}{dt^q} = f(x_s) + u = A_2 x_s + F(x_s) + \Delta g(x_s, t) + d(t) + u \quad (۸)$$

در رابطه فوق، $f(x_m), f(x_s), x_s, x_m \epsilon R^n$ متغیرهای حالت سیستم و $A_2, A_1 \epsilon R^{n\times n}$ ضرایب پارامتری سیستمی، $u \epsilon R$ سیگنال کنترلی و n تعداد متغیرهای سیستم‌ها می‌باشند. $|\frac{d^{1-q}}{dt^{1-q}}(\Delta g(x_s,t))| < \varepsilon_1$ معرف عدم قطعیت و $\left|\frac{d^{1-q}}{dt^{1-q}}(d(t))\right| < \varepsilon_2$ مبین اغتشاشات خارجی در برابر پارامترهای سیستم است که برای آن‌ها شرط کراندار بودن در نظر گرفته شده است.

خطا به صورت رابطه (۹) تعریف می‌شود:

$$e = x_s - x_m \quad (۹)$$

با توجه به تعاریف فوق، دینامیک خطا به صورت رابطه (۱۰) محاسبه می‌گردد:

$$\frac{d^q e}{dt^q} = f(x_s) + u - f(x_m) = f(x_m, x_s, e) + u = A_2 e + F(x_s) + \Delta g(x_s, t) + d(t) - F(x_m) + (A_2 - A_1)x_m + u \quad (۱۰)$$

برای سیستم مذکور سطح لغزش به صورت رابطه (۱۱) معرفی می‌شود.

$$s = \sum_{i=1}^{n} \left(\int_0^t D^q e_i(\tau)d\tau - \int_0^t \left(A_2 e(\tau)\right)_i d\tau - \int_0^t \left(ke(\tau)\right)_i d\tau\right) + \lambda_i e_i^{\frac{p}{q_1}} \quad (۱۱)$$

در رابطه فوق، k ماتریس فیدبک حالت می‌باشد.

بر اساس قانون سطح لغزش که باید $\dot{s} = 0$ باشد، داریم:

$$\dot{s} = \sum_{i=1}^{n} D^q e_i(t) - \left(Ae(t)\right)_i - \left(ke(t)\right)_i + \frac{p}{q_1}\dot{e}_i(t)e_i(t)^{\frac{p-q_1}{q_1}} = 0 \quad (۱۲)$$

با توجه به رابطه (۱۳)، u_{ieq} به صورت زیر به دست می‌آید:

$$u_{ieq} = -F(x_s) + F(x_m) + \left(ke(\tau)\right)_i - (A_2 - A_1)x_m - \frac{p}{q_1}\dot{e}_i(t)e_i(t)^{\frac{p-q_1}{q_1}} \quad (۱۳)$$

برای جلوگیری از تاثیر عوامل ناخواسته، عامل غیرخطی به صورت زیر را به سیگنال کنترلی اضافه می‌کنیم:

$$u_i = u_{ieq} + \left(k_r \frac{d^{q-1}}{dt^{q-1}}(sign(S))\right)_i \quad (۱۴)$$

قضیه ۱ (پایداری لیاپانوف): با در نظرگرفتن دینامیک خطای همزمان‌سازی رابطه (۱۰) و سطح لغزش رابطه (۱۱)، و اعمال ورودی (۱۴) دینامیک خطا پایدار مجانبی خواهد بود و شرط رسیدن به سطوح لغزش برآورده می‌شود، اگر وتنها اگر $K_r < -(\eta + \varepsilon_1 + \varepsilon_2)$ انتخاب شود. در واقع $\varepsilon_2, \varepsilon_1$ کران بالای عدم قطعیت و اغتشاش خارجی سیستم و η یک عدد مثبت هستند.

اثبات:

تابع لیاپانوف به‌صورت (۱۵) تعریف شده‌است:

$$V = \frac{1}{2}S^2 \quad (۱۵)$$

تابع معرفی شده، مثبت معین است و تمامی شرایط مربوط به توابع لیاپانوف را دارا می‌باشد. طبق تئوری پایداری لیاپانوف اگر مشتق این تابع منفی معین باشد، $S = 0$ پایدار مجانبی خواهد بود. اما در تئوری کنترل مد لغزشی برای تضمین همگرایی زمان محدود متغیر لغزش، شرط لغزش زیر باید برقرار شود.

$$\dot{V} = S\dot{S} \leq -\eta|S| \quad (۱۶)$$

η یک ثابت مثبت می‌باشد. با انتگرال‌گیری از طرفین شرط لغزش داریم:

$$t_r \leq \frac{|S(0)|}{\eta} \quad (۱۷)$$

t_r مدت زمان همگرایی متغیر لغزش است. همانطور که در این رابطه مشاهده می‌شود، مدت زمان صفر شدن متغیر لغزش با تغییر مقدار پارامتر η قابل تنظیم است. حال برای برقراری شرط (۱۶) داریم:

$$\dot{V} = S\dot{S} = S\frac{d^{1-q}}{dt^{1-q}}\Big(K_r\frac{d^{q-1}}{dt^{q-1}}(sign(S)) + \Delta g(x_s,t) + d(t)\Big) = S\Bigg(K_r sign(S) + \frac{d^{1-q}}{dt^{1-q}}\big(\Delta g(x_s,t)\big) + \frac{d^{1-q}}{dt^{1-q}}\big(d(t)\big)\Bigg) \le K_r|S| + \varepsilon_1 S + \varepsilon_2 S \le (K_r|S| + \varepsilon_1|S| + \varepsilon_2|S|) = |S|(K_r + \varepsilon_1 + \varepsilon_2) \le \eta|S| \quad (۱۸)$$

برای برقراری شرایط قضیه لیاپانوف، باید $\dot{V} < 0$ باشد، که تنها شرط لازم و کافی برای این امر، انتخاب $K_r < -(\eta + \varepsilon_1 + \varepsilon_2)$ می‌باشد. با پایداری دینامیک خطا، رفتار سیستم‌های پایه و پیرو در مدت زمان محدودی که توسط رابطه (۱۷) تعیین می‌گردد، با هم برابر می‌شوند.

با استناد به قضیه ۱، حدود مقدار پارامتر k_r تعیین می‌شود و با استفاده از روش الگوریتم ژنتیک سعی بر این شده تا مقدار بهینه‌ی این پارامتر با توجه به تابع هزینه‌ای که عملکرد کنترلی کنترل‌کننده بر سیستم را پوشش می‌دهد، انتخاب شود. تابع هزینه در نظر گرفته شده برای سیستم به صورت (۱۹) می‌باشد.

$$Fitness\ Function = \int_0^t \tau(|u(\tau)| + |e_1| + \cdots + |e_n|)d\tau \quad (۱۹)$$

در رابطه فوق $u(\tau)$ هزینه کنترلی و eها خطای سیستم می‌باشند. این مقدار با قدر مطلق در نظر گرفته شده است تا مقادیر منفی و مثبت یکدیگر را خنثی نکنند. الگوریتم ژنتیک ۳ پارامتر p, q_1, K_r را جهت رسیدن به هدف فوق تنظیم می‌کند.

۴- معرفی سیستم آشوبناک

در این بخش سیستمی که برای پیاده‌سازی روش همزمان‌سازی در بخش بعد مورد استفاده قرار می‌گیرند، معرفی شده‌اند.

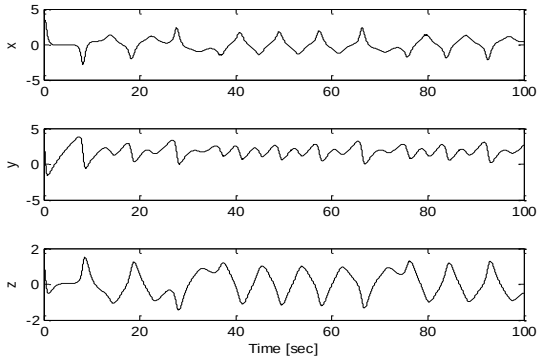
۴-۱- سیستم آشوبناک مرتبه کسری اقتصادی

معادلات این سیستم به صورت رابطه (۲۰) تعریف می‌گردد:

$$\begin{cases} \frac{d^q x}{dt^q} = z + (y-a)x \\ \frac{d^q y}{dt^q} = 1 - by - x^2 \\ \frac{d^q z}{dt^q} = -x - cz \end{cases} \quad (۲۰)$$

در رابطه فوق، $(a,b,c,q) \epsilon R$ می‌باشند.

در شکل ۱، شبیه‌سازی سیستم (۲۰) که نشان‌دهنده رفتار آشوبناک سیستم می‌باشد، آورده شده است.



شکل ۱. نتایج شبیه‌سازی سیستم اقتصادی به ازای $(a,b,c,q) =$ (1,0.1,1,0.98)

۵- نتایج شبیه‌سازی

در این بخش نتایج همزمان‌سازی سیستم معرفی شده در بخش قبل به روش پیشنهادی در این مقاله آورده شده‌اند.

۵-۱-همزمان‌سازی سیستم آشوبناک مرتبه‌کسری اقتصادی

سیستم‌های پایه و پیرو به صورت روابط زیر تعریف می‌گردند:

$$master\ system: \begin{cases} D_t^q x_m(t) = z_m + (y_m - 1)x_m \\ D_t^q y_m(t) = 1 - 0.1y_m - x_m^2 \\ D_t^q z_m(t) = -x_m - z_m \end{cases}$$

$$slave\ system: \begin{cases} D_t^q x_s(t) = z_s + (y_s - 0.9)x_s \\ D_t^q y_s(t) = 1 - 0.1y_s - x_s^2 + 0.1\sin(t) + 0.1\cos(x_s y_s) \\ D_t^q z_s(t) = -x_s - 1.1z_s + u \end{cases}$$

بر اساس سیستم اقتصادی، سیستم‌های پایه و پیرو فوق مفروضند. برای سیستم‌های مذکور ماتریس‌های A_1, A_2 و $f(x_m), f(x_s)$ داریم:

$$A_1 = \begin{bmatrix} -1 & 0 & 1 \\ 0 & -0.1 & 0 \\ -1 & 0 & -1 \end{bmatrix}$$

$$A_2 = \begin{bmatrix} -0.9 & 0 & 1 \\ 0 & -0.1 & 0 \\ -1 & 0 & -1.1 \end{bmatrix}$$

$$f(x_s) = \begin{bmatrix} x_s y_s \\ -x_s^2 \\ 0 \end{bmatrix}, f(x_m) = \begin{bmatrix} x_m y_m \\ -x_m^2 \\ 0 \end{bmatrix}$$

ماتریس k باید بگونه‌ای انتخاب شود که قطب‌های سیستم سمت چپ محور موهومی قرار گیرند و یا به عبارت دیگر پایداری سیستم تضمین شود.

$$k = \begin{bmatrix} -9.1 & 0 & -1 \\ 0 & -5.9 & 0 \\ 1 & 0 & -8.9 \end{bmatrix}$$

در مورد سیستم‌های پایه و پیرو سطح لغزش به صورت رابطه (۱۱) با پارامترهای تعریف می‌شود.

$$(\lambda_1, \lambda_2, \lambda_3, p, q_1, K_r) = (0.1,0.1,0.1,25,23, -118.157)$$

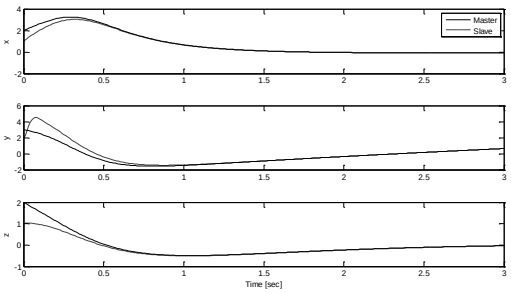
با درنظر گرفتن مقادیر زیر و اعمال سیگنال کنترلی (14) شبیه‌سازی‌ها انجام شده‌است.

$$(x_{m0}, y_{m0}, z_{m0}) = (2,3,2)$$

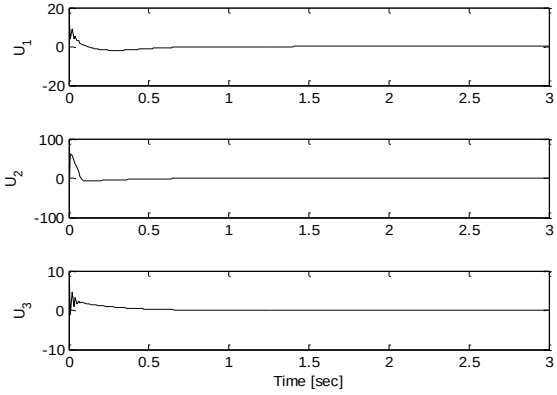
$$(x_{s0}, y_{s0}, z_{s0}) = (1,2,1) \quad , \quad q = 0.98$$

به ازای پارامترهای تعیین شده توسط الگوریتم ژنتیک، بهینه‌ترین مقدار تابع هزینه مقدار $Fitness\ Value = 2.4321$ به دست می آید.

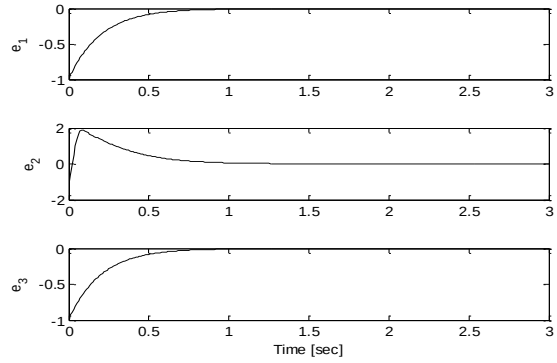
نتایج شبیه‌سازی در شکل‌های (۳-٦) آورده شده‌اند.



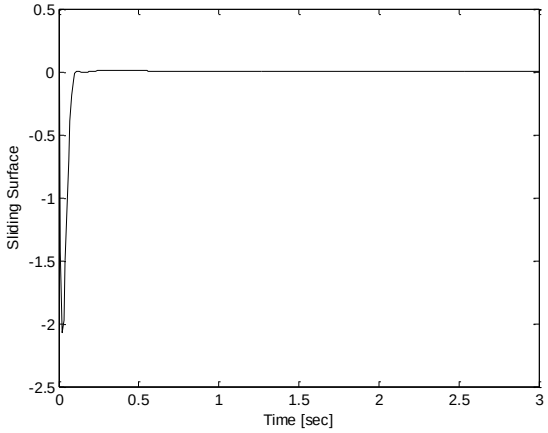
شکل۳. نتایج شبیه‌سازی همزمان‌سازی سیستم اقتصادی در شرایط ساختار متفاوت با کنترل‌کننده مودلغزشی ترمینال مرتبه‌کسری



شکل٤. سیگنال‌های کنترلی رابطه (١٤) کنترل‌کننده مودلغزشی ترمینال مرتبه‌کسری



شکل٥. سیگنال خطای همزمان‌سازی سیستم اقتصادی در شرایط ساختار متفاوت با کنترل‌کننده مودلغزشی ترمینال مرتبه‌کسری



شکل۵. سطح لغزش سیستم اقتصادی در شرایط ساختار متفاوت با کنترل‌کننده مودلغزشی ترمینال مرتبه‌کسری

همانگونه که از نتایج حاصله پیداست، عملکرد سیستم کنترلی کاملا قابل قبول می‌باشد. دو معیار مهم زمان و هزینه کنترلی بسیار مقادیر کوچک و قابل قبولی می‌باشند. در جدول ۱ مقایسه‌ای بین کارهای قبلی و کار انجام شده در این مقاله انجام شده است که عملکرد موفقیت آمیز کنترل‌کننده طراحی شده را نشان می‌دهد.

جدول۱. مقایسه عملکرد روش‌های مختلف کنترل مودلغزشی بر سیستم آشوبناک اقتصادی در شرایط ساختار متفاوت

روش کنترلی	هزینه کنترلی	خطای حالت ماندگار	زمان نشست سیگنال e_1	زمان نشست سیگنال e_2	زمان نشست سیگنال e_3
کنترل مودلغزشی	610.3	0.064	18.42	19.24	18.42
کنترل مودلغزشی مرتبه‌کسری با یک سطح لغزش	73.76	1.87	18.9	19.9	19.9
کنترل مودلغزشی مرتبه‌کسری با چند سطح لغزش	482.12	$3.3e^{-4}$	0.44	0.05	0.04
کنترل مودلغزشی ترمینال مرتبه‌کسری	2.4321	0	0.7	0.8	0.7

۶- نتیجه‌گیری

در این مقاله، یک روش مبتنی بر مد لغزشی به منظور همزمان‌سازی سیستم‌های آشوبناک مرتبه کسری معرفی شده است. پارامترهای این کنترل‌کننده توسط الگوریتم ژنتیک به منظور کاهش هزینه کنترلی و زمان عملکرد تعیین می‌گردند. روش پیشنهادی برای سیستم‌هایی با ساختارهای مشابه و متفاوت قابل اعمال می‌باشد. شبیه‌سازی‌های انجام شده عملکرد بسیار مناسب کنترل‌کننده را در مقایسه با سایر روش‌ها نشان می‌دهد. حذف اثر نایقینی و اغتشاش نیز به خوبی در سیستم انجام شده است.

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انتخاب ویژگی چند هدفه با استفاده از بهینه سازی ذرات برای بازشناسی الگو

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چکیده - در بازشناسی الگو دسته بندی داده های با ابعاد بالا کار سخت و زمان بری است طوری که این مسئله به نفرین ابعاد معروف است. یک راه حل این مسئله، به کاربردن روشهای انتخاب ویژگی برای کاهش ابعاد است. در این مقاله، پیشنهاد می شود که از روشهای تکاملی چند هدفه و بطور خاص از الگوریتم ازدحام ذرات به منظور در نظر گرفتن دو یا چند معیار همزمان جهت جستجو و انتخاب در فضای ویژگیها استفاده شود. به این منظور معیارهای ضریب همبستگی پیرسون، فاصله درون و برون کلاسی، اطلاعات متقابل که به ترتیب بیانگر وابستگی ویژگیها، میزان قدرت متمایز سازی ویژگیها، محتویات اطلاعاتی ویژگیها هستند، در نظر گرفته شده اند و ترکیب دو به دوی آنها به عنوان اهداف توام انتخاب ویژگی در تابع برازندگی الگوریتم تکاملی پیشنهاد شده اند. ارزیابی بر روی دادگان *UCI* و دسته بندهای گوناگون نشان می دهد که روشهای ترکیب پیشنهادی نسبت به دیگر روش های شناخته شده انتخاب ویژگی برتری دارد و یا کارآیی همپای آنها ارائه می دهد.

کلید واژه- انتخاب ویژگی، بهینه سازی ازدحام ذرات، همبستگی پیرسون، اطلاعات متقابل، فاصله درون_ برون کلاسی

1 -مقدمه

روش های مختلف انتخاب ویژگی، تلاش می کنند تا از میان تمامی زیر مجموعه های ویژگی ممکن، بهترین زیرمجموعه را پیدا کنند. در تمام این روش ها بر اساس کاربرد و نوع تعریف، زیر مجموعه ای به عنوان جواب انتخاب می شود، که بتواند مقدار یک تابع ارزیابی را بهینه کند[1]. یک تابع ارزیابی، میزان خوب بودن یک زیرمجموعه تولید شده را بررسی کرده و یک مقدار به عنوان میزان خوب بودن زیرمجموعه مورد نظر بازمی گرداند. روش های انتخاب ویژگی شامل روش های فیلتر ، پوشاننده و جاسازی شده است[2]. روش های فیلتر یکی از اولین روش ها برای انتخاب ویژگی در یادگیری ماشین است و از خصوصیات آماری داده ها برای ارزیابی استفاده می کند [2].

روشهای فیلتر از نظر محاسباتی ارزان تر هستند و همچنین عمومیت بیشتری نسبت به روش های پوشاننده یا روشهای جاسازی شده دارند به این دلیل که انها معیارهای طبقه بندی را در طبقه بند در نظر نمی گیرند. اما روش های پوشاننده چون بر اساس طبقه بند ویژگیها را انتخاب می کنند، بهتر از فیلترها عمل می کنند و در مقابل دارای بارمحاسباتی بیشتری هستند.

الگوریتم های انتخاب ویژگی بسیاری بر اساس PSO (particle-swarm optimization) معرفی گشته اند ، که هم رویکرد های فیلتر و هم رویکردهای پوشاننده را در بر می گیرد. چکرابورتی کارکرد BPSO (Binary PSO) با GA (Genetic Algorithm) را در الگوریتم انتخاب ویژگی بوسیله مجموعه های فازی براساس تابع هدف در مرجع [3] مقایسه نموده است. نتایج حاصله مشخص می نماید که عملکرد BPSO از نظر دقت طبقه بندی خوبتر از GA می باشد.

یک الگوریتم دو مرحله ای انتخاب ویژگی با به کارگیری هم روش فیلتر و هم روش پوشاننده به منظور استفاده از مزیتهای هر دو روش توسط یوان و همکاران اش در [4] پیشنهاد گردید. این روش ارائه شده با مدل فیلتر برای حذف ویژگی های بی ارتباط آغاز می گردد و پس از آن الگوریتم پوشاننده به منظور حذف ویژگی های افزونه مورد استفاده قرار می گیرد.

بینگ و همکارانش در مقاله [5] با در نظر گرفتن دو هدف اصلی انتخاب ویژگی که به حداقل رساندن تعداد ویژگی ها و به حداکثر رساندن عملکرد طبقه بندی است و بر اساس بهینه سازی ازدحام ذرات دودویی (BPSO) و با استفاده از معیار اطلاعات متقابل و آنتروپی به عنوان دو معیار ارزیابی فیلتر های مختلف روشی را پیشنهاد کرده اند .که روش پیشنهادی آن ها در مقایسه با روش های تک هدفه انتخاب ویژگی نتایج بهتری را نشان می دهد.

لیام و همکارانش در مقاله [6] یک الگوریتم انتخاب ویژگی فیلتر چند هدفه مبتنی بر بهینه سازی ازدحام ذرات (PSO) دودویی و نظریه مجموعه Rough پیشنهاد کردند که الگوریتم پیشنهادی آن ها می تواند به طور خودکار به یک مجموعه از زیر مجموعه های ویژگی non-dominated تکامل یابد.

در این مقاله، پیشنهاد می شود که از روشهای تکاملی چند هدفه و بطور خاص از الگوریتم ازدحام ذرات به منظور در نظر گرفتن دو یا چند معیار همزمان جهت جستجو و انتخاب در فضای ویژگیها استفاده شود. به این منظور معیارهای ضریب همبستگی پیرسون، فاصله درون و برون کلاسی و اطلاعات متقابل در نظر گرفته شده اند و ترکیب دو به دوی آنها به عنوان اهداف توام انتخاب ویژگی در تابع برازندگی الگوریتم تکاملی پیشنهاد شده اند.

ادامه مقاله به این صورت تنظیم شده است. در بخش دوم معیارهای

انتخاب ویژگی به صورت خلاصه تشریح می شود. در بخش سوم pso چندهدفه مورد بررسی قرار می گیرد. در بخش چهارم راه کار پیشنهادی معرفی می شود. در بخش پنجم نتایج روش پیشنهادی بر روی دادگان UCI گزارش می شود و در نهایت بخش ششم نیز حاوی نتیجه گیری می باشد.

2 -معیارهای انتخاب ویژگی

معیارهای متفاوتی جهت ارزیابی اهمیت ویژگیها در مقالات معرفی شده اند. در اینجا چند معیار که در روش های فیلتر استفاده می شود را معرفی می کنیم.

2 1 -اطلاعات متقابل

اطلاعات متقابل اطلاعات مشترک میان دو متغیر تصادفی، تعریف می گردد. متغیر تصادفی X فرض شده، تا چه اندازه قادر است در باره Y اطلاعات کسب نماید ، که اطلاعات متقابل $I(X;Y)$ می باشد.

$$I(X;Y)=H(X)-H(X|Y)=H(Y)-H(Y|X) \quad (1)$$
$$=-\sum_{x\in X,y\in Y}P(x,y)\log_2\frac{P(x,y)}{P(x)P(y)}$$

مطابق فرمول (1)، چنانچه دو متغیر X وY به یکدیگر دارای وابستگی نزدیکی باشند، اطلاعات متقابل $I(X;Y)$، بسیار زیاد خواهد شد. در غیراینصورت چنانچه X وY به طور کامل غیرمرتبط باشند $I(X;Y)=0$ خواهد شد. کلا اطلاعات متقابل به منظور اندازه گیری ارتباط میان ویژگی های انتخاب شده و برچسب کلاس در انتخاب ویژگی فیلترمورد استفاده قرار می گیرد.

2 2 -معیار فاصله درون و برون کلاسی

برای مجموعه N داده برچسب خورده را فرض نمایید:
$\{x_i^r ; i=\overline{1,N}\}$ ، $r\in\{1,...,k\}$ که برچسب کلاس و هر x_i^r برداری باشد با مؤلفه های عددی n هر مؤلفه با مقدار ویژگی مرتبط می باشد. به علاوه هر کلاس C_r شامل n_r داده فرض گردد. معیاری که تراکم داده ها در یک کلاس ارائه نماید فاصله درون کلاسی می باشد و می توان آن را برای میانگین فاصله میان داده ها و مرکز کلاس های متناظر ارائه نمود:

$$D_w=1/N\sum_{r=1}^{k}\sum_{i=1}^{n_r}d\left(x_i^r,m_r\right) \quad (2)$$

که $m_r=\left(\sum_{i=1}^{n_r}x_i^r\right)\Big/n_r$ بیان کننده مرکز کلاس c_r می باشد و $d(.,.)$ بیانگر فاصله اقلیدسی است.

به وسیله جداسازی بین کلاسی که برای میانگین فاصله میان مراکز کل کلاس ها و مرکز تمام مجموعه داده ها، تفکیک میان کلاس ها به صورت زیر تعریف می شود:

$$D_B=\frac{1}{N}\sum_{r=1}^{k}n_r d(m_r,m) \quad (3)$$

که m در فرمول بالا برابر است با: $m=\left(\sum_{r=1}^{k}n_r m_r\right)\Big/N$

به علاوه جهت به دست آوردن ویژگی هایی با کمترین فاصله درون کلاسی و بیشترین فاصله بین کلاسی که با طبقه بند ارتباط بیشتری دارند باید معیار فاصله درون و برون کلاسی حداکثر گردد [7]. به شکل نرمال شده زیر ترکیب دو معیار فاصله درون- برون کلاسی ارائه می گردد، پس:

$$\text{merit}_D=\left|D_w-D_B\right|\Big/\left|D_w^{\max}-D_B^{\min}\right| \quad (4)$$

2 3 - ضریب همبستگی پیرسون

ضریب همبستگی پیرسون بین دو متغیر به شکل کواریانس دو متغیر تقسیم بر حاصلضرب انحراف معیارشان بیان می گردد. برای ویژگی X با مقادیر x و کلاس Y با مقادیر y به عنوان متغیرهای تصادفی ضریب همبستگی به شکل زیر ارائه می گردد:

$$p(X,Y)=\frac{E(XY)-E(X)E(Y)}{\sqrt{\sigma^2(X)\sigma^2(Y)}}=\frac{\sum_i\left(x_i-\overline{x_i}\right)\sum_i\left(y_i-\overline{y_i}\right)}{\sqrt{\sum_i\left(x_i-\overline{x_i}^2\right)\sum_i\left(y_i-\overline{y_i}^2\right)}} \quad (5)$$

ضرایب همبستگی همیشه در بازه [1،-1] است. مثلا چنانچه $P(X,Y)$ در معادله (5) برابر 1 یا 1- باشد، دو مقدار نهایی این بازه، یک رابطه کاملا خطی را میان دو ویژگی بیان می کند. در مورد اول منفی (رابطه معکوس) در بقیه موارد مثبت (رابطه مستقیم). زمانی که $P(X,Y)$ برابرصفر باشد، به این معنی می باشد که هیچ ارتباطی بین دو ویژگی برقرار نیست. چنانچه $-1<P(X,Y)<0$ باشد یا چنانچه $0<P(X,Y)<1$ به این معنی می باشد که یک ارتباط مثبت یا منفی میان دو ویژگی برقرار است، به ترتیب مقدار بزرگتر $P(X,Y)$ ارتباط قوی تری را بیان می کند [8].

3 -بهینه سازی ذرات چند هدفه

روش های محاسبات تکاملی برای بررسی مسئله انتخاب ویژگی با موفقیت استفاده می شوند. در مقایسه با دیگر روش های محاسبات تکاملی PSO دارای مزایای محاسبات کم هزینه، سادگی در پیاده سازی، داشتن پارامترهای کمتر و سرعت همگرایی بیشتر است. اگرچه، همچنان به تحقیق بیشتر و بهبود عملکرد PSO برای انتخاب ویژگی نیاز دارد.

تعیین یک زیر مجموعه از ویژگی های مطلوب پیچیده و مشکل است. با توجه به محدودیت های روش های مرسوم ، محاسبات تکاملی (EC) مطرح شده است برای حل مشکلات انتخاب ویژگی، بهینه سازی ازدحام ذرات (PSO) یک تکنیک EC که اخیرا علاقه زیادی از محققان در این زمینه است. PSO یک تکنیک جستجوی سراسری کارا و موثر است. این تکنیک به دلایلی زیر یک الگوریتم مناسب برای حل مسئله انتخاب ویژگی است [9,10,11].

1. روش نمایش PSO برای وظایف انتخاب ویژگی مناسب است. PSO از یک آرایه یا یک بردار برای کد کردن هر عضو/ذره در دسته استفاده می‌کند که یک راه معمولی برای کدگذاری راه حل کاندید در مسئله انتخاب ویژگی می‌باشد، و در آن ابعاد برابر تعداد ویژگی‌ها بوده و مقدار هر بعد نشان دهنده این است که آیا ویژگی مرتبط انتخاب شده است یا خیر.

2. انتخاب ویژگی دارای فضای جستجوی بزرگی است، که اغلب موجب

گیر افتادن در بهینه محلی برای متدهای موجود می‌شود. بنابراین نیاز به یک تکنیک جستجوی سراسری است. متدهای محاسبات تکاملی به دلیل توانایی جستجوی سراسری‌شان معروف هستند. PSO یک الگوریتم محاسبات تکاملی است که قادر به جستجوی موثر فضاهای بزرگ برای یافتن راه‌حل‌های بهینه یا نزدیک به بهینه می‌باشد.

3. فضای بزرگ جستجو در انتخاب ویژگی همچنین منجر به بروز مشکل هزینه محاسباتی بالا می‌شود، به خصوص برای روش‌های پوشاننده. PSO نسبت به دیگر متدهای محاسبات تکاملی از نظر محاسباتی کم‌هزینه‌تر است.

4. در مقایسه با دیگر متدهای محاسبات تکاملی، PSO پیاده‌سازی آسان‌تری دارد، پارامترهای کمتری داشته و می‌تواند سریع‌تر همگرا شود.

5. تعداد مطالعات محدودی در مورد کاربرد PSO برای انتخاب ویژگی انجام شده است که نشان می‌دهند PSO پتانسیل حل مسائل انتخاب ویژگی را دارد. هرچند، قابلیت PSO برای انتخاب ویژگی تا کنون به صورت کامل بررسی نشده است.

بنابراین در روش پیشنهادی، از تکنیک محاسبات تکاملی PSO، به منظور جستجو زیرمجموعه ویژگی بهینه استفاده می شود و یک کاربرد از این الگوریتم برای ترکیب معیارهای روش فیلتر، ارائه می شود.

4 -معرفی راه کار پیشنهادی: انتخاب ویژگی چند_هدفه مبتنی بر ترکیب معیارهای متفاوت

هدف اصلی از به کارگیری روش چند هدفه بهینه سازی ذرات به منظور بوجود آوردن یک فرآیند فیلتر چند هدفه در جهت جستجوی یک مجموعه از راه حل های نامغلوب(زیر مجموعه ویژگی ها) می باشد.

در این مقاله از pso گسسته برای حل مسائل انتخاب ویژگی استفاده می شود، که نمایش یک ذره یک رشته باینری n بیتی است. موقعیت هر ذره، بولین است که "1" نشان می دهد که ویژگی مورد نظر انتخاب خواهد شد و در غیراین صورت "0" خواهد بود.

در نهایت زیرمجموعه ویژگی که دارای تعداد کمتری از ویژگی هاست انتخاب می گردد و در عین حال کارکرد طبقه بندی یکسان و یا حتی بالاتر در قیاس با به کارگیری کل ویژگی ها بوده است. نحوه کدگذاری و تنظیم پارامترPSO و MOPSO (multi object pso) در روش پیشنهادی به صورت:

PSO:

وزن ثابت: 0/7298

ثابت شتاب: 1.49618

حداکثر سرعت : 6.0

اندازه جمعیت : 100

حداکثر تعداد تناوب : 200

MOPSO:

وزن ثابت: 0/5

ثابت شتاب: 1.49618

حداکثر سرعت : 6.0

اندازه جمعیت : 100

حداکثر تعداد تناوب : 200

4 1 -رویکرد اول: انتخاب ویژگی چند هدفه مبتنی بر ترکیب معیارهای اطلاعات متقابل و ضریب همبستگی پیرسون (MICOR)

یکی دیگر از معیارها که برای انتخاب ویژگی به کار می رود معیار همبستگی خطی پیرسون است که مبتنی بر این فرض می باشد که "یک زیرمجموعه ویژگی مناسب شامل ویژگی هایی می باشد که همبستگی زیادی با طبقه بند داشته باشد، در صورتیکه با یکدیگر ناهمبسته هستند"، شایستگی هر ویژگی در مجموعه S که شامل k ویژگی می باشد در معادله (6) قابل مشاهده است.

(6)

$$LCFS = Corr(X_i, C) - \frac{1}{|S|}\sum Corr(X_i, X_j) \quad i, j \in \{1,2,3,...K\}$$

که K در اینجا مساوی با تعداد کل ویژگی ها است. $Corr(X,C)$ می تواند ارتباط میان هر ویژگی و کلاس C_j را محاسبه نماید. ویژگی با حداکثر ارتباط میان X و C که انتظار می رود دقت طبقه بندی را حداکثر کند، مورد توجه قرار می گیرد. به وسیله حداکثر ارتباط میان هر ویژگی با کلاسها ، انتخاب ویژگی ها دچار افزونگی بالایی می شوند به همین دلیل بین این ویژگی ها، وابستگی بالا می رود.

دو ویژگی که خیلی به یکدیگر وابسته هستند، چنانچه یکی از آن ها حذف گردد قدرت تمایز کلاس مربوطه فرق زیادی نمی کند. به دنبال این مضمون به منظور انتخاب ویژگی های دو به دو متمایز میان ویژگی های انتخابی و کلاس، لحاظ می گردد. هر دو معیار $Corr(X,C)$ و $Corr(X_i, X_j)$ به منظور انتخاب ویژگی با حداکثر ارتباط و حداقل افزونگی مورد توجه قرار می گیرند.

دو متغیر که دارای مقدار همبستگی خطی کم یا صفر نباشند، احتمال دارد دارای ارتباط غیرخطی قوی باشند، که بوسیله ضریب همبستگی پیرسون لحاظ نگردد. این ضعف معیار ضریب همبستگی پیرسون می باشد. بدین سبب معیار مکمل اطلاعات متقابل به کار گرفته می شود. که نام رویکرد پیشنهادی اول به اختصار با MICOR بیان می گردد.

4 2 -رویکرد دوم: انتخاب ویژگی چند هدفه مبتنی بر ترکیب معیارهای معیارهای فاصله درون_ برون کلاسی و اطلاعات متقابل (DMI)

در معیار مبتنی بر فاصله درون_برون کلاسی، کمترین فاصله درون کلاسی و بیشترین فاصله بین کلاسی به این معنی است که ویژگی ها ارتباط بیشتری با طبقه بندی دارند و باعث حداکثرسازی تمایز بین کلاس ها می شوند. ترکیب دو معیار فاصله درون_ برون کلاسی به فرم نرمال شده زیر در نظر گرفته می شود: بنابراین:

$$cost_D = \left|D_w - D_B\right| \Big/ \left|D_w^{max} - D_B^{min}\right| \qquad (7)$$

بنابراین ویژگی هایی انتخاب می شوند که رابطه زیر را حداکثر می کنند:

$$tie_D = Max(cost_D) \qquad (8)$$

که $\cos t_D$ ، فرم نرمال شده ترکیب دو معیار درون و برون کلاسی است. انتخاب ویژگی فیلتر با هدف حداکثرسازی ارتباط بین X و C، که انتظار می رود دقت و صحت طبقه بندی را حداکثر کند.

$$MI_{Rel}(X,c) = \max\left(\sum_{x\in X} I(x;c)\right) \quad (9)$$

که $I(x;c)$ ، اطلاعات متقابل x و c است. برای حداکثر رساندن ارتباط بین X و C، الگوریتم انتخاب ویژگی با معادله (9) به عنوان تابع برازش همیشه آن ویژگی هایی را انتخاب می کند که بیشترین $I(X,C)$ داشته باشد. حذف برخی از ویژگی ها احتمالاً عملکرد طبقه بندی آن ها را کاهش نمی دهد، بلکه حتی ممکن است به دلیل کاهش ابعاد، عملکرد را افزایش دهد. بنابراین کاهش افزونگی بین ویژگی ها بسیار ضروری است. براساس اطلاعات متقابل، افزونگی X را می توان با معادله زیر نشان داد.

$$MI_{red}(X) = \min\left(\sum_{x_i,x_j\in X} I(x_i,x_j)\right) \quad (10)$$

که $I(x_i,x_j)$ ، اطلاعات متقابل بین ویژگی x_i و x_j است. برای به حداکثر رساندن ارتباط و حداقل رساندن افزونگی، هر دو rel_{mi} و red_{mi} باید هنگام ارزیابی خوبی ویژگی های انتخاب شده در نظر گرفته شود. بدین سبب در رویکرد پیشنهادی با به کارگیری MI_{Rel} و MI_{red} و ترکیب دو معیار فاصله درون-بین کلاسی نرمال در MOPSO-DMI روند تکاملی MOPSO برای جستجو زیرمجموعه ویژگی بهینه هدایت می شود که نام این رویکرد پیشنهادی به اختصار با DMI بیان می گردد.

5 -ارزیابی و نتایج

جهت ارزیابی روش های پیشنهادی از چهار مجموعه داده Vowel و Waveform و Glass و Wine از پایگاه داده UCI استفاده شده است که مشخصات آن در جدول (1) بیان شده است.

جدول 1- مشخصات دادگان مورد استفاده

نام مجموعه داده	تعداد ویژگی-ها	تعداد نمونه-ها	تعداد دسته-ها
Glass	9	214	6
Vowel	13	990	11
Waveform	21	5000	3
Wine	13	178	3

همچنین از دسته بند های زیر جهت ارزیابی روش پیشنهادی استفاده شده است:

دسته بند های تابعی: دسته بندی بر پایه شبکه عصبی پرسپترون چندلایه (MLP)، دسته بندی بر اساس ماشین بردار پشتیبان (LIBSVM)

دسته بندهای تنبل : دسته بندی بر اساس K نزدیک ترین همسایگی (KStar)

دسته بندهای درخت: دسته بندی بر پایه درخت تصمیم (J4.8 یا نسخه 8 درخت تصمیم).

جدول (2) چگونگی نامگذاری روش های مورد استفاده شده را ارائه میدهد. در جدول (3)، نتایج قبل و پس از انجام انتخاب ویژگی آمده است. نام دسته بند بر روی ستونها و دادگان بر روی ردیفها نشان داده شده است. متغیر که دارای مقدار همبستگی خطی کم یا صفر نباشند، احتمال دارد دارای ارتباط غیرخطی قوی باشند، که بوسیله ضریب همبستگی پیرسون لحاظ نگردد. این ضعف معیار ضریب همبستگی پیرسون می باشد.

جدول 2 : توضیح نامگذاری روش ها

روش	توضیحات
PSO-D	روش فیلتر مبتنی‌بر PSO و معیار مبتنی‌بر فاصله درون ـ برون کلاسی
PSO-MI	روش فیلتر مبتنی‌بر PSO و معیار مبتنی‌بر اطلاعات متقابل
PSO-COR	روش فیلتر مبتنی‌بر PSO و معیار مبتنی‌بر ضریب همبستگی پیرسون
MOPSO-DMI	روش فیلتر مبتنی‌بر مرتب‌سازی نامغلوب الگوریتم PSO چند هدفه و ترکیب دو معیار مبتنی‌بر فاصله درون_ برون کلاسی و اطلاعات متقابل
MOPSO-MICOR	روش فیلتر مبتنی‌بر مرتب‌سازی نامغلوب الگوریتم PSO چند هدفه و ترکیب دو معیار مبتنی‌بر اطلاعات متقابل و ضریب همبستگی پیرسون

در این بخش به ارزیابی روش پیشنهادی با دو رویکرد تحت عنوان های MICOR, DMI با روشهای تک هدفه PSO و روش بدون انتخاب ویژگی با دادگان معرفی شده از پایگاه داده UCI پرداخته شده است. نتایج به دست آمده به صورت کلی در جدول (3) قابل مشاهده است. همانطور که مشاهده نمودید، در اکثر مجموعه دادگان روش های پیشنهادی دقت بالایی از دسته بندی را نسبت به روش های تک هدفه PSO و روش بدون انتخاب ویژگی داشته است.

6 - جمع بندی و نتیجه گیری

در این مقاله سعی شده است که مفاهیم و همچنین اهمیت روشهای انتخاب ویژگی در بازشناسی الگو بررسی گردد. از الگوریتم ازدحام ذرات به منظور در نظر گرفتن دو یا چند معیار همزمان جهت جستجو و انتخاب در فضای ویژگیها استفاده شد و ترکیب دو به دوی آنها به عنوان اهداف توام

جدول3 : مقایسه دقت دسته بندی و تعداد ویژگی انتخابی روش های پیشنهادی با روش های دیگر بر روی مجموعه داده waveform, vowel, wine, glass

دادگان	روش انتخاب ویژگی	تعداد ویژگی انتخابی	نوع دسته بند			
			LIBSVM	MLP	K-Star	J48
glass	**Without feature selection**	**(9)**	**69.15**	**55.60**	**75.70**	**65.88**
	MOPSO-DMI	(6)	68.22	60.28	76.63	68.22
	MOPSO-MICOR	(5)	71.49	61.68	71.49	66.35
	PSO-MI	(4)	49.06	56.07	64.48	60.74
	PSO-COR	(4)	55.60	50	67.28	63.55
	PSO-D	(5)	66.82	49.53	64.01	60.74
vowel	**Without feature selection**	**(13)**	**87.87**	**54.84**	**98.58**	**79.69**
	PSO-MI	(8)	83.13	50.10	96.96	79.89
	PSO-COR	(8)	80	49.49	96.06	79.79
	MOPSO-DMI	(9)	86.36	50.10	98.08	80.90
	PSO-D	(9)	86.96	50.90	97.47	77.77
	MOPSO-MICOR	(10)	87.97	55.95	98.38	78.78
waweform	**Without feature selection**	**(21)**	**86.1**	**86.62**	**76.62**	**75.94**
	PSO-D	(10)	79.2	79.5	70.56	73
	MOPSO-DMI	(15)	83.64	84.8	76.92	77.1
	MOPSO-MICOR	(14)	84.32	85.38	78.2	76.38
	PSO-MI	(12)	79.68	79.94	70.5	74
	PSO-COR	(9)	72.74	73.26	63.02	67.76
wine	**Without feature selection**	**(13)**	**44.38**	**97.19**	**98.87**	**93.82**
	MOPSO-MICOR	(9)	51.68	98.31	97.75	94.38
	MOPSO-DMI	(9)	51.12	98.31	96.06	94.38
	PSO-COR	(4)	53.37	92.69	94.38	89.88
	PSO-MI	(5)	52.80	93.82	94.38	92.69
	PSO-D	(5)	52.80	90.44	93.82	90.44

انتخاب ویژگی در تابع برازندگی الگوریتم تکاملی پیشنهاد شده اند. ارزیابی بر روی دادگان UCI و دسته بندهای گوناگون نشان می دهد که روشهای ترکیب پیشنهادی نسبت به دیگر روش های شناخته شده انتخاب ویژگی برتری دارد و یا کارآیی همپای آنها ارائه می دهد. در فرآیند نگارش این مقاله و قبل از آن در مرحله جمع آوری تحقیقات، اطلاعات و آزمایش ها کوشش شد که تا حد امکان پژوهشی جامع در زمینه ی مورد تحقیق انجام گیرد. در هر حال موارد زیر می تواند در بهبود روش پیشنهادی و نتایج حاصل از آن تاثیر بگذارد:

- استفاده از دیگر الگوریتم های تکاملی به صورت چند هدفه و تک هدفه برای انتخاب ویژگی
- استفاده از ترکیب معیارهای دیگری به صورت سه هدفه روش های مختلف انتخاب ویژگی، تلاش می کنند تا از میان N2 زیر مجموعه کاندید، بهترین زیرمجموعه را پیدا کنند.

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عوامل تاثیرگذار در بهینه‌سازی انرژی و زمان‌بندی بهینه مصرف

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چکیده - شاید از نظر برخی افراد ساخت خانه‌های هوشمند تجملاتی به نظر برسد اما در واقع هدف از ساخت این خانه‌ها استفاده از تکنولوژی در جهت کاهش هزینه‌هاست. با توجه به پژوهش‌های انجام شده در زمینه مصرف انرژی الکتریکی، در خانه‌های هوشمند، بار مصرفی به دو گروه بار ضروری و غیرضروری تقسیم می‌شوند. همچنین خانه‌های هوشمند به برق شهری، منابع تجدیدپذیر انرژی از جمله پنل خورشیدی و توربین بادی و همچنین به منبع ذخیره‌ساز انرژی همچون باتری متصل می‌شوند. از طرفی وجود و یا عدم وجود هر یک از عوامل در کاهش هزینه بسیار چالش برانگیز است. در این مقاله به بررسی تاثیر این پارامترها؛ یعنی وجود منابع انرژی تجدیدپذیر، باتری و امکان جابجایی بارهای غیرضروری پرداخته می‌شود. ورودی‌های مسئله شامل اطلاعات فنی و اولیه مربوط به باتری، مقادیر ساعتی توان تولیدی منابع تجدیدپذیر، قیمت‌های ساعتی انرژی الکتریکی، و مقادیر ساعتی بارهای ضروری و غیرضروری می باشند. با توجه به تعدد ورودی‌ها همچنین پویا بودن محیط، نیاز است تا مسئله توسط یک الگوریتم هوشمند بهینه شود. در این مقاله، مسئله مذکور توسط الگوریتم تبرید تدریجی و الگوریتم ژنتیک بهینه می شود و مقایسه‌ای بین نتایج انجام می‌شود و ملاحظه می‌شود که الگوریتم تبرید تدریجی نتیجه بهتری می‌دهد که در نهایت برای بررسی تاثیر پارامترهای ذکر شده مسئله با الگوریتم تبرید تدریجی بهینه‌سازی می‌شود. با بررسی نتایج آزمایشات انجام شده به منظور بررسی تاثیر پارامترها مشاهده می‌شود که وجود هر کدام از آن‌ها تاثیر بسزایی در کاهش هزینه‌ها خواهد داشت.

کلید واژه- الگوریتم بهینه سازی تبرید تدریجی، بهینه‌سازی انرژی، خانه هوشمند، زمان‌بندی بهینه مصرف.

۱- مقدمه

به دلیل مزایای زیاد مدیریت مصرف انرژی، این برنامه‌ها به‌عنوان اولین راهکار در سیاست‌گذاری‌های کلان انرژی هر کشور معرفی می‌شوند. با توجه به اینکه امروزه تقاضای الکتریکی در اثر رشد صنعت و رشد جمعیت افزایش یافته است، استقرار و اجرای برنامه‌های مدیریت سمت تقاضا با هدف صرفه‌جویی در مصرف انرژی الکتریکی، کاهش تقاضای الکتریکی هنگام پیک بار شبکه و همچنین کاهش مشکلات زیست‌محیطی ناشی از سوزاندن سوخت‌های فسیلی در دستور کار دولت‌ها قرار دارد [۱]. به دلیل تعدد زیاد مصرف کنندگان خانگی در هر شبکه توزیع الکتریکی، سهم عمده‌ای از توان شبکه به این مصرف کنندگان اختصاص داده می‌شود. بنابراین به منظور مدیریت موثر و جامع انرژی الکتریکی، نیاز است هر منزل مسکونی هوشمند شده و انرژی الکتریکی مصرفی خود را مدیریت و بهینه کند که این استراتژی در نهایت منجر به کاهش هزینه برق مصرفی مشترکین و کاهش هزینه برق تولیدی خواهد شد[۲]. در خانه‌های هوشمند که سعی در مصرف انرژی سبز دارند، عموما هدف، تنها کاهش هزینه در مصرف انرژی نمی‌باشد، بلکه نوع انرژی مصرفی نیز اهمیت دارد.

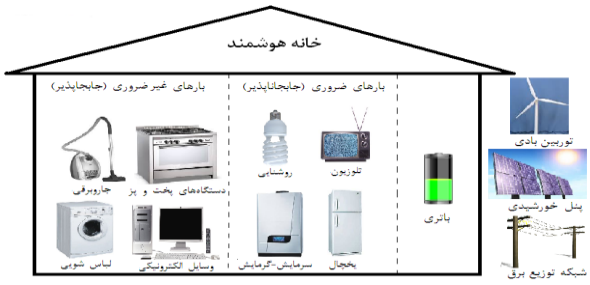
از سوی دیگر، منابع انرژی تجدید پذیر همچون پنل خورشیدی و توربین بادی که به صورت محلی می‌توانند در دسترس باشند، به دلیل عدم انتشار گازهای گلخانه‌ای و همچنین رایگان بودن برق تولیدیشان، از سوی شرکت‌های توزیع برق به منظور نصب روی شبکه الکتریکی خانه‌های هوشمند پیشنهاد می‌شوند[۳]. با توجه به اینکه برق تولیدی منابع انرژی تجدید پذیر به صورت نوسانی هست، از باتری‌ها به منظور ذخیره‌سازی انرژی و مقابله با این مشکل استفاده می‌شود[۴]. ولی باتری‌ها گران بوده و استفاده مداوم از آن‌ها و سوییچینگ‌های پی در پی، عمر این منابع ذخیره ساز انرژی را پایین می‌آورد. بنابراین، مصرف برق خانه هوشمند و همچنین استفاده از باتری باید با برق تولیدی منابع انرژی تجدیدپذیر محلی مطابق شده تا باعث کاهش هزینه‌های خانه هوشمند شود.

به عبارت دیگر مسئله هوشمندسازی مصرف خانه یک مسئله بهینه سازی بوده که هدف آن کاهش هزینه برق مصرفی با تخصیص بهینه منابع انرژی خانه هوشمند از قبیل منابع تجدیدپذیر، برق شهری و منبع ذخیره ساز انرژی (باتری) و همچنین زمان‌بندی بهینه مصارف خانه هوشمند است.

در مقالات [۵و۶و۷و۸] از روش زمان‌بندی بهینه مصرف در قالب مدیریت سمت تقاضا و پاسخگویی بار به منظور کاهش هزینه استفاده شده است و تخصیص بهینه منابع مد نظر قرار نگرفته است. در[۹] روشی برای زمان‌بندی استفاده از وسایل خانه هوشمند معرفی شده است، که در آن با جابجایی زمان مصرف بار، صرفه جویی در هزینه‌ها صورت می‌گیرد. در مقالات[۱۰و۱۱] به منظور استفاده بهینه از انرژی الکتریکی در خانه‌های هوشمند از ابزار تصمیم‌یار استفاده شده است. در مقالات[۱۲و۱۳]، جزئیات مربوط به یک سیستم مجهز به کنترل اتوماتیک برای مدیریت مصرف انرژی خانه هوشمند ارائه شده است. در مقاله[۱۴] مدیریت انرژی خانه هوشمند با در نظر گرفتن شبکه و ظرفیت تولید برق محلی انجام شده است. با در نظر داشتن قیمت‌های متفاوت برق در ساعات مختلف شبانه روز، در مقاله[۱۵] زمان‌بندی به منظور بهینه‌سازی مصارف انرژی خانه هوشمند ارائه شده است. در مقاله [۱۶] آسایش ساکنین خانه هوشمند مد نظر قرار گرفته شده است. برای بهینه‌سازی مسئله مدیریت انرژی، الگوریتم‌های مختلفی همچون برنامه‌ریزی خطی [۱۷]، برنامه نویسی پویای تطبیقی [۱۸]، مدل توزیع بهینه منابع انرژی[۱۹] مورد استفاده قرار گرفته‌اند.

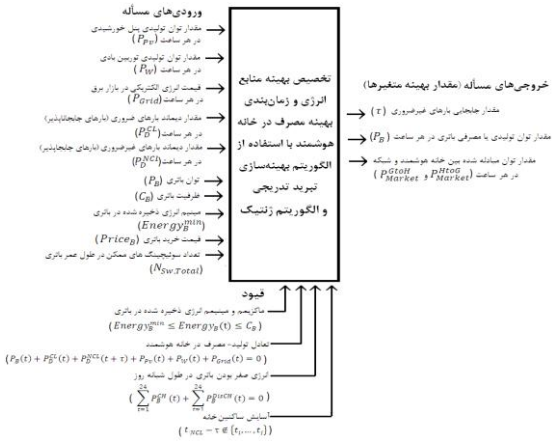
۲-فرمول‌بندی مسئله

در شکل ۱ نمای کلی یک خانه هوشمند که دارای توربین بادی و پنل خورشیدی است نشان داده می‌شود. این خانه هوشمند متصل به شبکه توزیع انرژی الکتریکی بوده و بار الکتریکی خانه هوشمند به دو گروه بارهای ضروری و بارهای غیرضروری تقسیم می‌شود. همان طور که مشاهده می‌شود تلویزیون، سیستم روشنایی، یخچال، و سیستم سرماش-گرمایش به عنوان بارهای ضروری و دستگاه‌های پخت و پز، جاروبرقی، وسایل الکترونیکی، و لباسشویی به عنوان بارهای غیرضروری بر اساس دیدگاه ساکنان خانه هوشمند در نظر گرفته می‌شود. همچنین از باتری به منظور ذخیره سازی انرژی در این خانه هوشمند استفاده می‌شود.



شکل ۱: نمای یک خانه هوشمند

در شکل ۲ نمایش گرافیکی مربوط به مدل پیشنهادی نشان داده شده است. همانطور که مشاهده می‌شود، این مدل شامل ورودی‌های مسئله، جزئیات مربوط به قیود مسئله و مقادیر بهینه خروجی‌های مسئله می‌باشد.



شکل ۲: نمایش گرافیکی ورودی‌ها، خروجی‌ها و قیود مسئله

۲-۱- ورودی‌های مسئله

اطلاعات فنی و اولیه مربوط به باتری (شامل: توان باتری (P_B)، ظرفیت باتری (C_B)، مینیمم انرژی ذخیره شده در باتری $(Energy_B^{min})$، قیمت اولیه باتری $(Price_B)$ و تعداد سوئیچینگ‌های ممکن در طول عمر باتری $(N_{Sw,Total})$)، مقدار توان تولیدی پنل خورشیدی در هر ساعت $(P_{Pv}(t))$، مقدار توان تولیدی توربین بادی در هر ساعت $(P_W(t))$، قیمت انرژی الکتریکی در بازار برق در هر ساعت $(P_{Grid}(t))$، مقدار بارهای ضروری در هر ساعت $(P_D^{CL}(t))$، مقدار بارهای غیرضروری در هر ساعت $(P_D^{NCL}(t))$.

۲-۲ متغیرها و خروجی‌های مسئله

متغیرهای مسئله که مقادیر بهینه آن‌ها به عنوان خروجی به دست می‌آیند عبارتند از: مقدار جابجایی بارهای غیرضروری (τ)، مقدار توان تولیدی یا مصرفی باتری در هر ساعت$(P_B(t))$، مقدار

توان مبادله شده بین خانه هوشمند و شبکه در هر ساعت $(P_{Market}^{HtoG}(t))$ و $(P_{Market}^{GtoH}(t))$.

۲-۳ تابع هدف

تابع هدف مسئله مربوط به تخصیص بهینه منابع انرژی و زمان‌بندی بهینه مصرف در خانه هوشمند به صورت مینیمم‌سازی هزینه کل خانه هوشمند در طول شبانه روز تعریف می‌شود. هزینه کل خانه هوشمند که از طریق فرمول (۱) محاسبه می‌شود دارای دو ترم (زیرتابع) هزینه و یک ترم درآمد است. ترم‌های هزینه خانه هوشمند شامل هزینه خرید انرژی الکتریکی از شبکه در هر ساعت و هزینه سوئیچینگ باتری در هر ساعت بوده و ترم درآمد خانه هوشمند مربوط به درآمد حاصل از فروش انرژی الکتریکی به شبکه در هر ساعت است که به ترتیب در (۲)، (۳)، و (۴) ارائه شده‌اند.

$$OF = min\left\{\sum_{t=1}^{Nt}\sum_{j=1}^{Nj} Cost_j(t)\right\} \quad (۱)$$

$$Cost_1(t) = Cost_{Grid}(t) \quad (۲)$$

$$Cost_2(t) = Cost_{Sw}(t) \quad (۳)$$

$$Cost_3(t) = -Income_{Grid}(t) \quad (۴)$$

مقدار ترم هزینه خرید انرژی الکتریکی از شبکه توسط رابطه (۵) محاسبه می‌شود که در آن $P_{Market}^{GtoH}(t)$ توان خریداری شده از شبکه و $Price_{Market}(t)$ قیمت انرژی الکتریکی در ساعت t است.

$$Cost_{Grid}(t) = Price_{Market}(t) * P_{Market}^{GtoH}(t) \quad (۵)$$

مقدار ترم هزینه مربوط به استهلاک باتری در رابطه (۶) نشان داده می‌شود. همان‌طور که مشاهده می‌شود، هزینه یک بار سوئیچینگ باتری برابر است با قیمت اولیه باتری تقسیم بر تعداد کل سوئیچینگ‌های ممکن در طول عمر مفید باتری.

$$Cost_{Sw}(t) = \frac{Price_B}{N_{Sw,Total}} \quad (۶)$$

مقدار ترم درآمد حاصل از فروش انرژی الکتریکی به شبکه از رابطه (۷) به دست می‌آید. در این رابطه $P_{Market}^{HtoG}(t)$ توان فروخته شده به شبکه در ساعت است.

$$Income_{Grid}(t) = Price_{Market}(t) * P_{Market}^{HtoG}(t) \quad (۷)$$

۲-۴ قیود مسئله

در مسئله مورد نظر چهار مورد قید وجود دارد که در هر ساعت باید برقرار باشد که عبارتند از:

- **قید ماکزیمم و مینیمم انرژی ذخیره شده در باتری**

به منظور افزایش طول عمر باتری، دشارژ یا تخلیه باتری به طور کامل انجام نمی‌شود. همچنین در انجام شبیه‌سازی مسئله دقت می‌شود که بیشتر از ظرفیت باتری، انرژی ذخیره شده در باتری در نظر گرفته نشود [۱۹].

در رابطه (۸)، $Energy_B^{min}$ و C_B به ترتیب مینیمم انرژی ذخیره شده در باتری و ظرفیت باتری هستند.

$$Energy_B^{min} \le Energy_B(t) \le C_B \quad (۸)$$

- **قید تعادل تولید- مصرف در خانه هوشمند**

در هر سیستم الکتریکی همواره باید بین تولید و مصرف انرژی الکتریکی تعادل برقرار باشد. در خانه هوشمند نیز این قید به صورت رابطه (۹) بین توان‌های تولیدی و توان‌های مصرفی در هر ساعت از شبانه روز برقرار می‌شود[۱۹].

$$P_B(t) + P_D^{CL}(t) + P_D^{NCL}(t+\tau) + P_{Pv}(t) + P_W(t) + P_{Grid}(t) = 0 \quad (۹)$$

- **قید انرژی صفر بودن باتری در طول شبانه روز**

یکی دیگر از قیودی که باید رعایت شود انرژی صفر بودن باتری است. قید مذکور در رابطه (۱۰) نشان داده می‌شود که در آن انرژی خالص ذخیره شده در باتری در طول شبانه روز صفر می‌باشد.

$$\sum_{t=1}^{24} P_B^{CH}(t) + \sum_{t=1}^{24} P_B^{DisCH}(t) = 0 \quad (۱۰)$$

- **قید آسایش ساکنین خانه**

این قید مهم‌ترین قید از لحاظ حفظ آسایش ساکنین خانه هوشمند به دلیل زمان‌بندی و جابجایی مصارف غیرضروری است. همان‌طور که در رابطه (۱۱) مشاهده می‌شود، بارهای جابجاپذیر نباید به ساعاتی منتقل شوند که ساکنان خانه تمایلی به آن زمان‌ها ندارند. ساعاتی که ساکنان خانه هوشمند آن را به عنوان ساعات استراحت خود انتخاب کرده‌اند. در رابطه (۳-۴)، t_{NCL} مربوط به زمان مصرف بارهای غیرضروری، τ مقدار پیشنهادی برای جابجایی بارهای غیرضروری، و $t_i, \dots, t_j$ زمان معرفی شده توسط ساکنان خانه هوشمند به عنوان زمان استراحت است.

$$t_{NCL} - \tau \notin \{t_i, \dots, t_j\} \quad (۱۱)$$

۳- معرفی الگوریتم‌های پیاده‌سازی شده برای بهینه‌سازی

در این بخش روش پیشنهادی برای حل مسئله تخصیص بهینه و زمان‌بندی بهینه مصرف در خانه هوشمند با روش الگوریتم تبرید تدریجی و الگوریتم ژنتیک ارائه می‌شود.

هنگام پیاده‌سازی تبرید تدریجی، مقدار تابع هدف (هزینه کل روزانه خانه هوشمند) به عنوان انرژی درونی فلز مذاب (E_K) تعریف شده و سعی می‌شود تا انرژی درونی فلز مذاب مینیمم شود.

مراحل مختلف مربوط به روند بهینه‌سازی مسئله تخصیص بهینه و زمان بندی بهینه مصرف در خانه هوشمند به روش الگوریتم تبرید تدریجی بدین شرح می‌باشد:

۱. دریافت اطلاعات مربوط به پارامترهای ورودی مسئله از قبیل توان تولیدی پنل خورشیدی و توربین بادی در هر ساعت، بارهای ضروری و غیر ضروری در هر ساعت، قیمت انرژی الکتریکی در هر ساعت، پارامترهای مربوط به باتری و ساعات مورد نظر برای آسایش ساکنان خانه.

۲. دریافت اطلاعات و پارامترهای کنترلی مربوط به الگوریتم تبرید تدریجی از قبیل دمای اولیه فلز مذاب و تعداد تولید حالت جدید در هر دما.

۳. تولید یک حالت تصادفی برای مقادیر متغیرهای مسئله

۴. بررسی وضعیت قیود

- ❖ در صورت برقرار نبودن قیود، مرحله ۳ تکرار می‌شود
- ❖ در صورت برقرار بودن همه قیود مرحله بعد اجرا می‌شود

۵. حالت جدید توسط رابطه (۱۲) پذیرش می‌شود.

- ❖ اگر انرژی درونی فلز کم شود، حالت جدید برای متغیرهای مسئله پذیرفته می‌شود.
- ❖ اگر انرژی درونی فلز زیاد شود، مقدار تابع بولتزمن محاسبه شده و با یک عدد تصادفی مقایسه می‌شود. اگر مقدار تابع بولتزمن از عدد تصادفی بزرگ‌تر باشد، حالت جدید برای متغیرهای مسئله پذیرفته می‌شود. اگر مقدار تابع بولتزمن از عدد تصادفی کوچک‌تر باشد، حالت جدید برای متغیرهای مسئله پذیرفته نمی‌شود.

$$min\left\{1\ ,e^{\frac{E_{K-1}-E_K}{\theta_K}}\right\} > random[1,0) \qquad (۱۲)$$

۶. تعداد حالات تصادفی جدید در دمای فعلی بررسی می‌شود

- ❖ اگر تعداد حالات جدید به اندازه کافی تولید نشده باشد، مرحله ۳ تکرار می‌شود.
- ❖ اگر تعداد حالات جدید به اندازه کافی تولید شده باشد، دمای فلز مذاب به صورت زیر کاهش می‌یابد و مرحله بعد اجرا می‌شود

$$\theta_{k+1} = \theta_k - 1 \qquad (۱۳)$$

۷. بررسی دمای فلز مذاب

- ❖ اگر دمای فلز مذاب صفر نشده باشد، مرحله ۳ تکرار می‌شود.
- ❖ اگر دمای فلز مذاب صفر شده باشد، الگوریتم پایان می‌پذیرد و مقادیر بهینه متغیرها معرفی می‌شود.

هنگام پیاده‌سازی الگوریتم ژنتیک، مقدار معکوس تابع هدف به عنوان مقدار برازندگی رشته (کروموزم) مربوطه تعریف شـده و سعی می‌شود تا مقدار برازندگی رشته‌های جمعیت بهبود یابد.

مراحل مختلف روند بهینه‌سازی مسئله تخصیص بهینه و زمان بندی بهینه مصرف در خانه هوشمند به روش الگوریتم ژنتیک:

۱-دریافت اطلاعات مربوط به پارامترهای ورودی مسئله از قبیل توان تولیدی پنل خورشیدی و توربین بادی در هر ساعت، بارهای ضروری و غیر ضروری در هر ساعت، قیمت انرژی الکتریکی در هر ساعت، پارامترهای مربوط به باتری، ساعات مورد نظر برای آسایش ساکنین خانه.

۲-دریافت اطلاعات و پارامترهای کنترلی مربوط به الگوریتم ژنتیک شامل: احتمال جهش (P_{Mut})، سایز جمعیت (N_{POP})، تعداد تکرار مربوط به به-روز-رسانی جمعیت (N_{reap}).

۳-مقداردهی جمعیت اولیه با داده‌های تصادفی

۴-اعمال اپراتور جهش به تک تک بیت‌های ماتریس‌های جمعیت، با احتمال P_{Mut}

۵-اعمال اپراتور ترکیب به هر زوج ماتریس و تولید دو ماتریس جدید

۶-محاسبه برازندگی هر کدام از ماتریس متغیرهای نسل جدید

۷-انتخاب جمعیت به تعداد N_{POP} از بین نسل قدیم و نسل جدید با استفاده از روش احتمالاتی

۸-بررسی تعداد تکرار (N)

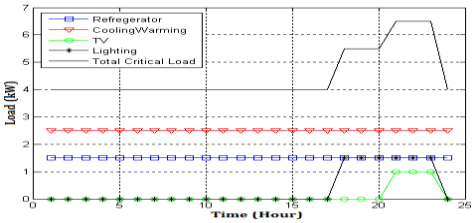
- اگر به تعداد مورد نظر(N_{reap}) اجرا نشده باشد، مرحله ۴ تکرار می‌شود
- اگر به تعداد مورد نظر انجام شده باشد، مرحله بعد اجرا می‌شود

۹-انتخاب بهترین ماتریس

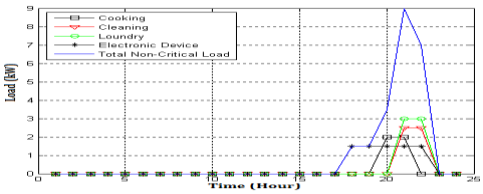
۴- مطالعه عددی

۴-۱- آماده‌سازی ورودی‌ها

مقادیر ساعتی بارهای غیرضروری از قبیل دستگاه‌های پخت و پز، جاروبرقی و غیره در شکل ۳ نشان داده شده است. در شکل ۴ مقادیر ساعتی بارهای ضروری شامل یخچال، سیستم سرمایش-گرمایش خانه هوشمند و غیره رسم شده است.



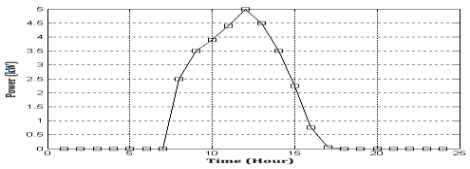
شکل۳: بارهای ضروری و جابه‌جا ناپذیر (کیلو وات)



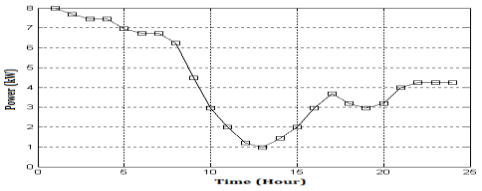
شکل۴: بارهای غیر ضروری و جابه‌جاپذیر (کیلو وات)

در شکل‌های ۵ و ۶ مقادیر ساعتی توان تولیدی مربوط به پنل خورشیدی و توربین بادی نشان داده می‌شود [۲۰و۲۱].

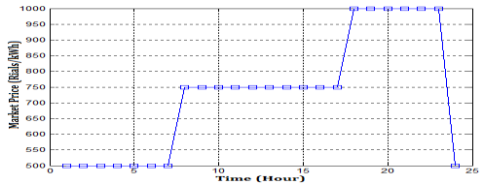
قیمت ساعتی انرژی الکتریکی در بازار برق در شکل ۷ نمایش داده می‌شود[۲۲]. همان‌طور که مشاهده می‌شود، قیمت انرژی الکتریکی در دوره‌های مختلف متفاوت است.



شکل۵: توان تولیدی مربوط به پنل خورشیدی در هر ساعت از شبانه روز (کیلو وات)



شکل۶: توان تولیدی مربوط به توربین بادی در هر ساعت از شبانه روز (کیلو وات)



شکل۷: قیمت ساعتی انرژی الکتریکی در بازار برق (ریال بر کیلو وات ساعت)

۴-۲- نتایج بهینه‌سازی مسئله پایه با استفاده از الگوریتم ژنتیک و الگوریتم تبرید تدریجی

نتایج حاصل از اعمال الگوریتم ژنتیک نشان دهنده این است که بیشترین سود پس از جابجایی بارهای غیر ضروری به هفت ساعت قبل حاصل می‌شود و مقدار آن برابر ۲۳۵۱۰ ریال است و این در حالی است که بهینه‌سازی مسئله با استفاده از الگوریتم تبرید تدریجی سودی برابر ۲۸۸۶۸ ریال به دست میدهد. در جدول ۱ میانگین مقادیر سود روزانه و میانگین زمان اجرای مسئله حاصل از ده بار اعمال الگوریتم‌های تبرید تدریجی و ژنتیک و همچنین انحراف معیار نتایج به دست آمده گردآوری شده است. همانطور که مشاهده می‌شود مقدار سودی که از اعمال الگوریتم تبرید تدریجی به طور میانگین حاصل شده است بیشتر از زمانی است که الگوریتم ژنتیک اعمال شده است. همچنین زمان اجرا و انحراف معیار الگوریتم تبرید تدریجی کم‌تر از الگوریتم ژنتیک است. کوچک بودن مقدار انحراف معیار نشان‌دهنده این است که نتایج به دست آمده دارای پراکندگی کم‌تری است.

جدول ۱: مقایسه نتایج بهینه‌سازی با الگوریتم ژنتیک و تبرید تدریجی

	مقدار سود روزانه (ریال)		زمان اجرای مسئله (ثانیه)	
	الگوریتم تبرید تدریجی	الگوریتم ژنتیک	الگوریتم تبرید تدریجی	الگوریتم ژنتیک
میانگین حاصل از ده مرحله اجرا	۲۸۲۳۰.۴	۱۹۹۶۶	۱.۷۵	۲۵۲.۶۶
انحراف معیار حاصل از ده مرحله اجرا	۹۱۸.۱۶	۱۹۴۲.۳	۰.۰۵	۶.۸۹

بنابراین به دلیل بهتر بودن خروجی‌های حاصل از الگوریتم تبرید تدریجی و سریع‌تر بودن این روش، در این مقاله برای بررسی تاثیر پارامترهای مختلف بر روی نتایج مسئله از این الگوریتم استفاده می‌شود.

۴-۳- اعمال الگوریتم بهینه‌سازی تبرید تدریجی روی مسئله در شرایط مختلف

نتایج به دست آمده از اعمال الگوریتم روی مسئله پایه (خانه هوشمند مجهز به منابع انرژی تجدیدپذیر و باتری و با تقسیم‌بندی بارها به دو دسته جابجاپذیر و غیر جابجاپذیر)، خانه هوشمند بدون منابع انرژی تجدیدپذیر، خانه هوشمند با منابع انرژی تجدیدپذیر بیشتر، خانه هوشمند با عدم امکان جابجایی بار غیرضروری، خانه هوشمند با امکان جابجایی کل بار، خانه هوشمند بدون منبع ذخیره ساز انرژی به شرح زیر هستند:

۴-۳-۱ مسئله پایه

در ابتدا مقدار هزینه روزانه خانه هوشمند در حدود ۱۵۰۰۰ ریال است که پس از بهینه‌سازی مسئله، مقدار هزینه خانه هوشمند به حدود ۲۸۸۶۸- می رسد. این مقدار کاهش هزینه و سود حاصل به دلیل جابجایی بهینه بارهای غیرضروری به ساعات مناسب و مبادله بهینه انرژی بین خانه هوشمند و شبکه است.

۴-۳-۲ خانه هوشمند بدون منابع انرژی تجدیدپذیر

برای بررسی تاثیر منابع انرژی تجدیدپذیر در کاهش هزینه، خانه هوشمند را در شرایطی که مجهز به پنل خورشیدی و توربین بادی نیست، تحلیل می‌کنیم. مقدار هزینه روزانه خانه هوشمند برابر ۷۵۳۰۰ ریال می‌باشد که پس از بهینه‌سازی مسئله مقدار آن برابر ۶۴۲۷۵ ریال می‌شود. این مقدار کاهش هزینه به دلیل جابجایی بهینه بارهای غیرضروری به ساعات مناسب و مبادله بهینه انرژی بین خانه هوشمند و شبکه است.

۴-۳-۳ خانه هوشمند با منابع انرژی تجدیدپذیر بیشتر

در این سناریو به بررسی تاثیر مقدار توان منابع انرژی تجدیدپذیر می پردازیم. در این حالت توان منابع تجدیدپذیر انرژی دو برابر می‌شود. سود اولیه برابر ۱۱۶۳۸۵ ریال است که پس از بهینه‌سازی مسئله به مقدار ۱۲۲۰۱۰ ریال می‌رسد. بارهای غیر ضروری به پنج ساعت قبل انتقال داده می‌شوند. در این سناریو دلیل افزایش سود جابجایی بارهای غیرضروری به ساعات مناسب، تولید انرژی بیشتر از طریق منابع انرژی تجدیدپذیر و فروش بیشتر انرژی به شبکه است.

۴-۳-۴ خانه هوشمند با عدم امکان جابجایی بار غیرضروری

در این سناریو بارهای خانه هوشمند، غیرقابل جابجایی در نظر گرفته شده است. مقدار سودی که حاصل می‌شود برابر ۲۳۲۴۳ ریال می‌باشد. در این حالت علت افزایش سود، انرژی حاصل از منابع انرژی تجدیدپذیر و تبادل انرژی بین شبکه و خانه هوشمند است.

۴-۳-۵ خانه هوشمند با امکان جابجایی کل بار

در این سناریو همه بارهای خانه جابجاپذیر در نظر گرفته شده‌اند. همه بارها به مقدار شش ساعت به عقب جابجا شده‌اند، در نهایت سودی که حاصل می‌شود برابر ۳۱۸۶۸ ریال است. در این حالت این مقدار افزایش سود به دلیل امکان جابجایی بار، تبادل بار بین شبکه و خانه هوشمند و وجود منابع انرژی تجدیدپذیر است.

۴-۳-۶ خانه هوشمند بدون منبع ذخیره ساز انرژی

در این سناریو خانه هوشمند، بدون منبع ذخیره ساز انرژی یعنی باتری بررسی شده است. بارهای غیرضروری به مقدار پنج ساعت به عقب جابجا شده‌اند که در نهایت به میزان ۶۱۳۲ ریال برای ساکنان هزینه دارد. در این حالت علت کاهش هزینه، امکان جابجایی بارهای غیرضروری، تبادل انرژی بین خانه هوشمند و شبکه و منابع انرژی تجدیدپذیر است.

۴-۴- مقایسه نتایج به دست آمده

در جدول ۲ سود حاصل قبل و بعد از بهینه‌سازی با داده‌های مختلف نشان داده شده است. علامت منفی نشان دهنده هزینه و علامت مثبت نشان دهنده سود است. ابتدا مسئله پایه که با استفاده از الگوریتم تبرید تدریجی بهینه‌سازی شده است نمایش داده شده است. هزینه اولیه برابر ۱۵۰۰۰ ریال و بعد از بهینه‌سازی دارای ۲۸۸۶۸ ریال سود است. با مقایسه نتایج به دست آمده مشاهده می‌شود که منابع انرژی تجدید پذیر و منبع ذخیره ساز انرژی تاثیر به سزایی در کاهش هزینه و در نهایت سوددهی دارند.

جدول ۲: نمایش سود مسئله قبل و بعد از بهینه‌سازی با داده‌های مختلف

	سود روزانه بعد از بهینه‌سازی مسئله (ریال)	سود روزانه قبل از بهینه‌سازی مسئله (ریال)
مسئله پایه	۲۸۸۶۸	-۱۵۰۰۰
خانه هوشمند بدون منابع انرژی تجدیدپذیر	-۶۴۲۷۵	-۷۸۴۰۰
خانه هوشمند با منابع انرژی تجدیدپذیر بیشتر	۱۲۲۰۱۰	۱۰۲۸۸۵
خانه هوشمند با عدم امکان جابجایی بار غیر ضروری	۲۳۲۴۳	۷۴۴۲
خانه هوشمند با امکان جابجایی بار ضروری	۳۱۸۶۸	۱۷۲۴۳
خانه هوشمند بدون منابع ذخیره ساز انرژی	-۶۱۳۲	۱۱۷۵۸

نتیجه گیری

در این مقاله، خانه هوشمندی مجهز به منابع انرژی تجدیدپذیر و منبع ذخیره‌ساز انرژی معرفی شد و با استفاده از الگوریتم تبرید تدریجی و الگوریتم ژنتیک تخصیص منابع و زمان‌بندی مصرف به صورت بهینه انجام شد و مشاهده شد که نه‌تنها می‌توان هزینه برق مصرفی خانه هوشمند را به صفر رساند بلکه می‌توان سود قابل توجهی هم به دست آورد و سود به دست آمده از بهینه‌سازی با الگوریتم تبرید تدریجی بیشتر از سود حاصل از الگوریتم ژنتیک است. در ادامه به منظور بررسی تاثیر پارامترهای مختلف تخصیص منابع خانه هوشمند با الگوریتم تبرید تدریجی در شرایط مختلف انجام شد و این نتیجه حاصل شد که وجود منابع انرژی تجدیدپذیر و منبع ذخیره ساز انرژی و امکان جابجایی بارهای غیرضروری هرکدام در کاهش هزینه‌ها و در نهایت سوددهی بیشتر موثر می‌باشند.

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تشخیص انجمن‌های هم‌پوشان در شبکه‌های اجتماعی با استفاده از رویکرد شبیه‌سازی تصادفی

چکیده - تشخیص انجمن اهمیتی بنیادین در تحلیل شبکه‌های اجتماعی دارد. شناسایی انجمن‌ها نقش مهمی در شناخت ساختار و تحول شبکه‌های اجتماعی دارد. تاکنون روش‌های مختلفی برای شناسایی انجمن‌ها ارائه شده است. بیشتر روش‌ها بر اساس فرض وجود انجمن‌های غیرهم‌پوشان و یا انجمن‌های هم‌پوشان پراکنده می‌باشد. علاوه بر آن در یک رویکرد نوین بر اساس آزمایشهای تجربی نشان داده شده است که ارتباطات در نقاط هم‌پوشان انجمن‌ها بیشتر از ارتباطات در سایر نواحی انجمن‌ها می‌باشد. در این مقاله بر اساس معیارهای مختلف و رویکرد شبیه سازی تصادفی کارآیی الگوریتم های معتبر در این زمینه مورد ارزیابی قرار داده می شود. همچنین از چند شبکه واقعی برای ارزیابی عملکرد بهره گرفته شده است. آزمایشهای شبیه‌سازی گسترده و بهره‌گیری از معیارهای ارزیابی نوین نشان داده است که الگوریتم‌های ارائه شده از عملکرد مطلوبی برای شناسایی انجمن‌های همپوشان برخوردار نمی‌باشند و بر همین اساس پیشنهاداتی برای رفع آنها ارائه می‌شود.

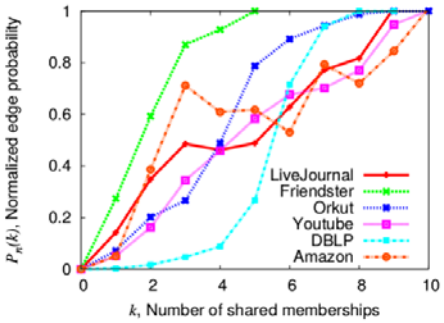
کلید واژه- انجمن‌های هم‌پوشان متراکم، تشخیص انجمن، شبکه‌های اجتماعی، شبکه‌های مصنوعی، هدایت‌پذیری و ارزیابی

۱- مقدمه

یکی از مسائل اساسی در شبکه‌های اجتماعی، تشخیص انجمن‌ها می‌باشد، [۱]. با تحلیل شبکه‌های اجتماعی و شناسایی انجمن‌ها می‌توان به نحوه‌ی ارتباط افراد در جامعه و نحوه‌ی همکاری و رقابت شرکت‌ها با یکدیگر را شناسایی کرد. از طرفی نتایج بررسی‌ها نشان می‌دهد که در شبکه اجتماعی فیسبوک میانگین فاصله‌ها بین هر دو کاربر در آمریکا برابر با ۴.۳ و در کل شبکه برابر با ۴.۷ می‌باشد، [۲]. بنابراین شبکه‌های اجتماعی می‌توانند نقش بسزایی در تبلیغات، بازاریابی و تجارت ایفا کنند و تشخیص انجمن در این شبکه‌ها می‌تواند به عنوان ابزاری مناسب برای سیستم‌های توصیه‌گر، هدایت رفتار مصرف‌کننده و بازاریابی به کار گرفته شود، [۱]. تاکنون تعاریف متفاوتی از انجمن در شبکه‌های اجتماعی ارائه شده است. اما بطور کلی یک انجمن عبارتست از مجموعه‌ای از گره‌ها که با یکدیگر تعاملات گسترده‌ای دارند و با سایر گره‌ها ارتباطات کمتری دارند. روش‌های مختلفی برای شناسایی انجمن در شبکه‌های اجتماعی ارائه شده‌اند که برخی از این روش‌ها مبتنی بر گراف، برخی دیگر از روش‌های مبتنی بر بهینه‌سازی و سایر روش‌ها مبتنی بر روش‌های یادگیری ماشین می‌باشد. از منظر یادگیری ماشین، تشخیص انجمن در شبکه‌های اجتماعی معادل با خوشه‌بندی شبکه و یافتن زیرگراف‌ها است بطوریکه گره‌های داخل هر زیرگراف با یکدیگر ارتباطات گسترده و با گره‌های سایر زیرگراف‌ها ارتباطات کمتری داشته باشند، [۱، ۳، ۴].

غالب روش‌های تشخیص انجمن، مبتنی بر تشخیص انجمن‌های غیرهم‌پوشان می‌باشد، بطوریکه در این روش‌ها یک گره، حداکثر متعلق به یک انجمن می‌باشد، [۵]. در حالیکه در مسائل دنیای واقعی هر گره می‌تواند متعلق به چندین انجمن باشد. اخیرا دانشمندان با مشاهده تجربی بر روی شبکه‌های دنیای واقعی بدین نتیجه رسیدند که در نواحی هم‌پوشان ارتباطات گسترده‌تری نسبت به سایر نواحی وجود دارد، [۶]. بعبارتی دیگر هر چه افراد اشتراکات بیشتری داشته باشند، احتمال برقراری ارتباط نیز بین آنها بیشتر می‌شود. به عنوان مثال افرادی که در یک کلاس درس می‌خوانند و هر دوی آنها به موسیقی علاقمندند با احتمال بیشتری با یکدیگر ارتباط برقرار می‌کنند. در شکل ۱ پژوهشگران با مشاهده شبکه‌های اجتماعی واقعی مانند یوتیوب، آمازون و ارکات بدین نتیجه رسیدند که هر چه افراد در انجمن‌های مشترک بیشتری حضور داشته باشند، احتمال برقراری ارتباط نیز بین آنها بیشتر می‌شود. بنابران

پژوهشگران با استفاده از مشاهدات تجربی مفهوم دیگری را از انجمن ارائه نمودند، [۶]. در حالیکه در گذشته بر این باور بودند که ساختار انجمن‌ها در شبکه‌های اجتماعی، یک ساختار هم‌پوشان پراکنده می‌باشد. بنابراین با توجه به فرضیاتی که روش‌های سابق داشته‌اند، به نتایج قابل قبولی دست پیدا نمی‌کردند.



شکل ۱: احتمال برقراری ارتباط براساس تعداد انجمن‌های مشترکی که با یکدیگر دارند.

بنابراین پژوهشگران سعی بر ارائه روش‌هایی نوین برای شناسایی انجمن‌های هم‌پوشان متراکم در شبکه‌های اجتماعی شدند. در این مقاله برای اولین بار با استفاده از رویکرد شبیه‌سازی تصادفی به ارزیابی الگوریتم‌های مطرح در این زمینه پرداخته می‌شود. بر اساس آزمایشهای شبیه‌سازی گسترده و برخی شبکه‌های واقعی نتایج جالبی به دست می‌آید که نشانگر ضعف روش‌های کنونی دارد. بر همین اساس پیشنهاداتی برای رفع آنها پیشنهاد شده است.

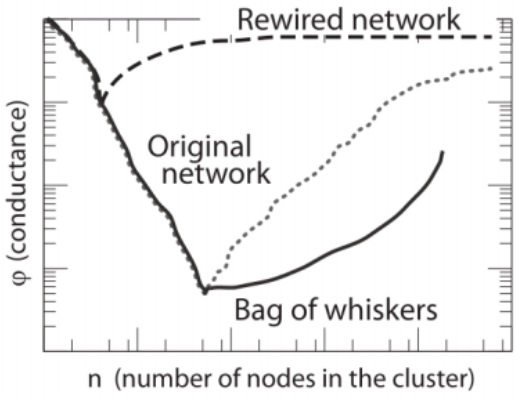
در ادامه و در بخش ۲- برخی از تعاریف اولیه بیان می‌شود. سپس روش‌های ارائه شده تشریح خواهد شد. توصیف دیتاست در بخش ۴- صورت می‌گیرد. در ادامه نتایج حاصل شده بیان خواهد شد و در بخش ۶- نتیجه‌گیری و کارهای آینده صورت می‌گیرد.

۲- تعاریف اولیه

همانطور که در بخش قبل اشاره شد، یک انجمن عبارتست از مجموعه‌ای از گره‌ها که با یکدیگر ارتباطات گسترده‌ای دارند و با سایر گره‌ها ارتباطات کمتری دارند، [۱]. یکی از مسائل اساسی در شناسایی انجمن‌ها، تعیین نقاط اولیه برای هر یک از خوشه‌ها می‌باشد. روش‌های متعددی برای تعیین نقاط اولیه معرفی شده‌اند، [۷، ۸، ۹]. اخیرا پژوهشگران بدین نتیجه رسیدند که هدایت‌پذیری[1] می‌تواند به عنوان ابزاری مناسب برای یافتن نقاط اولیه در انجمن‌ها باشد، [۱۰، ۱۱]. هدایت‌پذیری یک انجمن برابر با تعداد یال‌های برشی انجمن(یال‌هایی که از آن انجمن خارج می‌شوند.) تقسیم بر مینیمم مقدار مجموع یال‌های داخل انجمن با مجموع یال‌های خارج از انجمن می‌باشد. در رابطه (۱) مقدار هدایت‌پذیری یک انجمن نمایش داده شده است.

$$\Phi(s) = \frac{cut(S)}{min(Vol(S), vol(\bar{S}))} \qquad (۱)$$

یکی از کاربردهای هدایت‌پذیری، تعیین کیفیت انجمن شناسایی شده می‌باشد، [۱۲]. لسکویچ هدایت‌پذیری انجمنها را براساس اندازه آنها محاسبه کرد. نتایج تجربی نشان داد که هدایت‌پذیری در تمامی شبکه‌ها از رفتار مشابهی پیروی می‌کند، بطوریکه با افزایش تعداد انجمن‌ها مقدار هدایت‌پذیری ابتدا کاهش و سپس افزایش می‌یابد، [۱۲]. شکل ۲ نمودار مربوط به هدایت‌پذیری انجمن‌ها براساس اندازه آنها را نمایش می‌دهد. نتایج بر روی تمامی شبکه‌ها رفتار مشابهی دارد.



شکل ۲: هدایت‌پذیری انجمن‌ها براساس اندازه آنها[۱۲]

[1] Conductance

۳- تشریح الگوریتم‌ها

در این بخش برخی از معروفترین روش‌هایی که تاکنون در شناسایی انجمن‌های هم‌پوشان معرفی شده‌اند ارائه خواهد شد. در این بخش ابتدا به معرفی روش مدل‌های بلوکی-احتمالاتی و سپس روش AGM معرفی می‌شود.

۳-۱- مدل‌های بلوکی-احتمالاتی

مدلهای بلوکی احتمالاتی برای خوشه‌بندی بر روی شبکه‌هایی کاربرد دارد که اشیا آن با یکدیگر در ارتباطند و رفتار هر شی براساس همسایه‌های آن شی تعیین می‌شود، [۱۳]. یافتن انجمن‌های مربوط به یک گره با استفاده از مدل‌های بلوکی احتمالاتی در دو گام صورت میگیرد.

در گام اول(گام سراسری) احتمال عضویت هر یک از گره‌ها در انجمن محاسبه می‌شود. احتمال عضویت با استفاده از توزیع دیریکله و براساس پدیده ثروتمندان ثروتمندتر می‌شوند محاسبه می‌شود. به عنوان مثال اگر در انجمن اول ۶۰ گره در انجمن دوم ۴۰ گره و در انجمن سوم ۲۰ گره موجود باشد آنگاه احتمال عضویت گره در انجمن اول بیشتر و با استفاده از رابطه (۲) محاسبه می‌شود:

$$p(\pi|\alpha_1,\alpha_2,...,\alpha_n)=\frac{\Gamma(\alpha_1+\alpha_2+...+\alpha_k)}{\Gamma(\alpha_1)\Gamma(\alpha_2)...\Gamma(\alpha_k)} \quad (۲)$$

در رابطه (۲) پارامتر π بیانگر سهم هر یک از جامعه‌ها(خوشه‌ها. میزان بزرگی هر یک از خوشه‌ها براساس تعداد گره‌هایی که در آن عضو است) می‌باشد. این پارامتر از توزیع دیریکله تبعیت می‌کند، [۱۳].

$$\pi_p \sim Dirichlet(\vec{\alpha}) \quad (۳)$$

در رابطه (۳)، α پارامتر توزیع دیریکله می‌باشد و این پارامتر نشان دهنده میزان هم‌پوشانی انجمن‌ها می‌باشد. بطوریکه اگر مقدار این پارمتر کمتر باشد، هم‌پوشانی انجمن‌ها کمتر و هر چه مقدار این پارامتر بیشتر باشد آنگاه میزان هم‌پوشانی انجمن‌ها بیشتر خواهد شد، [۱۳].

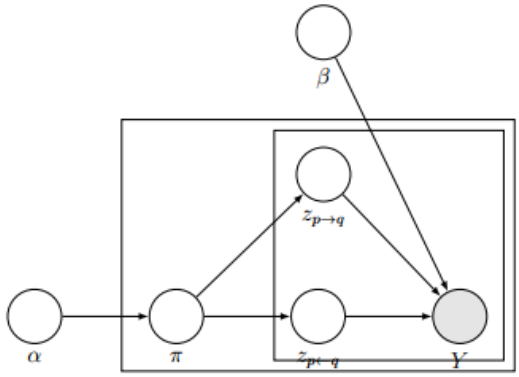
گام دوم، گام محلی در تشخیص انجمن‌ها می‌باشد. از طرفی دیگر رفتار گره‌ها در شبکه‌های واقعی از رفتار محلی تبعیت می‌کند. بالا بودن ضریب خوشه‌بندی، تعداد کلیک‌ها و توزیع توانی بودن مرکزیت‌های مختلف گواه بر این ادعا می‌باشد [۱۴]. بنابراین گره‌ها انجمن‌های خود را بصورت محلی و با توجه به رفتار همسایه‌های خویش تعیین می‌کنند. در این گام دو پارامتر تعریف می‌شود که هر یک از این پارامترها نشان دهنده احتمال عضویت یک گره در انجمن‌ها با استفاده از رفتار همسایگانش می‌باشد.

$$\vec{Z}p \to q \sim Mutlinomial(\overrightarrow{\pi_p}) \quad (۴)$$

$$Y(p,q) \sim Bernoulli(\overrightarrow{Z^T}_{p\to q} B \vec{Z}_{q\to q}) \quad (۵)$$

در رابطه (۵)، α پارامتر توزیع دیریکله می‌باشد. این پارامتر نشان‌دهنده میزان هم‌پوشانی انجمن‌ها می‌باشد بطوریکه هر چه مقدار αکمتر باشد به معنای هم‌پوشانی کمتر انجمن‌ها و بزرگتر بودن پارامتر میزان هم‌پوشانی انجمن‌ها را افزایش می‌دهد، [۱۳].

فرم گرافیکی احتمالاتی مربوط به این نمودار در شکل ۳ نمایش داده شده است.



شکل ۳: فرم احتمالاتی مربوط به مدل‌های بلوکی احتمالاتی

در شکل ۳ پارامتر β بیانگر ارتباط میان انجمن‌ها می‌باشد. همانطور که در بخش قبل بدان اشاره شد یک انجمن بصورت مجموعه‌ای از گره‌ها می‌باشد، بطوریکه در داخل هر یک از انجمن‌ها ارتباطات گسترده و با سایر گره‌های شبکه ارتباطات کمتری دارند. با استفاده از این تعریف، هر چه ماتریس β قطری‌تر شود آنگاه انجمن‌ها بهتر شناسایی شده‌اند، [۱۳].

مدل بلوکی احتمالاتی از روش بیشینه کردن مقدار تغییرات[۲] و با استفاده از نظریه میدان متوسط[۳] استفاده می‌کند

[2] Variational expectation maximization
[3] Mean field theory

تا با استفاده از یک تابع کمکی[4] مقدار توزیع پسین هر یک از متغیرهای مخفی را به درستی تقریب بزند.

$$q(\vec{\pi}_{1:N}, Z_{\rightarrow}, Z_{\leftarrow}|\vec{\gamma}_{1:N}, \Phi_{\rightarrow}, \Phi_{\leftarrow}) = \prod_p q_1(\vec{\pi}_p|\vec{\gamma}_p) \prod_{p,q}(q_2(Z_{p\rightarrow q}|\phi_{p\rightarrow q})q_2(Z_{p\leftarrow q}|\Phi_{p\leftarrow q}))$$

در رابطه فوق، q1 یک توزیع دیریکله، q2 یک توزیع چندجمله‌ای و $\Delta = (\vec{\pi}_{1:N}, \Phi_{\rightarrow}, \Phi_{\leftarrow})$ نشان دهنده مجموعه‌ای از متغیرهای مخفی که باید مقادیر هر یک از آنها محاسبه شود. پس از کمینه کردن میزان اختلاف KL[5] بین $q(\vec{\pi}_{1:N}, Z_{\rightarrow}, Z_{\leftarrow}|\Delta)$ و مقدار اصلی متغیرهای مخفی $p(\vec{\pi}_{1:N}, Z_{\rightarrow}, Z_{\leftarrow})$ شبه کد مربوط به این الگوریتم در ادامه آمده است.

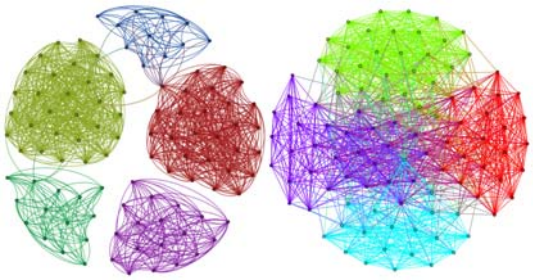
Algorithm ۱ Mixed Membership Stochastic Blockmodels

initialize $\vec{\gamma}^0_{pk} = \frac{2N}{K}$ for all p, k.
repeat
  for $p = 1$ *to* N **do**
    for $q = 1$ *to* N **do**
      get **variational** $\vec{\phi}^{t+1}_{p\rightarrow q}$ *and* $\vec{\phi}^{t+1}_{p\leftarrow q} = f(Y(p,q), \vec{\gamma}^t_p, \vec{\gamma}^t_q, B^t)$
      Partially update $\vec{\gamma}^{t+1}_p$ ، $\vec{\gamma}^{t+1}_q$ *and* B^{t+1}
until convegence

Algorithm ۲ f function of previous algorithm

initialize for all $\phi^0_{p\rightarrow q,g} = \phi^0_{p\leftarrow q,h} = \frac{1}{K}$ g, h.
repeat
  for $g = 1$ *to* K **do**
    update $\phi^{s+1}_{p\rightarrow q} \propto f_1(\vec{\phi}^s_{p\leftarrow q}, \vec{\gamma}_p, B)$
  normalize $\vec{\phi}^{s+1}_{p\rightarrow q}$ to sum to ۱.
  for $h = 1$ *to* K **do**
    update $\phi^{s+1}_{p\leftarrow q} \propto f_2(\vec{\phi}^s_{p\rightarrow q}, \vec{\gamma}_q, B)$
    normalize $\vec{\phi}^{s+1}_{p\leftarrow q}$ to sum to ۱.
until *convergence*

همانطور که در شبه کد بالا نشان داده شده است، این روش با استفاده از یک حلقه تکرار، انجمن‌های موجود در یک شبکه را شناسایی می‌کند. یکی از نقاط ضعف عمده روش مدل‌های بلوکی احتمالاتی در پیچیدگی این روش و سخت بودن تعیین پارامتر توزیع دیریکله می‌باشد. همانطور که در بخش قبل بیان شد مقدار پارامتر توزیع دیریکله نشان‌دهنده میزان هم‌پوشانی انجمن‌ها می‌باشد. بطوریکه هر چه میزان این پارامتر کمتر باشد، میزان هم‌پوشانی انجمن‌ها کمتر و هر چه مقدار پارامتر بیشتر باشد میزان هم‌پوشانی انجمن‌ها در شبکه بیشتر است. در شکل ۴ شبکه‌ای با ۱۰۰ گره و ۵ انجمن با استفاده از مدل‌های بلوکی احتمالاتی ساخته شده است. همانطور که مشاهده می‌شود پارامتر توزیع دیریکله تاثیر زیادی بر روی شبکه می‌گذارد. بطوریکه هر چه مقدار این پارامتر کوچکتر باشد(۰.۰۰۱) میزان هم‌پوشانی شبکه‌ها کمتر و هر چه مقدار این پارامتر بزرگتر باشد(۰.۰۲) میزان هم‌پوشانی شبکه‌ها بیشتر می‌شود.



شکل ۴: تاثیر میزان پارامتر توزیع دیریکله بر هم‌پوشانی انجمن‌ها

در ادامه یکی دیگر از روش‌های شناخته شده برای شناسایی انجمن‌های هم‌پوشان در شبکه‌ها اجتماعی ارائه می‌شود.

۳-۲- مدل وابستگی گرافی

تاکنون تعاریف متفاوتی از مفهوم انجمن در شبکه‌های اجتماعی ارائه شده است، [۱]. در گذشته پژوهشگران بر این باور بودند که یک انجمن مجموعه‌ای از گره‌ها می‌باشد بطوریکه ارتباطات داخل انجمن‌ها بیشتر از ارتباطات بین انجمن‌ها می‌باشد. از طرفی دیگر در نواحی هم‌پوشان ارتباطات کمتری نسبت به نواحی غیر هم‌پوشان در انجمن‌ها وجود دارد، [۱۵].

اخیرا دانشمندان با مطالعه تجربی ساختارهای مختلف انجمن در شبکه‌های اجتماعی گوناگون بدین نتیجه رسیدند که در نواحی هم‌پوشان ارتباطات بسیار گسترده‌تری نسبت به سایر نواحی در انجمن‌ها وجود دارد، [۶]. بنابراین اکثر روش‌های سابق در شناسایی انجمن‌های هم‌پوشان پراکنده قادر به شناسایی انجمن‌های هم‌پوشان متراکم در شبکه‌ها نمی‌باشند. اخیرا روش‌های آماری متفاوتی در شناسایی انجمن‌های هم‌پوشان متراکم در شبکه‌های اجتماعی ارائه شده است که در ادامه برخی از این روش‌ها توضیح داده می‌شود:

[4] Auxiliary function
[5] Kulback-Leibler divergence

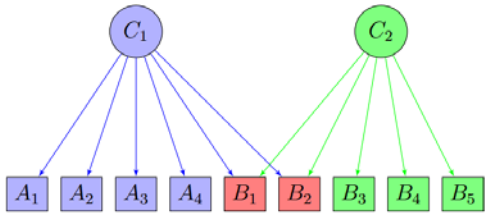
۳-۳- مدل تمایل گرافی

در سال ۲۰۱۲ لسکویچ روش جدیدی ارائه داد که این روش قادر به شناسایی انجمن‌های هم‌پوشان متراکم در شبکه‌ها می‌باشد، [۱۶]. فرض اصلی مدل بدین صورت است که احتمال وجود یال بین دو گره با افزایش تعداد انجمن‌های مشترک، افزایش می‌یابد. این فرضیه در شکل ۱ و بر روی شبکه‌هایی که برچسب مربوط به انجمن آنها مشخص است، ارزیابی شده است. نتایج بیان می‌کند که مدل ارائه شده شباهت زیادی به شبکه‌های واقعی دارد. برخی از روش‌ها از این رویکرد جهت شناسایی انجمن‌ها استفاده می‌کنند، [۹، ۱۱، ۱۷].

فرض کنید که $B(V, C, M)$ یک گراف دو بخشی باشد بطوریکه V مجموعه گره‌ها، C مجموعه انجمن‌ها و $(u, c) \in M$ به معنای آنست که گره u در داخل انجمن c قرار دارد. همچنین فرض کنید که p_a احتمال عضویت به هر یک از انجمن‌ها را نمایش می‌دهد. با داشتن هر یک از پارامترهای فوق می‌توان شبکه را به صورت زیر بوجود آورد. بعبارتی دیگر احتمال وجود یال بین دو گره (u, v) به صورت زیر محاسبه می‌شود:

$$p(u,v) = \prod_{k \in C_{uv}} (1 - P_k) \qquad (۶)$$

در رابطه (۶) C_{uv} نشان دهنده انجمن‌هایی می‌باشد بطوریکه گره‌های u و v متعلق به این انجمن‌ها باشند. در شکل ۵ فرم احتمالاتی مربوط به این روش نشان داده شده است.



شکل ۵: فرم گرافی احتمالاتی مربوط به تولید شبکه با استفاده از روشAGM

همانطور که در شکل ۵ مشاهده می‌شود با استفاده از میزان عضویت هر یک از گره‌ها در هر انجمن، شبکه را می‌توان با استفاده از رابطه (۶) تولید کرد. هدف این روش یافتن متغیرهای مخفی هر یک از گره‌ها می‌باشد. بنابراین با داشتن ماتریس مجاورت شبکه و با استفاده از یک حلقه تکرار انجمن مربوط به هر یک از گره‌ها در شبکه بروز می‌شود. هر گره در هر مرحله ۳ استراتژی مختلف ترک انجمن، پیوستن به یک انجمن جدید و تغییر انجمن دارد، [۱۶]. الگوریتم مربوط به این روش بدین صورت است که با استفاده از یک حلقه تکرار، انجمن مربوط به هر یک از گره‌هابصورتی بروز می‌شود که میزان تابع درستنمایی بیشینه شود. این روش تا زمانی تکرار می‌شود که انجمن مربوط به تمامی گره‌ها تغییر نکند. تابع درستنمایی در این روش به صورت زیر تعریف می‌شود [۱۶]:

$$argmax\ ll = \prod_{(u,v)\in E} p(u,v) * \prod_{(u,v)\notin E} (1 - p(u,v)) \qquad (۷)$$

در بخش بعدی هر یک از روش‌های ارائه شده در این بخش بر روی تعدادی از شبکه‌های مصنوعی و شبکه‌های واقعی پیاده‌سازی می‌شوند نتایج آن با یکدیگر مقایسه می‌شوند.

۴- توصیف دیتاست

در این بخش قصد داریم که برای ارزیابی هر یک از روش‌های فوق شبکه‌های مختلفی را تولید نماییم بطوریکه میزان هم‌پوشانی انجمن‌ها در این شبکه‌ها متراکم و پراکنده باشد. بدین منظور از دو روش احتمالاتی برای شبیه‌سازی شبکه‌های واقعی استفاده می‌شود. شبکه اول با استفاده از روش [۱۳] و با استفاده از رابطه‌های (۳) و (۵) تولید می‌شود. در جدول ۱ نحوه تولید شبکه با استفاده از روش‌های مختلف، نوع شبکه و تعداد گره‌های مربوط به این شبکه‌ها نمایش داده شده است.

جدول ۱: روش‌های مختلف برای تولید شبکه

روش	نوع(متراکم ـ پراکنده)	پارامترها	تعداد گره‌ها
مدل‌های بلوکی	متراکم ـ پراکنده	پارامتر مربوط به دیریکله α	۱۰۰-۵۰۰
ال اف آر	متراکم ـ پراکنده	پارامتر مخلوط و میانگین درجه	۱۰۰-۵۰۰

بنابراین برای هر یک از حالت‌های ارائه شده دو شبکه تولید می‌شود بطوریکه در حالت اول انجمن‌ها با یکدیگر هم‌پوشانی پراکنده و در حالت دوم انجمن‌ها با یکدیگر هم‌پوشانی گسترده‌ای دارند. بدین منظور از روش ضریب پیمانگی[۵] برای تعیین میزان هم‌پوشانی انجمن‌ها و متعاقبا برای تعیین نوع شبکه استفاده می‌شود. بطوریکه پس از تولید شبکه، اگر میزان ضریب پیمانگی شبکه بیش از ۰.۵ باشد آنگاه شبکه دارای انجمن‌های هم‌پوشان پراکنده و اگر میزان ضریب پیمانگی شبکه کمتر از ۴.۰ باشد شبکه دارای انجمن‌های هم‌پوشان متراکم می‌باشد.

جدول ۲: تاثیر پارامتر دیریکله بر روی میزان هم‌پوشانی انجمن‌ها با یکدیگر

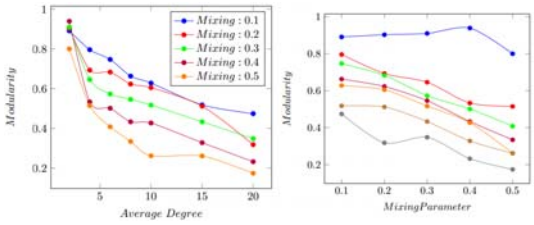
تعداد گره‌ها	تعداد یال‌ها	تعداد انجمن‌ها	ضریب پیمانگی	نوع(متراکم-پراکنده)	پارامتر دیریکله
۱۰۰	۱۰۲۱	۵	۰,۷۱	متراکم	۰,۰۰۳
۱۰۰	۱۲۷۷	۵	۰,۳۷	پراکنده	۰,۰۳
۲۰۰	۴۶۳۵	۱۱	۰,۲۶	متراکم	۰,۰۵
۲۰۰	۲۲۲۴	۱۱	۰,۷۱	پراکنده	۰,۰۰۲
۵۰۰	۶۰۷۴	۳۲	۰,۳۲	متراکم	۰,۰۲
۵۰۰	۴۲۷۷	۳۲	۰,۸۱	متراکم	۰,۰۰۱

روش دیگری که در این مقاله برای تولید شبکه‌های مختلف با انجمن‌های هم‌پوشان متراکم و پراکنده به کار رفته است روش ال اف آر[6] می‌باشد . با این روش دو نوع شبکه مختلف با انجمن‌های متراکم و پراکنده ایجاد می‌شود. بدین منظور ابتدا برخی از پارامترهای این روش معرفی خواهند شد.

جدول ۳: پارامترهای مربوط به روش ال اف آر

پارامتر	توصیف
N	تعداد گره‌ها
k	میانگین درجه
$maxk$	ماکزیمم درجه
mu	پارامتر ترکیبی
$t1$	توان مربوط به توزیع درجه(منفی)
$t2$	توان منفی مربوط به اندازه انجمن‌ها
$minc$	حداقل اندازه انجمن‌ها
$maxc$	حدامثر اندازه انجمن‌ها
on	تعداد گره‌های هم‌پوشان
om	تعداد انجمن‌های هم‌پوشان به ازای هر یک از گره‌های هم‌پوشان

برای تولید شبکه، در گام اول بایستی تاثیر هر یک از پارامترها را بر روی نوع هم‌پوشانی انجمن‌ها شناسایی نماییم. دو تا از مهمترین پارامترها در این روش، پارامتر ترکیبی و میانگین درجه می‌باشد. بطوریکه هر چه مقدار این پارامترها بزرگتر باشد آنگاه میزان هم‌پوشانی در شبکه بیشتر و مقدار ضریب پیمانیگی انجمن‌ها کمتر خواهد شد، [۱۸].



شکل ۶: تاثیر پارامترهای میانگین درجه و ترکیبی بر روی هم‌پوشانی انجمن‌های شبکه.

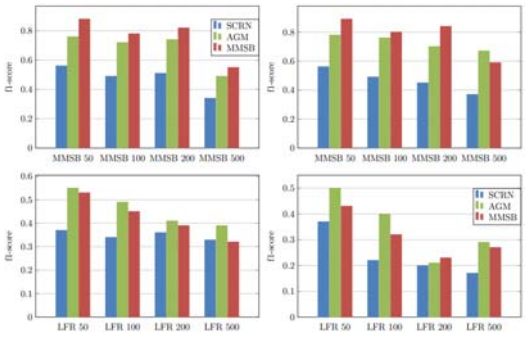
پس از تعیین هر یک از پارامترها در میزان هم‌پوشانی انجمن‌ها، شبکه‌هایی با۵۰، ۱۰۰، ۲۰۰ و ۵۰۰ گره در دو حالت میزان هم‌پوشانی متراکم و پراکنده تولید می‌شوند.

جدول ۴: ویژگی شبکه‌های تولید شده با روش LFR

تعداد گره‌ها	تعداد انجمن‌ها	ضریب پیمانگی	نوع (متراکم یا پراکنده)	پارامتر ترکیبی	تعداد گره‌های هم‌پوشان
۱۰۰	۶	۰,۳۳۶	متراکم	۰,۳	۲۰
۱۰۰	۵	۰,۶۰۵	پراکنده	۰,۱	۱۰
۲۰۰	۱۰	۰,۲۷۷	متراکم	۰,۵	۴۰
۲۰۰	۱۱	۰,۶	پراکنده	۰,۲	۲۰
۵۰۰	۱۶	۰,۳۰۶	متراکم	۰,۵	۱۰۰
۵۰۰	۱۶	۰,۶۱	پراکنده	۰,۲	۵۰

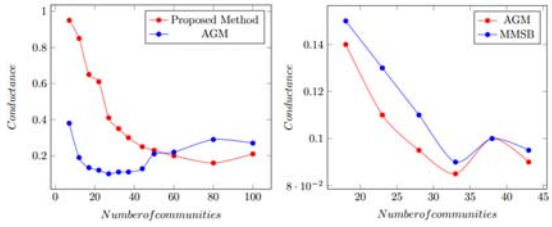
۵- نتایج

در این بخش هر یک از روش‌های ارائه شده را بر روی شبکه‌های تولید شده بخش قبل و برخی از شبکه‌های واقعی پیاده‌سازی می‌کنیم. نتایج حاصل از پیاده‌سازی را با استفاده از معیار امتیاز f1[7] و برخی دیگر از معیارها مانند هدایت‌پذیری [۱۰] (که با استفاده از ویژگی‌های انجمن‌های شناسایی شده کیفیت انجمن را بررسی می‌کند که در بخش ۲- بدان پرداخته شد.) صورت می‌گیرد، [۱۳، ۱۶، ۱۹].



شکل ۷: امتیاز f1 روش‌های مختلف بر روی شبکه‌های تولید شده بخش قبل (سمت چپ شبکه‌های متراکم و سمت راست شبکه‌های پراکنده می‌باشد.)

در ادامه میزان هدایت‌پذیری هر یک از روش‌ها را براساس تعداد انجمن‌های مختلف محاسبه می‌کنیم.



شکل ۸: میزان هدایت‌پذیری هر یک از روش‌ها براساس تعداد انجمن‌ها در شبکه. شکل سمت راست شبکه حاصل شده مدل‌های بلوکی و شکل سمت چپ شبکه حاصل شده از مدل ال اف آر را نمایش می‌دهد.

[6] Lancichinetti, Fortunato, Radicchi

[7] f1-score

همچنین هر یک از روش‌ها بر روی برخی از شبکه‌های واقعی نیز پیاده‌سازی شده‌اند. شبکه‌های واقعی که در این مقاله به کار رفته‌اند عبارتند از: شبکه فوتبالیست‌های آمریکایی، [۲۰]، شبکه دلفین‌ها، [۲۱] و شبکه مربوط به کتاب‌های سیاسی سایت آمازون می‌باشد. در ادامه میزان امتیاز هر یک از روش‌های توضیح داده شده بر روی این شبکه‌ها در جدول ۵ نمایش داده شده است.

جدول ۵: مقدار امتیاز روش‌های ارائه شده بر روی شبکه‌های واقعی

شبکه	تعداد گره‌ها	تعداد یال‌ها	انجمن‌ها	امتیاز f1	متدولوژی
فوتبال آمریکایی	۱۱۵	۶۱۶	۱۲	۰,۴۳	مدل بلوکی
فوتبال آمریکایی	۱۱۵	۶۱۶	۱۲	۰,۳	وابستگی گرافی
دلفین	۶۲	۱۵۹	۲	۰,۴۱	مدل بلوکی
دلفین‌ها	۶۲	۱۵۹	۲	۰,۸۶	وابستگی گرافی
کتاب‌های سیاسی	۱۰۵	۴۴۱	۳	۰,۳۱	مدل بلوکی
کتاب‌های سیاسی	۱۰۵	۴۴۱	۳	۰,۵	وابستگی گرافی

۶- نتیجه‌گیری و کارهای آینده

در این مقاله برای اولین بار بر اساس رویکرد شبیه‌سازی تصادفی به مقایسه عملکرد الگوریتم‌های محبوب در زمینه شناسایی انجمن پرداخته شد و بر اساس معیارهای ارزیابی مختلف به بررسی کارآیی آنها پرداخته شد. استفاده از رویکرد شبیه‌سازی تصادفی و بهره‌گیری از مقادیر مختلف برای تولید شبکه‌های متنوع، ما را قادر ساخت تا نقاط ضعفی که تاکنون در ادبیات مرتبط ارائه نشده بود، را شناسایی کنیم. اگرچه روش مدل تمایل گرافی(AGM) در مجموع دقت بالاتری نسبت به روش مدل‌های بلوکی-احتمالاتی(MMSB) در شناسایی انجمن‌های هم‌پوشان متراکم دارد، اما هیچ یک از این روش‌ها دقت بالایی در شناسایی انجمن‌های هم‌پوشان متراکم ندارند. نتایج به دست آمده حاکی از آن است که یک الگوریتم بر اساس فرض همپوشانی متراکم و یا همپوشانی پراکنده به تنهایی نمی‌تواند در شناسایی انجمن در شبکه‌های اجتماعی موثر عمل کند. ارائه یک رویکرد ترکیبی و بهره‌گیری از یک فرض جدید می‌تواند منجر به ایجاد یک تحول در امر شناسایی انجمن‌ها شود.

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ارائه‌ی یک گراف فعالیت جدید در ردگیری اشیاء در محیط‌های چنددوربینی با استفاده از مدل‌های احتمالاتی

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چکیده - برای ردگیری در محیط‌های نظارتی وسیع، نیاز به سامانه‌ای از دوربین‌های ناهمپوشان است که با فاصله‌ی زیاد از هم قرار گرفته‌اند. فاصله‌ی زیاد بین دوربین‌ها منجربه به وجود آمدن نواحی کور بین آن‌ها می‌شود. نواحی کور سبب می‌شود که مشاهدات از نظر مکانی و زمانی پیوسته نباشند. در این مقاله برای حل مسئله‌ی ردگیری در چنددوربین از مدلسازی بیزین و زنجیره‌ی مارکوی مونت کارلو استفاده کردیم. نوآوری این مقاله مربوط به استخراج الگوی حرکت می‌باشد، به این صورت که گراف فعالیت جدیدی معرفی می‌شود که نسبت به روش‌های پیشین توانایی بهتری در جداسازی الگوهای حرکت دارد. ارزیابی روش پیشنهادی در یک سامانه‌ی نظارتی شامل سیزده دوربین تنظیم نشده و ناهمپوشان است. ویدئوی ضبط شده مربوط به شلوغ‌ترین بازه‌های زمانی است و تعداد افراد ردگیری نامشخص است. نتایج ارزیابی نشان می‌دهد که روش پیشنهادی عملکرد بهتری نسبت به روش‌های قبلی دارد.

کلید واژه- دوربین‌های هم‌پوشان، دوربین‌های ناهمپوشان، ردگیری در چنددوربین، مدل بیزین

۱- مقدمه

در سال‌های اخیر پیشرفت جوامع بشری باعث بروز نیازمندی‌های جدید شده است که توسعه و بکارگیری سامانه‌های نظارت خودکار از جمله این نیازمندی‌ها است. کاهش قیمت دوربین‌های تصویربرداری باعث شده است تا در اغلب محیط‌های عمومی و حتی خصوصی، تعداد زیادی از این دوربین‌ها برای نظارت مورد استفاده قرار گیرند. تعداد زیاد این دوربین‌ها و نیاز به نظارت پیوسته بر محتوای آن‌ها باعث می‌شود که نتوان از کاربر انسانی برای نظارت کامل در این محیط‌ها استفاده کرد. ناتوانی کاربر انسانی در نظارت همزمان دوربین‌ها، همچنین خستگی و کاهش دقت در نظارت، هزینه‌های مربوط به آموزش کاربر انسانی باعث شده است که تمایل به استفاده از سامانه‌های نظارتی هوشمند افزایش یابد. سامانه‌های نظارت خودکار (هوشمند) نیازمند تحلیل رفتار اشیاء متحرکی هستند که در محدوده دید دوربین‌ها قرار می‌گیرند. تحلیل رفتار این اشیاء مستلزم استخراج اطلاعاتی در مورد هر یک از آن‌هاست. ردگیری شیء یکی از مهمترین اجزاء این اطلاعات است که تعریف دقیق آن عبارت است از تعیین محل یک شیء در طول زمان.

مسئله‌ی ردگیری با چالش‌های مختلفی روبرو است که از مهمترین آنها می‌توان به تغییرات شدت روشنایی در طول زمان، انسداد (overlap) اشیاء موجود در تصویر و حرکت دوربین‌ها اشاره کرد[۱]. به منظور افزایش محدوده دید دوربین‌ها و رفع مشکل انسداد در اغلب سامانه‌های نظارتی از چندین دوربین به طور همزمان استفاده می‌شود. استفاده از سامانه‌های چند دوربینی علاوه‌بر مزایایی که ذکر شد با چالش‌های جدیدی نظیر تناظر اشیاء در دیدهای مختلف از یک صحنه، تخمین توپولوژی دوربین‌ها و ترکیب اطلاعات استخراج شده از دوربین‌های مختلف رو برو است[۲]. روش‌هایی که تاکنون برای ردگیری در چنددوربین ارائه شده‌اند، فرضیات مختلفی را برای محیط تحت نظارت در نظر گرفته‌اند. این فرضیات عبارتند از: داخل یا خارج ساختمان بودن، همپوشان یا ناهمپوشان بودن دوربین‌ها، تنظیم دوربین‌ها، ایستا یا پویا بودن دوربین‌ها. متاسفانه تاکنون روشی که بتواند در تمام محیط‌ها عملکرد خوبی داشته باشد، ارائه نشده است به همین دلیل به تحقیقات بیش‌تر در این زمینه نیاز است.

در این مقاله فرض می‌کنیم، دوربین‌ها تنظیم‌نشده، ناهمپوشان، ایستا و تعداد اهداف متحرک نامشخص است. برای حل مسئله‌ی ردگیری در چند دوربین ابتدا در هر یک از دوربین‌ها اهداف متحرک شناسایی و ردگیری می‌شوند. مسیرهای ردگیری شده در یک دوربین را مسیر تک دوربینی

می‌نامیم. سپس این مسیرهای تک‌دوربینی با استفاده از یک معماری متمرکز یا توزیع‌شده با یکدیگر ترکیب می‌شوند و مسیرهای چنددوربینی نهایی استخراج می‌شود. زیرمجموعه‌ای از مسیرهای تک‌دوربینی که مربوط به یک شیء مشخص هستند را مسیرچنددوربینی می‌نامیم.

همانطور که اشاره شد در مسئله‌ی ردگیری در چند دوربین تمام چالش‌های مسئله‌ی ردگیری در یک دوربین مانند تشخیص اشیاء متحرک، استخراج ویژگی و ... وجود دارد اما با توجه به اینکه تمرکز این مقاله ردگیری در محیط‌های چنددوربینی است به همین دلیل بر بخش‌های اصلی مسئله‌ی ردگیری در چند دوربین متمرکز می‌شویم. اغلب روش‌های موجود برای ردگیری چند دوربینی از سه گام اصلی استفاده می‌کنند [۲]: تناظر اشیاء، استخراج توپولوژی دوربین‌ها و ترکیب اطلاعات. در بخش تناظر اشیاء از ویژگی‌های استخراج شده اشیاء در دوربین‌های مختلف به منظور شناسایی مسیرهای تک‌دوربینی یک شیء مشخص در دوربین‌های مختلف استفاده می‌شود.

در گام تخمین توپولوژی هدف استخراج توپولوژی دوربین‌ها است. منظور از توپولوژی دوربین‌ها نحوه‌ی ارتباط مکانی بین دوربین‌ها است که نشان دهنده‌ی این است که فردی که از محدوده‌ی دید یک دوربین خارج می‌شود در یک مرحله بعد در چه دوربین‌هایی ممکن است ظاهر شود. استخراج توپولوژی به دو صورت دستی و خودکار انجام می‌شود.

اکثر روش‌های ردگیری در چنددوربین از یک مدل احتمالاتی برای نشان دادن توپولوژی بین دوربین‌ها استفاده می‌کنند. این مدل انتقال معمولا با یک گراف جهت‌دار نشان داده می‌شود. هر گره معادل یک دوربین بوده و وزن یال‌ها احتمال انتقال بین دوربین‌ها را نشان می‌دهد. به این مدل گرافی توپولوژی فعالیت می‌گویند [۳].

هدف ترکیب اطلاعات این است که ویژگی‌های استخراج شده را با توپولوژی اطلاعات ترکیب کند و نهایتا اشیاء را ردگیری کند. روش‌های مختلفی برای ترکیب اطلاعات وجود دارد؛ مثلا در مقاله‌ی [۴] و [۵] از روش بیزین در مقاله‌ی [۶] از روش‌های مبتنی‌بر فیلتر کالمن و در مقاله‌ی [۷] از روش‌های مبتنی‌بر فیلتر ذره استفاده شده است.

تاکنون گراف‌های فعالیت مختلفی برای ردگیری چنددوربینی ارائه شده است که در ادامه‌ی مقاله به معرفی برخی از آن‌ها خواهیم پرداخت. در این مقاله گراف فعالیت جدیدی ارائه می‌شود که نسبت به روش‌های پیشین توانایی بهتری در مدل‌سازی الگوهای حرکتی موجود در محیط دارد. گراف‌های فعالیت قبلی رفتاری یکسان با الگوهای حرکت با سرعت‌های مختلف داشتند اما گراف فعالیتی که در این مقاله ارائه می‌شود بین الگوهای حرکتی با سرعت متفاوت نیز تمایز قائل می‌شود.

ساختار کلی این مقاله به این صورت است که در بخش دوم به بررسی کارهای پیشین می‌پردازیم. در بخش سوم سامانه‌ی طراحی شده برای ردگیری در چند دوربین را توضیح می‌دهیم. در بخش چهارم نتایج تجربی را ارائه می‌کنیم و در بخش آخر رویکردهای آتی را بیان می‌کنیم.

۲- کارهای پیشین

بررسی روش‌های ردگیری نشان می‌دهد که دو رویکرد اصلی در معماری شبکه‌ی چند دوربینی وجود دارد. این دو رویکرد عبارت‌اند از: معماری متمرکز و معماری توزیع‌شده که در ادامه به بررسی بیش‌تر هریک از این معماری‌ها می‌پردازیم.

۲-۱- معماری متمرکز

بیش‌تر روش‌های ارائه‌شده در ردگیری با چند دوربین، از معماری متمرکز استفاده می‌کنند. در این روش اطلاعات دوربین‌های مختلف به یک پردازنده‌ی مرکزی فرستاده می‌شود و در آنجا محاسبات انجام می‌شود. در این معماری جداسازی حرکت، بررسی اشیاء متحرک درصحنه، تطابق با مسیرهای موجود در فریم قبل و تناظر اولیه برای هریک از دوربین‌ها انجام می‌شود. سپس نتایج به‌دست‌آمده از هریک از دوربین‌ها به واحد پردازش مرکزی فرستاده می‌شود. در واحد پردازش مرکزی، اطلاعاتی مانند رابطه‌ی مکانی حوزه‌ی دید دوربین‌ها و مشخصات ظاهری و ... استخراج می‌شود و تناظر بین مسیرهای موجود به دست می‌آید. روش پیشنهاد داده‌شده در [۴] از اولین روش‌های ارائه‌شده برای ردگیری در چند دوربین است. این روش برای ردیابی افراد در یک راهرو بکار گرفته‌شده است. دوربین‌های استفاده‌شده ناهمپوشا، ایستا و تنظیم‌نشده هستند. در این مقاله ردگیری به‌صورت یک مسئله‌ی بیزین ارائه‌شده است. در [۸] با استفاده از مجموعه‌ای از دوربین‌های تنظیم‌شده و هم‌پوشان به ردگیری اشیاء در محیط چنددوربینی پرداخته شده است. در روش ارائه‌شده با استفاده از فیلتر کالمن در هر دوربین ردگیری انجام می‌شود سپس با استخراج متغیرهای دوربین، از ویژگی‌های هندسی برای تطبیق مسیرهای ردگیری بین دوربین‌های مختلف استفاده می‌شود. در مقاله‌ی [۹] از تابع تجمعی انتقال شدت روشنایی برای کاهش تغییرات شدت روشنایی استفاده کردند. در مقاله‌ی [۹] براساس هیستوگرام رنگ تجمعی یک تابع انتقال

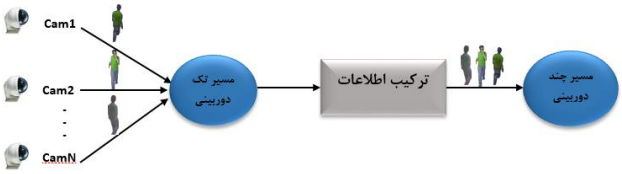
ساخته شده است. عملکرد این تابع از تابع انتقال پیشنهاد داده شده در مقاله‌ی [۱۰] بهتر است زیرا مقاله [۱۰] تابع انتقال را به صورت تجمعی محاسبه نمی‌کند، بلکه از میانگین‌گیری توابع مختلف بدست می‌آورد. همین امر سبب می‌شود دقت تطبیق در مقاله‌ی [۹] افزایش یابد. در [۱۱]، روشی برای ردگیری چندین فرد دارای انسداد پیشنهاد داده شده است. در این روش تمام دوربین‌ها با هم در تشخیص و ردگیری همکاری می‌کنند. از مزایای این روش این است که مبتنی بر تصویر است و تنها از ساختار دوبعدی استفاده می‌کند. در [۱۲] روشی برای ردگیری شیء در محیط چنددوربینی ارائه شده‌است. این روش ضمن کاهش ۷۰ درصدی بار محاسباتی، دقتی برابر با فیلتر ذره‌ی استاندارد دارد. در [۱۳] از مشخصات مربوط به رنگ و حجم افراد، برای ردگیری در دوربین‌های مختلف استفاده می‌کند. این سامانه شامل مجموعه‌ای از دوربین‌های تنظیم‌شده است. در این سامانه برای تشخیص و تعیین محل افراد تنها از اطلاعات حجمی استفاده می‌شود. اما برای ردگیری اهداف تشخیص داده شده از اطلاعات رنگ و اطلاعات هندسی استفاده می‌شود.

۲-۲- معماری توزیع‌شده

همان‌طور که پیشتر اشاره شد در معماری توزیع‌شده هر دوربین به‌طور جداگانه اطلاعات مشخص را به دست می‌آورد و آن را بین دوربین‌های همسایه به اشتراک می‌گذارد. در [۱۴] روشی برای ردگیری در محیط چنددوربینی با معماری توزیع‌شده پیشنهاد شده است. در این سامانه از مفهوم اجماع که در سامانه‌های مبتنی بر چند عامل مطرح شده است استفاده می‌شود. در این سامانه هر دوربین متغیرهای معینی را براساس اطلاعاتی که در دسترس قرار دارد تخمین می‌زند و سپس آن‌ها را به صورت محلی با همسایه‌هایش به اشتراک می‌گذارد. تخمین نهایی با استفاده از الگوریتم اجماع کالمن محاسبه می‌شود. در یک شبکه‌ی توزیع‌شده‌ی پیشنهادی در [۱۵] گره‌های شبکه پردازشگرهای متصل به دوربین‌ها هستند. هر دوربین تصاویر گرفته شده را به پردازشگر مربوط به خود ارسال می‌کند و اشیاء متحرک موجود در ویدیوها را ردگیری می‌کند. اطلاعات مربوط به هریک از گره‌ها از طریق شبکه بین گره‌های دیگر جابه‌جا می‌شود. در این روش شبکه‌ی تشکیل شده از دوربین‌ها به صورت یک شبکه‌ی بیزی مدل می‌شود.

۳- سامانه‌ی ردگیری چند دوربینی پیشنهادی

شکل ۱ شمای کلی سامانه‌ی ردگیری چنددوربینی را نشان می‌دهد. همانطور که مشاهده می‌شود ابتدا در هر دوربین ردگیری تک دوربینی انجام می‌شود. سپس اطلاعات ردگیری تک‌دوربینی و توپولوژی دوربین‌ها با استفاده از یک مدل بیز ترکیب می‌شوند و سپس با استفاده از استنتاج زنجیره‌ی مارکفی مسیرهای چنددوربینی بدست می‌آیند.



شکل ۱: سامانه‌ی ردگیری چند دروبینی طراحی شده

همانطور که ذکر شد ردگیری چنددوربینی از سه گام اصلی تطبیق اشیاء، استخراج توپولوژی و ترکیب اطلاعات تشکیل شده است، در ادامه روش‌های استفاده شده در هر بخش را توضیح می‌دهیم. در روش پیشنهادی از گراف فعالیت جدیدی برای نمایش توپولوژی دوربین‌های استفاده شده است که در بخش بعد تاثیر بکارگیری آن به صورت عملی نمایش داده می‌شود.

۳-۱- ردیابی تک دوربینی و استخراج اطلاعات اشیاء

در این مرحله مسیرهای تک دوربینی در کلیه‌ی دوربین‌ها شناسایی می‌شوند. فرض کنید شیء m از مقابل دوربین c_i عبور کند. دوربین c_i بعد از تشخیص این شیء و ردگیری آن از لحظه‌ی ورود به محدوده‌ی دید دربین تا خروج شیء از این ناحیه، بردار ویژگی شیء را استخراج می‌کند. بردار ویژگی اشتخراج شده برای شیء m در دوربین c_i به صورت زیر تعریف می‌شود:

$$Z(X_{in}, X_{out}, T_{in}, T_{out})$$

X_{in} و X_{out} در واقع گره‌های گراف فعالیت هستند که در ادامه توضیح خواهیم داد؛ اما در حالت کلی می‌توان فرض کرد که X_{in} ناحیه‌ی ورود شیء به محدوده‌ی دید دوربین c_i و X_{out} ناحیه‌ی خروج شیء از محدوده‌ی دید این دوربین می‌باشد. برای استخراج این ویژگی باید نواحی ورود و خروج اشیاء در هر دوربین را تعیین کنیم. نواحی ورودی، نواحی هستند که شیء متحرک وارد محدوده‌ی دید دوربین می‌شود. نواحی خروجی، نواحی هستند که شیء از محدوده‌ی دید دوربین خارج می‌گردد. در اکثر محیطها نواحی ورودی و خروجی در هر دوربین یکسان هستند یعنی در همه‌ی آن‌ها امکان ورود و خروج اشیاء وجود دارد. به این نواحی که هم ناحیه‌ی ورودی هستند و هم خروجی، نواحی ورودی/خروجی می‌گویند. T_{in} زمان ورود شیء به محدوده‌ی دید دوربین c_i و T_{out} زمان خروج شیء از محدوده‌ی

دید این دوربین می‌باشد.

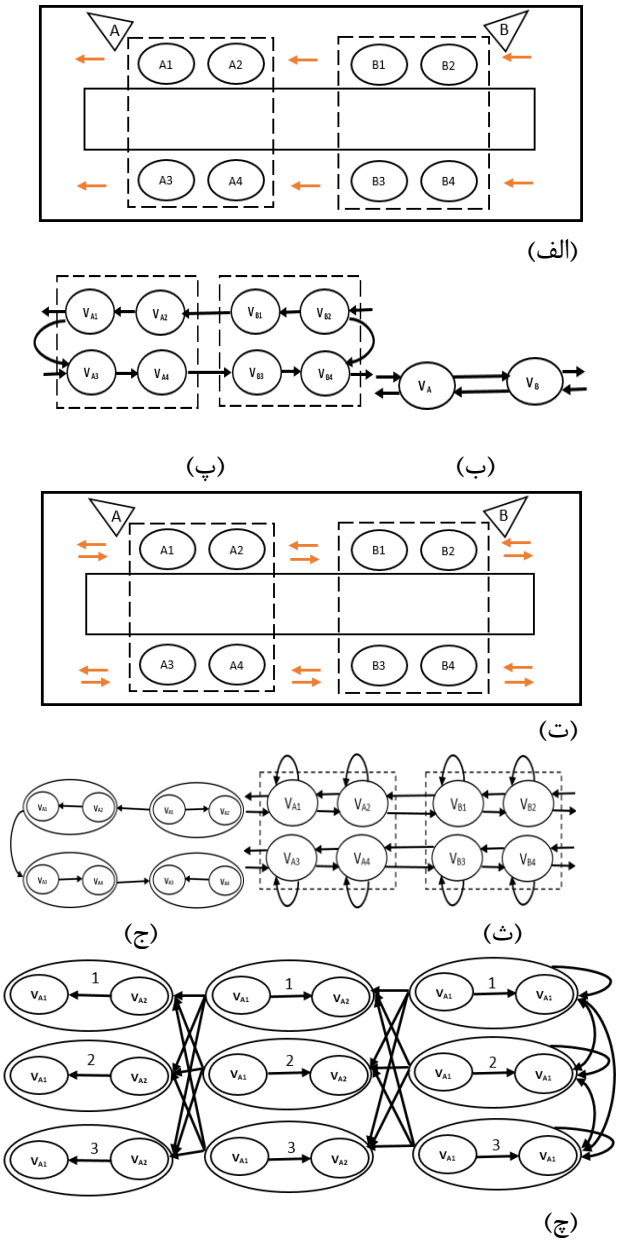
۳-۲- تخمین توپولوژی

در این مقاله گراف فعالیت بین دوربین‌ها به صورت دستی استخراج شده است. گراف فعالیت رفتار اشیاء در شبکه‌ای از دوربین‌ها را توصیف می‌کند. این گراف علاوه‌بر نحوه‌ی اتصال دوربین‌ها، مسیرهایی که اشیاء می‌توانند حرکت کنند را نیز نشان می‌دهد. یال‌های گراف، انتقال بین دوربین‌ها را نشان می‌دهد. وزن هر یال احتمال انتقال از یک دوربین به دوربین دیگر را نشان می‌دهد. مسیر طی شده توسط یک شیء به صورت فرآیند مارکفی مرتبه اول در نظر گرفته می‌شود، یعنی مکان آینده‌ی شیء تنها به محل جاری آن شیء بستگی دارد.

مدل گرافی ممکن است در توصیف حرکت اشیاء باعث به وجود آمدن حالت‌های نامطلوب شود، بخصوص زمانی که گراف شامل حلقه باشد. ساده‌ترین نوع گراف فعالیت، گرافی است که گره‌های آن دوربین‌ها هستند. برای مثال در شکل ۲- الف دوربین‌های A و B در یک راهرو قرار گرفته‌اند. مسیرهای مجاز در محیط با فلش نشان داده شده‌است. شکل ۲-ب گراف فعالیت (نوع اول) مربوط به این محیط را نشان می‌دهد. در این گراف، گره‌ها دوربین‌های A و B هستند. همانطور که گفته شده حرکت‌های مجاز با فلش نشان داده شده است و حرکتی مشابه دور زدن نداریم؛ اما گراف فعالیت شکل ۲-ب منجربه بروز ابهام شده است زیرا دور زدن را در گراف فعالیت مدل کرده است. دلیل بروز این مسئله این است که این گراف فعالیت نمی‌تواند طور کامل الگوی حرکتی دورزدن را از دیگر الگوها جداکند.

برای حل این مشکل این می‌توان مشابه مقاله‌ی [۱۶] عمل کرد به این صورت که از نواحی ورودی و خروجی دوربین‌ها به جای خود دوربین‌ها به عنوان‌های گره‌های گراف فعالیت استفاده کنیم. همانطور که در شکل ۲-الف دیده می‌شود، برای هر دوربین دو ناحیه‌ی ورودی و دو ناحیه‌ی خروجی مشخص شده است. با استفاده از این نواحی گراف فعالیت شکل ۲-پ (نوع دوم) را برای شکل ۲-الف طراحی می‌کنیم. اگرچه با این گراف فعالیت توانستیم دورزدن را از دیگر الگوهای حرکتی جدا کنیم اما این کار همیشه امکان‌پذیر نیست. زمانی که در یک محیط نواحی ورودی نواحی خروجی نیز هستند، یعنی محیط دارای نواحی ورودی/خروجی است، این گراف فعالیت دچار مشکل می‌شود. در شکل ۲-ت سامانه‌ی نظارتی چند دوربینی برای ردگیری اهداف متحرک در یک راهرو نشان داده شده است. همانطور که مشاهده می‌شود این سامانه مشابه سامانه‌ی شکل ۲-الف است با این تفاوت که در راهروها حرکت در هر دو جهت نیز جریان دارد شکل ۲-ث گراف فعالیت طراحی شده با استفاده از نواحی ورود/خروج را برای این سامانه نشان می‌دهد. همانطور که در این شکل دیده می‌شود، اگرچه این گراف می‌تواند حرکت دورزدن بین راهروها را از دیگر مدل‌های حرکتی جدا کند، اما نمی‌تواند دورزدن در یک راهرو را از دیگر الگوهای حرکت جدا نماید.

برای حل مشکل گراف فعالیت قبل گراف فعالیت پیشنهاد شده در مقاله‌ی [۵] معرفی می‌شود. این گراف مجموعه‌ای از ابرگره‌ها تشکیل شده است. هر ابرگره زوج مرتبی از نواحی ورود/خروج است. همانطور که مشاهده می‌شود، در شکل ۲-ت هر دوربین شامل چهار ناحیه‌ی ورود/خروج است. مسیر ورودی به صورت زوج مرتب‌هایی مثل (z_{A1}, z_{A2})، (z_{A2}, z_{A1}) و ... می‌باشد. بخش‌هایی از این گراف در شکل ۲-ج (نوع سوم) نشان داده شده است. برخلاف شکل ۲-ث این گراف می‌تواند علاوه‌بر دورزدن بین راهروها، دورزدن در یک راهرو را نیز از الگوهای حرکتی دیگر جدا کند. اگرچه این گراف فعالیت نسبت به گراف‌های دیگر کامل‌تر است اما این گراف توانایی جدا کردن الگوهای حرکت مانند دویدن و قدم زدن را ندارد. در این مقاله با استفاده از اطلاعات سرعت حرکت اشیاء در محیط می‌توان بین الگوهای حرکت مانند دویدن، قدم زدن و راه‌رفتن تمایز قائل شد. به علت اینکه استخراج اطلاعات مربوط به سرعت حرکت اشیاء چالش‌برانگیز است، می‌توان از طول مسیر تک دوربینی بجای سرعت استفاده کرد. طول مسیر تک دوربینی تعداد فریم‌هایی است که یک شیء ردگیری شده‌است. این گراف مشابه گراف فعالیت شکل ۲-ج است با این تفاوت که اطلاعات مربوط به طول مسیر تک دوربینی را نیز در نظر می‌گیرد. شکل ۲-چ قسمتی از گراف فعالیت پیشنهادی برای شکل ۲-ت را نشان می‌دهد. اعداد نوشته شده برروی یال‌های داخل ابرگره، مرتبه‌ی نسبت داده شده به طول مسیر تک دوربینی است. به این صورت که بازه‌های مربوط به طول مسیرهای تک دوربینی در هر دوربین را به سه قسمت تقسیم می‌کنیم. اهدافی که طول مسیر تک دوربینی آن‌ها در بازه‌ی اول باشد در مرتبه‌ی ۱، اگر در بازه‌ی دوم باشد، در مرتبه‌ی ۲ و اگر در بازه‌ی سوم باشد در مرتبه‌ی ۳ قرار می‌گیرد. همانطور که مشاهده می‌شود این گراف می‌تواند بین الگوهای حرکتی با طول‌های مختلف تمایز قائل شود. برای مثال می‌تواند دویدن و قدم زدن آهسته را از هم جدا کند زیرا طول مسیر تک‌دوربینی دویدن از قدم‌زدن کمتر است.



شکل ۲: شکل-الف مثالی از سامانه‌ی نظارتی، شکل-ب و شکل-ت گراف‌های فعالیت نوع اول و دوم برای شکل-الف. شکل-ت مثالی از سامانه‌ی نظارتی، شکل-ث، شکل-ج و شکل-چ گراف‌های فعالیت نوع دوم، سوم و پیشنهادی برای شکل-ت.

۱-۱-۱- ترکیب اطلاعات

هدف گام ترکیب اطلاعات این است که ویژگی‌های ظاهری شیء را با گراف فعالیت ترکیب کنیم. برای ترکیب اطلاعات روش‌های مختلفی وجود دارد. مشابه مقاله‌ی [۴] و [۵] ما نیز ازروش استنتاج بیز برای ترکیب اطلاعات استفاده می‌کنیم.

فرض کنید که یک دوربین شامل N ناحیه‌ی ورود و خروج است، مجموعه راس‌های گراف فعالیت را با مجموعه‌ی $V=\{\upsilon_m; m=1,...,M\}$ نشان می‌دهیم. علاوه بر گره‌های فوق، دو گره‌ی منبع υ_s و مقصد υ_e را نیز تعریف می‌کنیم، این دو گره از نظر مفهومی یکسان هستند یعنی هر دو ناحیه‌ی خارج از منطقه‌ی پوشش داده شده توسط دوربین‌ها را نشان می‌دهد؛ اما با بیان جداگانه‌ی این دو گره می‌توانیم، بگوییم که مسیرهای جدید در گره‌ی منبع تولید شده و در گره‌ی مقصد تمام می‌شوند؛ به ازای ردگیری هر شیء متحرک در یک دوربین بردار ویژگی $Z(X_{in},X_{out},T_{in},T_{out})$ استخراج می‌شود. X_{in},X_{out} در واقع گره‌های گراف فعالیت هستند. با توجه به اینکه از چه گراف فعالیتی استفاده کنیم، مقادیر مختلفی خواهد گرفت.

فرض کنید Ω، مجموعه‌ی تمام جواب‌های ممکن برای مسئله است. هر عضو این مجموعه یک افراز برروی تمام مسیرهای تک دوربینی است. فرض کنید ω_K عضوی از این مجموعه است که مسیرهای تک دوربینی را به K زیرمجموعه‌ی جدا از هم افراز می‌کند. ω_K را به صورت زیر تعریف می‌شود:

$$\omega_K=\{T_k; k=1,...,K\}$$

که در آن T_k مسیرهای مربوط به شیء k ام می‌باشد. برای حل مسئله ردگیری در چند دوربین باید بیشنه مقدار تابع احتمال شرطی $P(\omega|O)$ را محاسبه کنیم. O مسیرهای تک دوربینی است و ω یک افراز پیشنهادی برروی مسیرهای تک-دوربینی است. هدف ما این است که ωای پیدا کنیم که احتمال $P(\omega|O)$ را حداکثر کنند. طبق قاعده‌ی بیز در احتمال می-دانیم که:

$$P(\omega|O)\propto P(\omega)P(O|\omega)$$

فرض می‌کنیم مسیرهای طی شده مستقل از هم است، با این فرض $P(O|\omega_K)$ را می‌توان به صورت زیر نوشت:

$$P(O|\omega_K\in\Omega)=\prod_{k=1}^{K}P(O_k|T_k)$$

فرضیه‌ی T_k بیان می‌کند که مشاهدات O_k مربوط به یک شخص یکسان است. پس احتمال $P(O_k|T_k)$ برابر است با:

$$P(O_k|T_k)=P(o_{k,1})\prod_{i=2}^{N_k}P(o_{k,i}|o_{k,i-1})=$$

$$P(t_{in_{k,1}}|x_{in_{k,1}})\prod_{i=2}^{N_k}P(t_{in_{k,i}}|t_{out_{k,i-1}},x_{in_{k,i}},x_{out_{k,i-1}})$$

N_k تعداد اعضای موجود در مجموعه‌ی T_k می‌باشد.

$$P(\omega_K)=\prod_{k=1}^{K}P(T_k)$$

$$P(T_k) = P(\upsilon_{k,s})P(x_{k,1} \mid \upsilon_{k,s}) \times \prod_{i=2}^{N_k} P(x_{k,i} \mid x_{k,i-1})P(\upsilon_e \mid x_{k,N_k})$$

احتمال $P(\upsilon_s)$ برابر ۱ در نظر گرفته می‌شود. با ترکیب احتمالات بالا به معادله‌ی زیر خواهیم رسید.

$$P(\omega \mid O) \propto \prod_{k=1}^{K} (P\left(t_{in_{k,1}} \mid x_{out_{k,1}}\right) \times P\left(x_{out_{k,1}} \mid \upsilon_s\right) \times P\left(\upsilon_e \mid x_{in_{k,N_k}}\right) \times \prod_{i=2}^{N_k} (P\left(x_{in_{k,i}} \mid x_{out_{k,i-1}}\right) \times P\left(t_{in_{k,i}} \mid t_{out_{k,i-1}}, x_{in_{k,i}}, x_{out_{k,i-1}}\right)))$$

در این مقاله مشابه [۵] از زنجیره‌ی مارکو مونت کارلو برای یافتن پاسخ مناسب استفاده می‌شود. زنجیره‌ی مارکو مونت کارلو یک روش نمونه‌برداری خوب برای یافتن راه‌حل برای توزیع‌های پیچیده است. برای تولید زنجیره‌ی مارکوی از الگوریتم متروپلیس-هستینگ استفاده می‌شود، این الگوریتم یک انتقال از ω به ω' با توزیع پیشنهادی $q(\omega' \mid \omega)$ می‌سازد. انتقال با احتمال α پذیرفته می‌شود.

$$\alpha = \min(1, \frac{\pi(\omega')q(\omega \mid \omega')}{\pi(\omega)q(\omega' \mid \omega)})$$

$\pi(\omega)$ توزیع پسین فرمول (۱) می‌باشد. q شامل سه حرکت، بروزرسانی، ادغام و تقسیم می‌باشد. فرض کنید ω حالت کنونی باشد. K تعداد زیرمجموعه‌ها در افراز ω است. O_k، k امین زیرمجموعه در ω است. N_k، تعداد مشاهدات تخصیص داده شده به O_k است. $o_{k,i}$، i امین مشاهده‌ی زیرمجموعه‌ی O_k و $t_{k,i}$ زمان مشاهده‌ی $o_{k,i}$ است. فرض کنید مسیرهای تک‌دوربینی در یک زیرمجموعه از نظر زمانی همپوشانی ندارد همچنین براساس زمان مرتب شده‌اند. در حرکت بروزرسانی زیر مجموعه‌ی O_{s1} با احتمال تصادفی یکنواخت از $\{O_k; k = 1,...,K\}$ و O_{s2} از $\{O_k; k = 1,...,K, k \neq s1\} \cup \{O_{K+1} = \phi\}$ انتخاب می‌شود. سپس $o_{s1,r}$ به صورت تصادفی یکنواخت از $\{o_{s1,i}; i = 1,...,N_{s1}\}$ انتخاب و به زیرمجموعه‌ی O_{s2} تخصیص داده می‌شود. زیرمجموعه‌های جدید تولید شده را O'_{s1} و O'_{s2} می‌نامیم. اگر $N_{s1} = 1$ و $N_{s2} = 0$ حرکت رد می‌شود. در غیر اینصورت حرکت با احتمال زیر پذیرفته می‌شود:

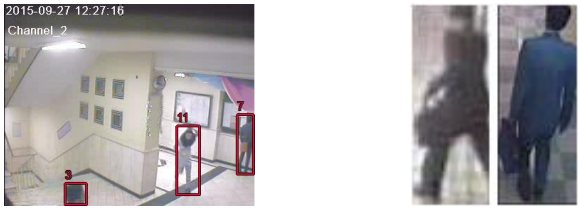
$$\alpha = \min(1, \frac{P(T'_{s1} \mid O'_{s1})P(T'_{s2} \mid O'_{s2})}{P(T_{s1} \mid O_{s1})P(T_{s2} \mid O_{s2})})$$

برای تقسیم، به صورت تصادفی یکنواخت O_s را از $\{O_k; k = 1,...,K \ and \ N_s > 2\}$ و r را از $\{1,...,N_s - 1\}$ انتخاب کرده و به دو زیر مجموعه‌ی $O_{s1} = \{o_{s1,i}; i = 1,...r\}$ و $O_{s2} = \{o_{s2,i}; i = r+1,...N_s\}$ تقسیم می‌کنیم. این حرکت نیز با احتمال α پذیرفته می‌شود.

برای حرکت ترکیب O_{s1} و O_{s2} را به صورت تصادفی از $\{O_k; k = 1,...,K\}$ انتخاب می‌کنیم به طوری که $t_{s1,N_{s1}} < t_{s2,1}$ یا $t_{s2,N_{s2}} < t_{s1,1}$ و زیرمجوعه‌ی جدید را به صورت $O'_s = O_{s1} \cup O_{s2}$ تعریف می‌کنیم این زیرمجموعه با احتمال α پذیرفته می‌شود.

۳-۳- نتایج تجربی

سامانه‌ی ردگیری مورد استفاده برای ارزیابی روش پیشنهادی شامل سیزده دوربین تنظیم نشده و ناهمپوشان است، این دوربین‌ها در پنج طبقه تعبیه شده‌اند. ویدئوهای ضبط شده مربوط به یازده دقیقه از شلوغ‌ترین بازه‌های زمانی است. در بازه‌ی زمانی مورد نظر ۵۹۹ مسیر تک دوربینی (عبور یک فرد از جلوی یک دوربین) وجود دارد که متعلق به ۱۸۳ شیء متمایز (مسیر چند دوربینی) بوده‌اند. ویدئوهای ضبط شده بسیار چالش‌برانگیزند. از جمله‌ی این چالش‌ها عبارتند از: حالت خواب‌رفتگی (Sleep) ویدئوها، تغییرات رنگ و شدت روشنایی بین دوربین‌ها، تنوع زیاد الگوهای حرکتی در محیط، تعداد زیاد اهداف متحرک در یک دوربین و عدم دسترسی به پارامترهای دوربین مانند ارتفاع. در شکل ۳-الف مثالی از تغییرات شدت روشنایی و در شکل ۳-ب نمونه‌ای از تنوع الگوهای حرکتی دیده می‌شود. در این شکل فرد شماره‌ی ۱۱ در حال دویدن و فرد شماره‌ی ۷ در حال خواندن برد دانشکده است و مدت زمان زیادی همانجا می‌ایستد و یا به آرامی جابه‌جا می‌شود.



(ب) (الف)

شکل ۳: نمونه‌ای از چالش‌های سامانه‌ی تحت نظارت

در این مقاله به منظور یافتن مسیرهای چنددوربینی ابتدا در هر دوربین ردگیری تک دوربینی انجام می‌شود، سپس با استفاده از مدل بیز اطلاعات مسیرهای تک دوربینی و گراف فعالیت ترکیب شده و با استفاده از زنجیره‌ی مارکوی مونت کارلو استنتاج انجام می‌گردد. جدول ۱ نتایج بدست آمده در آخرین گام اجرای الگوریتم را نشان می‌دهد. تعداد زیرمجموعه‌های

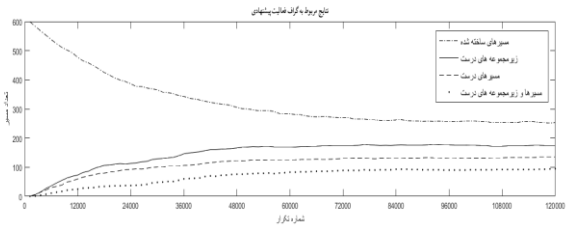
درست مربوط به تعداد مسیرهای چنددوربینی که تمام مسیرهای تک‌دوربینی آن مربوط به یک شخص هستند. تعداد مسیرهای درست، تعداد مسیرهای چنددوربینی را نشان می‌دهد که الزاما تمام مسیرهای تک‌دوربینی مربوط به یک شخص نیستند اما مسیر طی شده یک مسیر چندوربینی درست در محیط است که توسط داده‌های تست طی شده است.

همانطور که در جدول ۱ مشاهده می‌شود، الگوریتم پیشنهادی توانسته است بیش‌ترین تعداد زیرمجموعه‌های درست و مسیرهای درست را نسبت به روش‌های پیشین، پیدا کند.

جدول ۱- نتایج مربوط به انوع گراف فعالیت

نوع گراف فعالیت	مسیرهای ساخته شده	زیرمجموعه های درست	مسیرهای درست	مسیر و زیرمجموعه های درست
۱	۵۰۶	۳۰	۱۶	۵
۲	۲۶۱	۱۳۶	۱۳۰	۷۴
۳	۲۵۰	۱۴۹	۱۳۲	۸۳
پیشنهادی	۲۵۴	**۱۷۴**	**۱۳۵**	**۹۵**

گام‌های تکرار الگوریتم زنجیره‌ی مارکو مونت کارلو یک میلیون و دویست هزار بار در نظر گرفته شده است. شکل ۴ نتایج مربوط به اجرای این الگوریتم، برای گراف فعالیت پیشنهادی را نشان می‌دهد. خط نقطه تعداد مسیرهای ساخته شده، خط پیوسته تعداد زیرمجموعه‌های ساخته شده، خط چین تعداد مسیرهای درست و نقطه چین تعداد مسیر و زیرمجموعه‌های درست استنتاج شده را نشان می‌دهد.



شکل ۴- نتایج مربوط به اجرای زنجیره‌ی مارکو مونت کارلو به ازای گراف‌های فعالیت مختلف

۴- نتیجه‌گیری

در این مقاله گراف فعالیت جدیدی برای ردگیری تعداد نامشخصی از اهداف متحرک در سامانه‌ای از دوربین‌های ناهمپوشان معرفی کردیم. در گراف فعالیت پیشنهادی با در نظر گرفتن اطلاعات مربوط به سرعت حرکت اهداف توانستم توانایی گراف فعالیت در جداسازی الگوهای حرکت را افزایش دهیم. به منظور یافتن پاسخ مناسب از زنجیره‌ی مارکو مونت کارلو استفاده کردیم. ارزیابی مسئله با استفاده از سیزده دوربین ناهمپوشان انجام شد، نتایج نشان می‌داد که روش پیشنهادی عملکرد بهتری نسبت به روش‌های پیشین دارد.

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ارائه یک الگوریتم جفت‌دسته‌ای برای بهینه‌سازی مسائل ایستای Multimodal بر اساس الگوریتم PSO

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چکیده – بهینه‌سازی یکی از مهمترین مسائل در حوزه‌ی مهندسی، صنعت و اقتصاد می‌باشد. یکی از راه‌حل‌های حل مسائل بهینه‌سازی پیچیده که دارای پارامترهای زیادی هستند، استفاده از الگوریتم‌های هوش جمعی می‌باشد. اخیراً توجه خاصی به حل مسائل بیهنه‌سازی شده است. مسائل بهینه‌سازی دارای چالش‌های مختلفی هستند که باعث شده تا کنون روش‌های متعددی توسط محققان برای رفع آن‌ها ارائه شود. در این مقاله، الگوریتم جدید *Bi-swarmPSO* برای بهینه‌سازی در محیط‌های ایستای *multimodal* بر پایه‌ی الگوریتم بهینه‌سازی دسته ذرات پیشنهاد شده است. در الگوریتم پیشنهادی از مکانیزم جفت‌دسته‌ای برای پوشش فضای مسئله استفاده شده است. همچنین در روش پیشنهادی یک مکانیزم کنترل دسته‌های جدید برای افزایش کارایی ارائه شده است. هدف اصلی این الگوریتم جلوگیری از افتادن در بهینه‌های محلی و تقسیم وظایف جستجوی سراسری و محلی بین دو دسته از ذرات می‌باشد. کارایی الگوریتم پیشنهادی بر روی بنچمارک های متعدد و با کارایی چندین الگوریتم شناخته شده‌ی دیگر در این زمینه مقایسه گردیده است. نتایج آزمایشات نشان دهنده‌ی برتری و کارایی بالای الگوریتم پیشنهادی می‌باشد.

کلید واژه- بهینه سازی دستهٔ ذرات، چنددستگی، مسائل بهینه سازی ایستا، هوش جمعی.

۱- مقدمه

بهینه‌سازی یکی از مهمترین مسائل موجود در اقتصاد، صنعت و مهندسی بشمار می‌رود و به نوعی قلب بسیاری از فرآیندهایی است که در طبیعت رخ می‌دهند. در واقع در تمام مسائل بهینه سازی ما به دنبال رسیدن به بهترین نتیجه با صرف کمترین هزینه هستیم. به طور معمول برای حل مسائل بهینه سازی، ابتدا یک تابع هزینه طراحی می‌شود، سپس با استفاده از روش های ریاضی و یا روش‌های هوشمند مقادیر این تابع به گونه ای تنظیم می شوند که مقدار تابع هزینه کمینه یا بیشینه (بسته به نوع مسئله) شود. هنگامی که پیچیدگی مسائل بهینه سازی زیاد باشد، استفاده از روش‌های ریاضی بسیار بسیار سخت و یا حتی غیرممکن می شود. برای چنین مسائلی از روش‌های هوشمند برگرفته شده از طبیعت استفاده می‌شود.

بطور کلی استفاده از هوش جمعی یکی از موضوعات مورد تحقیق در سال‌های اخیر می‌باشد. الگوریتم‌های علامت محور و تقلید محور بسیاری معرفی شدند. الگوریتم بهینه‌سازی دسته ذرات (PSO) یکی از معروف‌ترین روش‌ها به حساب می‌آید که در روش پیشنهادی این مقاله مورد استفاده قرار گرفته است. از دیگر الگوریتم‌های هوش جمعی می‌توان به الگوریتم‌های دسته ماهی‌های مصنوعی و کلونی زنبور عسل و غیره اشاره نمود که در بسیاری از کاربردهای جدید مورد استفاده قرار می‌گیرند[4-1].

در این مقاله یک الگوریتم جدید برای بهینه‌سازی در محیط‌های ایستا ارائه می‌شود. هدف اصلی الگوریتم پیشنهادی بهینه‌سازی در محیط‌های ایستای Multimodal می‌باشد. الگوریتم پیشنهاد شده در این مقاله بر اساس الگوریتم PSO طراحی شده است. الگوریتم پیشنهادی بر روی بنچمارک‌های متعدد و با کارایی چندین الگوریتم شناخته شده‌ی دیگر در این زمینه مقایسه گردیده است. در بخش ۲، به مروری بر الگوریتم بهینه‌سازی دسته ذرات (PSO) می‌پردازیم. در بخش ۳ الگوریتم پیشنهادی معرفی می‌شود. در بخش ۴ آزمایشات و نتایج حاصل از پیاده‌سازی ارائه می‌گردد. نتیجه گیری در بخش ۵ ارائه می‌شود.

۲- مروری بر الگوریتم PSO

روش PSO، یک تکنیک بهینه‌سازی مبتنی بر قوانین احتمال است که ایده اولیه آن توسط دکتر راسل ابرهارت دانشمند علوم کامپیوتری ودکتر جیمزکندی روانشناس مسائل اجتماعی در سال ۱۹۹۵ معرفی شد[5] .

هر ذره به صورت چند بعدی (بسته به طبیعت مسئله) با دو مقدار X_{id} , V_{id} که به ترتیب معرف مکان و سرعت مربوط به بعد dام از iامین ذره هستند تعریف می‌شود. در هر مرحله از حرکت جمعیت، هر ذره با توجه به دو مقدار بهترین به روز می‌شود.

اولین مقدار بهترین جواب از لحاظ شایستگی است که تا کنون برای هر ذره به طور جداگانه به دست آمده است. این مقدار بهترین فردی است و pbest نامیده می‌شود. مقدار بهترین دیگر که توسطPSO به دست می‌آید، بهترین مقداریست که تاکنون توسط تمام ذره ها در میان جمعیت به دست آمده است این مقدار بهترین کلی است و gbest نام دارد. پس از یافتن دو مقدار pbest , gbest هر ذره سرعت و مکان جدید خود را با دو رابطه زیر به روز می کند:

$$X_i(t+1) = X_i(t) + V_i(t+1) \quad (1)$$

$$V_{ij}(t+1) = w(V_{i,j}(t)+c_1r_{1,j}(t)[pbest_{i,j} - X_{i,j}(t)] + c_2r_{2,j}(t)[gbest_i(t)-X_{i,j}(t)]) \quad (2)$$

به طوری که wوزن اینرسی c_2 , c_1 ضرایب شتاب و r_2 , r_1 اعداد تصادفی در بازه (۱و۰) می‌باشند. برای جلوگیری از واگرایی الگوریتم، مقدار نهایی سرعت هر ذره در بازه $[-V_{MAX} , V_{MAX}]$ محدود می‌شود. c_2, c_1, w از پارامترهای PSO هستند و همگرایی الگوریتم وابسته به مقدار این پارامترهاست. معمولاً بهترین انتخاب $c_1 = c_2 =$ ۲/۰۵ می باشد [6]، [7] و $0 \leq w \leq 1$ انتخاب می‌شود[6][7]. همگرایی شدیداً به مقدار w وابسته است و بهتر است به صورت داینامیک تعریف شود. در بازه(۰/۹-۰/۲) بدین ترتیب که به صورت خطی در طی روند تکامل جمعیت کاهش می‌یابد. در ابتدا باید بزرگ باشد تا امکان یافتن جوابهای خوب در همان مراحل اولیه فراهم شود و در مراحل پایانی کوچک بودن w، همگرایی بهتری را سبب می‌شود[7].

۳- روش پیشنهادی

هدف اصلی BSPSO جلوگیری از افتادن در بهینه‌های محلی و تقسیم وظایف جستجوی سراسری و محلی بین دو دسته از ذرات می‌باشد. در ابتدای اجرای الگوریتم یک دسته از ذرات که آن را دسته مادر می‌نامیم وجود دارد که وظیفه آن انجام جستجوی سراسری می‌باشد. در ابتدای الگوریتم، ذرات دسته مادر به صورت تصادفی در فضای مسئله تعیین موقعیت می‌گردند. نحوه حرکت این ذرات در فضای مسئله بر اساس الگوریتم PSO با همسایگی Global Star و وزن اینرسی با روش کاهشی خطی می‌باشد. دسته مادر جستجو را تا جایی که همگرا شود ادامه می‌دهد. برای تعیین همگرایی دسته مادر ابتدا فاصله اقلیدسی موقعیت تمامی ذرات دسته با یکدیگر محسابه می‌گردد، پس از آن در صورتی که دورترین فاصله کوچکتر از پارامتر شعاع همگرایی (r_{conv}) باشد، دسته مادر همگرا شده در نظر گرفته می‌شود. مقدار r_{conv} برای مسائل مختلف با ابعاد متفاوت و همچنین بازه های فضای جستجو متفاوت خواهد بود. برای الگوریتم پیشنهادی، مقدار این پارامتر بر اساس رابطه (۳) محاسبه می گردد:

$$r\text{-}conv=\alpha\times(UpperBound-LowerBound)\times logD \quad (3)$$

که در آن α برابر با یک ضریب ثابت مثبت کوچکتر از یک است، D برابر با یک ضریب ثابت مثبت کوچکتر از یک است و UpperBound-LowerBound طول فضای جستجو را در هر بعد نشان می دهد.

پس از اینکه دسته مادر همگرا شد، دسته فرزندی را در مکان همگرا شده ایجاد می‌کند. دسته فرزند از جمعیت کمتری نسبت به دسته مادر برخوردار است زیرا برای جستجوی سراسری، ذرات بیشتری مورد نیاز است. برای ایجاد دسته فرزند و با توجه به کمتر بودن اندازه جمعیت این دسته، ابتدا ذرات دسته مادر بر اساس کیفیت مقدار بهترین تجربه شخصی مرتب می‌شوند و دسته فرزند با کپی کردن اطلاعات بهترین ذرات دسته مادر ایجاد می‌گردند که این اطلاعات شامل، موقعیت ذرات، سرعت، بهترین تجربه شخصی و بهترین تجربه گروهی می‌باشد. پس از ایجاد دسته فرزند، دسته مادر تنظیم مجدد می‌شود تا به دنبال موقعیت های بهتر باشد و دسته فرزند ادامه جستجو را در محلی که ایجاد شده انجام می‌دهد.

دسته‌های فرزند نیز برای انجام جستجوی محلی از روال الگوریتم PSO با همسایگی ستاره سراسری و همچنین وزن اینرسی کاهشی خطی استفاده می‌کنند. در ادامه فرآیند جستجو، دسته مادر جستجوی سراسری را ادامه داده و دسته فرزند جستجوی محلی را در دستور کار خود قرار می‌دهد. در واقع دسته فرزند با توجه به کاهش تنوع در دسته، توانایی خروج از منطقه‌ای که در آن ایجاد شده را ندارد اما دسته مادر با تنظیم مجدد شدن مجددا دارای گستره وسیع یا همان تنوع بالا می‌گردد. هر بار که پس از این دسته مادر همگرا شود، مقدار بهترین تجربه گروهی آن با فرزندش مقایسه می‌گردد، در صورتی که مقدار بهترین تجربه گروهی در دسته فرزند بیشتر باشد، دسته مادر تنظیم مجدد می‌گردد و در صورتی که مقدار موجود در دسته مادر بهتر باشد، دسته فرزند قبلی نابود و دسته فرزند جدیدی در مکان جدیدی که مادر به آن همگرا شده ایجاد میگردد. بدین ترتیب مادر با انجام جستجوی‌های سراسری مختلف شانس خود را برای یافتن موقعیت‌های بهتر امتحان می‌کند در حالی که دسته فرزند جستجوی محلی را در بهترین موقعیت یا قله یافت شده ادامه می‌دهد. شبه کد الگوریتم BSPSO در محیط‌های ایستا در شکل 1 معرفی می‌شود.

```
Bi-Swarm PSO
1:    Initialize Mother Swarm
2:    Repeat
3:        Execute PSO procedure for Mother Swarm
4:        If Mother Swarm converged Then
5             If there is no child swarm Then
6                 create child swarm
7                 Re-initialize Mother swarm
8             Else if Gbest of Mother swarm  is better than of child swarm Then
9                 Remove previous Child swarm
10                create new child swarm
11                Re-initialize Mother swarm
12            Else
13                Re-initialize Mother swarm
14        Execute PSO procedure for Child Swarm
15    Until number of performed function evaluations == max
```

شکل 1: شبه کد الگوریتم پیشنهادی برای محیط‌های ایستا

4- آزمایشات

نتایج الگوریتم‌های پیشنهادی BSPSO به همراه پنج الگوریتم شناخته شده‌ی دیگر به نام‌های نسخه بهبود یافته الگوریتم دسته ماهی‌های مصنوعی (CM-AFSA) [8]، GPSO[9] ، LPSO [10] ، نسخه تغییر یافته الگوریتم کلونی زنبورهای مصنوعی (M-ABC) [11]، ، و نسخه بهبود یافته الگوریتم رقابت استعماری (I-ICA) [12] بر روی تابع استاندارد Multimodal و دو تابع Unimodal صورت گرفته است که معمولاً به عنوان معیار سنجش الگوریتم‌های بهینه‌سازی در فضاهایی پیوسته و ایستا مورد استفاده قرار می‌گیرند.

جدول ۱ مشخصات توابع بنچمارک معروف استفاده شده در این مقاله را نشان می‌دهد. مقادیر پارامترهای الگوریتم‌های تست شده به همراه الگوریتم پیشنهادی در جدول ۲ آورده شده است. مقادیر مشخص شده برای الگوریتم پیشنهادی بر اساس آزمایشات بسیار زیادی که بر روی توابع بنچمارک مختلف صورت گرفته تعیین شده است و تنظیم پارامترها به مقادیر دیگر، افت کارایی را به همراه خواهد داشت. در آزمایشات، شرط خاتمه فرآیند بهینه سازی، رسیدن به ۲۰۰۰۰۰ ارزیابی شایستگی در نظر گرفته شده است. آزمایشات ۵۰ بار انجام شده اند و متوسط نتایج بدست آمده از الگوریتم‌ها به همراه انحراف معیار بدست آمده در جدول ۳ نشان داده شده است.

جدول 1: مقادیر پارامترهای الگوریتم‌های تست شده به همراه الگوریتم پیشنهادی

Algorithm	Parameter Setting	Algorithm	Parameter Setting
BSPSO	Mother swarm Population size = 20 Child swarm Population size = 10 α=0.1 c_1=c_2=2 W_{min}=0.4 W_{max}=0.9 neighbor topology=Global star Inertia weight = linear decrement	CM-AFSA	Population size =50 try-number=5 crowd factor=0.75 Visual=Par[1] Step = Visual/5 c_3=c_6=2
G-PSO	Population size =20 c_1=c_2=2 W_{min}=0.4 W_{max}=0.9 neighbor topology=Global star Inertia weight = linear decrement	I-ICA	Country number=200 empire number = 10 revolution rate=0.3 ξ=0.1 β=2
L-PSO	Population size =20 c_1=c_2=2 W_{min}=0.4 W_{max}=0.9 neighbor topology=ring Inertia weight = linear decrement	M-ABC	Population size =40 Modification rate=0.8 Limit = 0.5 ×Dimension ×Population size Scaling factor = 1

جدول ۲: مشخصات توابع بنچمارک معروف

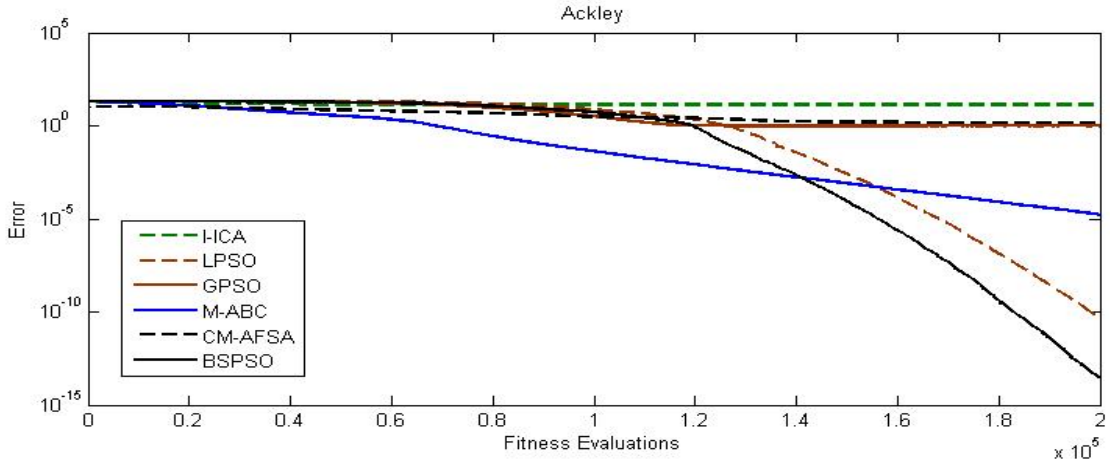
Name	type	Test Function	D	Search range	f_{Min}
Bohachevsky1	M	$f_1(x)=x_1^2+2x_2^2-0.3\cos(3\pi x_1)-0.4\cos(4\pi x_2)+0.7$	2	$[-100,100]^D$	0
Bohachevsky2	M	$f_2(x)=x_1^2+2x_2^2-0.3\cos(3\pi x_1)(4\pi x_2)+0.3$	2	$[-100,100]^D$	0
Bohachevsky3	M	$f_3(x)=x_1^2+2x_2^2-0.3\cos(3\pi x_1+4\pi x_2)+0.3$	2	$[-100,100]^D$	0
Schaffer	M	$f_4(x)=0.5+\frac{\sin^2\left(\sqrt{x_1^2+x_2^2}\right)-0.5}{\left(1+0.001\left(x_1^2+x_2^2\right)\right)^2}$	2	$[-100,100]^D$	0
Butterfly	M	$f_5(x)=\left(x_1^2-x_2^2\right)\sin(x_1+x_2)/\left(x_1^2+x_2^2\right)$	2	$[-10,10]^D$	-1
Six Hump Camel Back	M	$f_6(x)=4x_1^2-2.1x_1^4+\frac{1}{3}x_1^6+x_1x_2-4x_2^2+4x_2^4$	2	$[-5,5]^D$	-1.03163
Ackley	M	$f_7(x)=-20\exp\left(-0.2\sqrt{\frac{1}{D}\sum_{i=1}^{D}x_i^2}\right)-\exp\left(\frac{1}{D}\sum_{i=1}^{D}\cos 2\pi x_i\right)+20+e$	30	$[-32,32]^D$	0
Weierstrass	M	$f_8(x)=\sum_{i=1}^{D}\left(\sum_{k=0}^{k\max}\left(a^k\cos\left(2\pi b^k(x_i+0.5)\right)\right)\right)-D\sum_{k=0}^{k\max}\left(a^k\cos\left(2\pi b^k\times 0.5\right)\right)$ $a=0.5, b=3, k_{\max}=20$	30	$[-0.5,0.5]^D$	0
Griwank	M	$f_9(x)=\frac{1}{4000}\sum_{i=1}^{D}x_i^2-\prod_{i=1}^{D}\cos\left(\frac{x_i}{\sqrt{i}}\right)+1$	30	$[-600,600]^D$	0
Penalized1	M	$f_{10}(x)=\frac{\pi}{D}\left\{10\sin^2(\pi y_1)+\sum_{i=1}^{D-1}(y_i-1)^2\left(1+10\sin^2(\pi y_{i+1})\right)+(y_D-1)^2\right\}$ $+\sum_{i=1}^{D}u(x_i,10,100,4)$ $y_i=1+\frac{1}{4}(x_i+1)$ $u(x_i,a,k,m)=\begin{cases}k(x_i-a)^m, & x_i>a\\ 0, & -a\le x_i\le a\\ k(-x_i-a)^m, & x_i<-a\end{cases}$	30	$[-50,50]^D$	0
Penalized2	M	$f_{11}(x)=0.1\left\{\sin^2(\pi x_1)+\sum_{i=1}^{D-1}(x_i-1)^2\left(1+\sin^2(3\pi x_{i+1})\right)\right.$ $\left.+(x_D-1)^2\left(1+\sin^2(2\pi x_D)\right)\right\}$ $+\sum_{i=1}^{D}u(x_i,5,100,4)$ $u(x_i,a,k,m)=\begin{cases}k(x_i-a)^m, & x_i>a\\ 0, & -a\le x_i\le a\\ k(-x_i-a)^m, & x_i<-a\end{cases}$	30	$[-50,50]^D$	0
Sphere	U	$f_{12}(x)=\sum_{i=1}^{D}x_i^2$	30	$[-100,100]^D$	0
Schwefel 2.21	U	$f_{13}(x)=\max\left(\lvert x_i\rvert, 1\le i\le D\right)$	30	$[-100,100]^D$	0

جدول ۳: متوسط نتایج بدست آمده از الگوریتم‌ها به همراه انحراف معیار بدست آمده

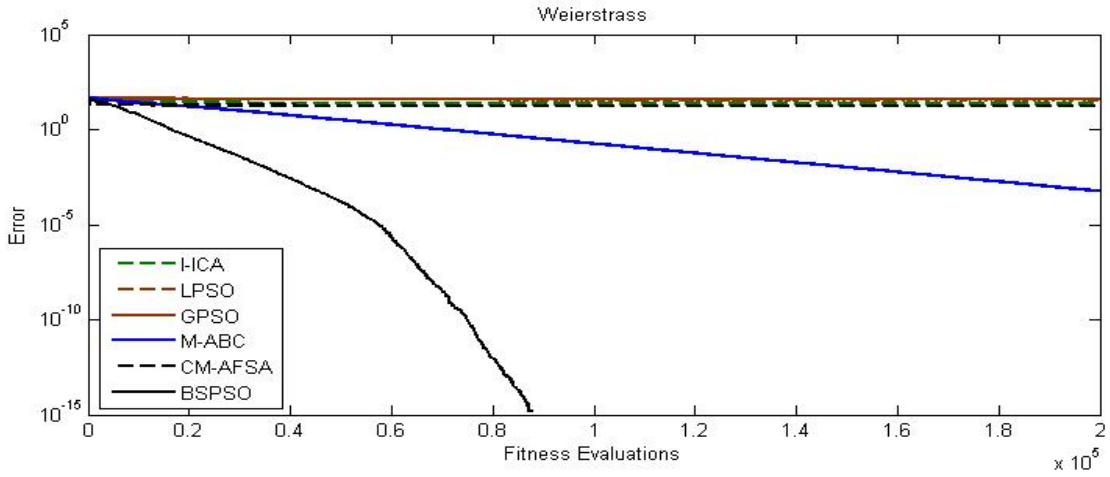
Function	Algorithm					
	G-PSO	L-PSO	I-ICA	M-ABC	CM-AFSA	BSPSO
f_1	**0 (0)**	**0 (0)**	**0 (0)**	**0 (0)**	**0 (0)**	**0 (0)**
f_2	**0 (0)**	**0 (0)**	**0 (0)**	**0 (0)**	**0 (0)**	**0 (0)**
f_3	**0 (0)**	**0 (0)**	**0 (0)**	**0 (0)**	**0 (0)**	**0 (0)**
f_4	**0 (0)**	**0 (0)**	0.003 (0.004)	0.0001 (0.0001)	9.79e-5 (0.0004)	**0 (0)**
f_5	-0.99 (1.219e-09)	-0.99 (6.37e-09)	**-1 (0)**	-0.99 (1.38e-05)	**-1 (0)**	**-1 (0)**
f_6	**-1.0316 (2.24e-16)**	**-1.0316 (2.24e-16)**	**-1.0316 (3.04e-16)**	**-1.0316 (2.24e-16)**	**-1.0316 (2.30e-16)**	**-1.0316 (2.29e-16)**
f_7	0.98 (2.79)	4.72e-11 (1.24e-10)	13.28 (3.74)	1.63e-05 (5.30e-06)	1.49 (0.92)	**2.93e-14 (2.33e-14)**
f_8	35.55 (3.33)	36.00 (2.30)	22.47 (3.51)	0.0005 (0.0001)	16.08 (3.98)	**0 (0)**
f_9	0.05 (0.05)	0.01 (0.01)	0.10 (0.11)	**0.002 (0.006)**	0.07 (0.04)	0.005 (0.003)
f_{10}	0.05 (0.13)	9.40e-17 (3.22e-16)	2.30 (3.38)	2.15e-10 (1.35e-10)	2.73 (1.44)	**2.35e-32 (5.76e-28)**
f_{11}	4.65e-31 (6.29e-31)	5.07e-17 (1.38e-16)	0.13 (0.27)	7.50e-09 (5.16e-09)	0.03 (0.07)	**2.49e-31 (7.56e-31)**
f_{12}	**2.48e-50 (3.82e-51)**	1.33e-20 (3.11e-20)	1.27e-19 (3.06e-19)	1.35e-09 (6.55e-10)	7.19e-08 (4.57e-08)	2.90e-25 (4.49e-25)
f_{13}	**1.63 (1.19)**	9.84 (3.06)	37.06 (7.50)	3.43 (3.44)	3.21 (2.89)	2.41 (1.06)

همانطور که در جدول ۳ مشاهده می‌شود، در سه تابع اول به همراه تابع ۶، تمامی الگوریتم‌های تست شده از جمله الگوریتم پیشنهادی موفق به بهینه‌سازی کامل شده اند (برای تابع ۶، همگی بسیار بسیار نزدیک به نقطه بهینه شده اند) و به نقطه بهینه دست یافته اند. برای تابع ۴، الگویتم های مبتنی بر PSO که شامل الگوریتم پیشنهادی نیز می‌گردد موفق به بهینه‌سازی کامل گردیده‌اند. در توابع ۷ تا۱۱ که همگی دارای محیط‌های Multimodal هستند، الگوریتم پیشنهادی به جز در تابع ۹ به بهترین نتیجه دست یافته است و در تابع ۹ نیز رتبه دوم را در میان الگوریتم‌ها کسب کرده است. دلیل کارایی قابل قبول الگوریتم پیشنهادی در این توابع (خصوصا نسبت به دونسخه دیگر PSO) بهره گیری این الگوریتم از دو دسته مختلف با وظایف جداگانه جستجوی سراسری و جستجوی محلی می‌باشد که این امر باعث برقراری تعادل میان این دو نوع جستجو شده است. همچنین با دادن فرصت‌های چندباره به دسته مادر، الگوریتم شانس بیشتری برای فرار از بهینه‌های محلی که ممکن است در آنها گیر کرده باشد را داراست. در دو تابع Unimodal، الگوریتم پیشنهادی کارایی قابل قبولی نشان داده و در هر دو مورد دومین رتبه را پس از الگوریتم GPSO کسب کرده است. این در حالی است که این الگوریتم برای بهینه‌سازی در محیط‌های Multimodal طراحی شده است. دلیل افت کارایی الگوریتم پیشنهادی نسبت به GPSO، برتری دسته موجود در GPSO به دسته فرزند برای بهینه سازی محلی است زیرا دسته فرزند به سبب مصرف منابع ارزیابی شایستگی توسط دسته مادر، فرصت کمتری را برای انجام جستجوی محلی نسبت به دسته موجود در الگوریتم GPSO دارد.

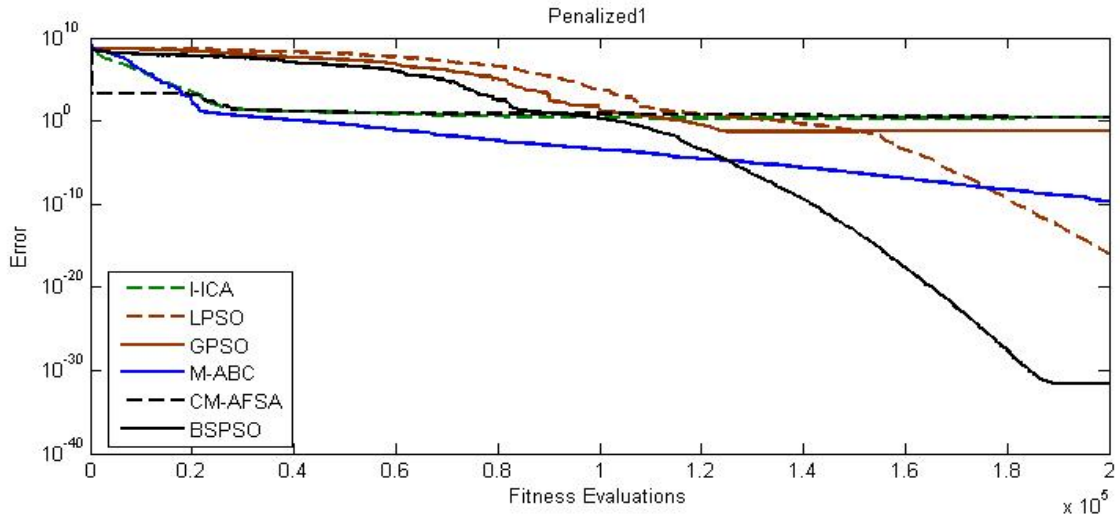
مقایسه‌ی همگرایی الگوریتم پیشنهادی BSPSO با الگوریتم های بهینه سازی بهبود یافته الگوریتم دسته ماهی‌های مصنوعی (CM-AFSA)، نسخه تغییر یافته الگوریتم کلونی زنبورهای مصنوعی (M-ABC)، GPSO، LPSO و نسخه بهبود یافته الگوریتم رقابت استعماری (I-ICA) بر روی سه تابع بنچمارک معروف Akley، Penalized1 و Weierstrassدر شکل های ۲ و۳و ۴ ارائه میشود. نتایج پیاده سازی کارایی بهتر الگوریتم BSPSO در مقایسه با دیگر الگوریتم‌ها را نشان می‌دهد.



شکل : نمودار مقایسه‌ی همگرایی الگوریتم پیشنهادی BSPSO بر روی بنچمارک Akley



شکل : نمودار مقایسه‌ی همگرایی الگوریتم پیشنهادی BSPSO بر روی بنچمارک Weierstrass



شکل : نمودار مقایسه‌ی همگرایی الگوریتم پیشنهادی BSPSO بر روی بنچمارک Penalized 1

۵- نتیجه گیری

در این مقاله الگوریتم جدید BSPSO برای بهینه‌سازی در محیط‌های پویا بر پایه‌ی الگوریتم بهینه‌سازی دسته‌ی ذرات ارائه گردید. در الگوریتم پیشنهادی که به صورت چند دستگی می‌باشد، هر دسته، یک دسته از ذرات می‌باشد که از روند الگوریتم بهینه سازی دسته ذرات تبعیت می‌کنند. در این الگوریتم یک دسته از ذرات به نام دسته‌ی مادر وجود دارد که وظیفه‌ی آن یافتن قله و ایجاد دسته‌هایی به نام دسته فرزند است. بدین ترتیب الگوریتم با قرار دادن دسته‌های فرزند قادر به پوشش دادن بهینه‌های محلی می‌شود. الگوریتم پیشنهادی BSPSO با تعداد زیادی از بنچمارک‌های معروف بهینه‌سازی مورد مقایسه قرار گرفت و نتایج کارایی بالای الگوریتم را نشان می‌دهد. در ادامه این تحقیق، طراحی الگوریتمی برای محیط‌های پویا با پیچیدگیی‌های بالاتر و چالش‌های بیشتر مورد توجه قرار می‌گیرد. برای نزدیک شدن به کاربرد عملی الگویتم‌های بهینه‌سازی پویا باید بتوان با بهبود و تغییر آن‌ها، همچنین افزودن مکانیزم‌های جدید، قابلیت بهینه‌سازی در محیط‌های پیچیده‌تر را به آن‌ها داد.

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ارائه روشی نظارتی جهت ساخت لغت‌نامه احساسی در زبان فارسی

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چکیده - به سبب رشد روز افزون محتویات دیجیتالی در اینترنت و شبکه‌های اجتماعی تجزیه و تحلیل احساسات به عنوان موضوع تحقیقاتی مهم در پردازش زبان طبیعی توجه بسیاری از محققان را به خود جلب کرده است. ساخت و تولید واژگان احساسی به عنوان منبع زبانی ارزشمند، یکی از زمینه‌های مطالعاتی مهم در این حوزه می‌باشد. تاکنون بیشتر تحقیقات صورت گرفته در زمینه تجزیه و تحلیل احساسات در زبان انگلیسی متمرکز شده‌اند و به دلیل فقدان منابع مورد نیاز پژوهش‌های کمی به تجزیه و تحلیل احساسات در زبان فارسی پرداخته‌اند، در این مقاله هدف ارائه روشی با ناظر جهت ایجاد لغت‌نامه احساسی در زبان فارسی است که با استخراج ویژگی‌های زبانی موجود در متن نظرات و معیار وابستگی آماری اطلاعات متقابل، جهت‌گیری احساسی کلمات را مشخص می‌نماید . به منظور ارزیابی روش پیشنهادی، از مجموعه نظرات موجود در سایت خرده‌فروشی آنلاین در دامنه‌های مختلف استفاده شده است و لغت‌نامه ایجاد شده با سنتی وردنت موجود مورد مقایسه قرار گرفته است. نتایج حاکی از دقت ۸۰٪ روش پیشنهادی جهت تعیین گرایش احساسی کلمات است.

کلید واژه- تجزیه و تحلیل احساسات، جهت‌گیری معنایی، رویکرد اطلاعات متقابل نقطه‌ای، لغت‌نامه احساسی

۱- مقدمه

با توسعه سریع فناوری اطلاعات محتویات تولید شده توسط کاربر می‌توانند به آسانی و به صورت آنلاین نوشته شوند و تولید گردند. حجم زیاد و رشد نمایی این اطلاعات، ارزش بالقوه‌ای را برای دولت‌ها، کسب‌وکارها و حتی خود کاربران فراهم می‌نماید. این بررسی‌ها از یک سو توسط وب‌سایت‌های تجارت الکترونیک برای تنظیم استراتژی‌های کسب‌وکار استفاده می‌شوند و از سوی دیگر به عنوان راهنمایی برای مشتریانی هستند که قصد خرید محصولات را دارند. از این رو طراحی ابزارهایی که به‌طور خودکار نظر افراد را از نظرات آنلاین استخراج نمایند در سال‌های اخیر مورد توجه زیادی قرار گرفته است [۱-۳]. به فرایند استخراج نظرات در داخل متن نظرکاوی گفته می‌شود که در تحقیقات مختلف از آن با عناوین دیگری از جمله تجزیه و تحلیل احساسات، تجزیه و تحلیل مقصود، تحلیل ذهنیت و تحلیل نظر نام برده شده است که هدف اصلی آن تعیین گرایش احساسی (مثبت یا منفی و نظری یا حقیقی) بیان شده در نظرات با ترکیب تکنیک‌های متن‌کاوی و پردازش زبان طبیعی است. [۳-۵]

کلمات و عبارات احساسی به عنوان واحدهای زبانی اساسی جهت بیان نظرات هستند به همین منظور ساخت واژگان احساسی نقش بسزایی در تعیین گرایش متن مورد نظر دارند [۶]. با این حال ساخت چنین واژگانی به صورت دستی کاری زمانبر و دشوار است به همین دلیل در سال‌های اخیر محققان دو رویکرد را جهت مقابله با این مسئله پیشنهاد کرده اند: روش مبتنی بر لغت‌نامه و روش مبتنی بر مجموعه [۳, ۶-۸]. روش مبتنی بر لغت‌نامه [۹-۱۲] از روابط معنایی، مترادف‌ها، مفاهیم و تعاریف متنی موجود در لغت‌نامه جهت تعیین گرایش احساسی کلمات استفاده می‌نماید. روش مبتنی بر مجموعه از اطلاعاتی هم‌رخدادی آماری در مجموعه بزرگی از اسناد استفاده می‌نماید و بر این فرض استوار است که کلمات احساسی که دارای قطبیت یکسانی هستند با همدیگر در مجموعه رخ می‌دهند [۷, ۱۳-۱۶]. روش‌های مبتنی بر لغت‌نامه گرایش کلمات را مستقل از محتوای متنی تعیین می‌نمایند و جهت یافتن کلمات احساسی وابسته به متن یا دامنه عملکرد خوبی ندارند و در زبان‌هایی که فاقد لغت‌نامه هستند نمی‌توانند به کار روند [۱۴, ۱۷] همچنین در فرهنگ لغت عبارات چند کلمه‌ای و اصطلاحات عامیانه که نشان‌دهنده احساس نویسنده نظر است وجود ندارد و این محدودیت دیگر استفاده از این روش می‌باشد [۱۸, ۱۹].

رویکردهای مبتنی بر مجموعه محدودیت رویکرد مبتنی بر لغت نامه را در زمینه مربوط به دامنه حل می‌نمایند و در یافتن کلمات احساسی موجود در دامنه و متن و تعیین جهت‌گیری معنایی آن‌ها عملکرد بهتری دارند که این مهمترین مزیت این روش‌ها نسبت به روش‌های مبتنی بر لغت‌نامه است اما ازجمله معایب این روش آن است که قادر به ایجاد مجموعه غنی و کاملی از کلمات احساسی نیستند. [۱۷, ۲۰]

تنها مطالعه موجود جهت ساخت واژگان احساسی در زبان فارسی [۲۱] می‌باشد که از روش مبتنی بر لغت‌نامه استفاده نموده است.

در این مقاله رویکرد خودکار و باناظر جهت تولید و ساخت لغت‌نامه احساسی برای زبان فارسی با استفاده از رویکرد مبتنی بر مجموعه ارائه شده است. روش پیشنهادی شامل سه گام می‌باشد: پیش‌پردازش متن نظرات موجود در زبان فارسی و ستخراج ویژگی‌های زبانی، برچسب‌زنی ادات سخن (تعیین نقش کلمات در جملات)، استخراج و تعیین کلمات نظری، تعیین جهت‌گیری معنایی (تعیین قطبیت) کلمات.

نوآوری این تحقیق ساخت واژگان احساسی از داخل متن نظرات در زبان فارسی می‌باشد تا بتواند خاصیت‌های مورفولوژیک موجود در زبان فارسی را تحت پوشش قرار دهد.

ساختار مقاله به این ترتیب است: در بخش دوم کارهای انجام شده در زمینه ساخت لغت‌نامه احساسی ارائه می‌گردد. در بخش سوم گام‌های موجود در روش پیشنهادی با جزئیات کامل توضیح داده می‌شود. در بخش چهارم نتایج حاصل از آزمایشات ارائه می‌گردد و در نهایت بخش پایانی به نتیجه‌گیری و پیشنهادات آتی اختصاص دارد.

۲- پیشینه پژوهش

تاکنون مطالعات صورت گرفته روش‌های متعددی را جهت ساخت واژگان احساسی ارائه نموده‌اند. اغلب این مطالعات از لیستی از کلمات پارادایم و شباهت کلمات جهت ساخت لغت‌نامه احساسی استفاده کرده‌اند. براساس شیوه دستیابی به شباهت کلمات روش‌های موجود به دو دسته طبقه‌بندی می‌شوند: رویکرد مبتنی بر لغت‌نامه و رویکرد مبتنی بر مجموعه.

۲-۱- رویکرد مبتنی بر لغت‌نامه

روش مبتنی بر لغت‌نامه از مترادف‌ها و روابط معنایی تعریف شده برای تعیین قطبیت مثبت و منفی کلمات استفاده می‌نمایند [۸]. این روش‌ها با استفاده از لغت‌نامه مانند وردنت کلمات احساسی را تولید می‌نمایند در اکثر این روش‌ها ابتدا یک سری کلمات احساسی که قطبیت مثبت و منفی آنها مشخص است به صورت دستی جمع آوری شده و سپس با استفاده از الگوریتم‌های رو به جلو مترادف‌ها و متضادهای آنها در لغت‌نامه یافت می‌شود و کلمات در هر تکرار به لیست کلمات مثبت و منفی اضافه می‌شوند تا زمانی‌که کلمه جدید دیگری یافت نشود. [۳]

هو و لیو [۹] از مجموعه‌ای از مترادف‌ها و متضادهای صفات در وردنت جهت پیش‌بینی جهت‌گیری معنایی صفات استفاده نمودند که ایده کلی آن بود که مترادف‌های یک صفت دارای قطب همسان با آن صفت هستند و متضادهای صفت دارای قطب مخالف با آن صفت می‌باشند. کمپس و همکارانش [۱۰] استراتژی را برای تفسیر جهت‌گیری معنایی با استفاده از ایجاد شبکه واژگانی و تعیین میزان ارتباط معنایی میان کلمات ارائه دادند. طبق این مطالعه دو کلمه تمایل به داشتن جهت‌گیری معنایی یکسان دارند اگر ارتباط قوی با هم داشته باشند. بنابراین روی استفاده از روابط واژگانی موجود در وردنت برای محاسبه فاصله میان صفات تمرکز کردند و گرایش احساسی هر کلمه را با توجه به فاصله آن از دو صفت اولیه خوب (good) و بد (bad) بدست آوردند. کیم و هاوی [۲۲] با استفاده از روش‌های احتمالاتی و در نظر گرفتن مترادف و متضادهای موجود در وردنت برای یک کلمه گرایش احساسی آن را مشخص نمودند. بریگلر و اندروسکیا [۱۲] با استفاده از الگوریتم فازی و در نظر گرفتن مترادف‌ها و متضادهای کلمات و همچنین تعاریف متنی به تعیین گرایش احساسی کلمات پرداختند و برای هر کلمه درجه احساسی تعیین گردید. اسیلای [۲۳] رویکرد نیمه نظارتی را برای طبقه بندی کلمات در دو دسته مثبت و منفی ارائه داد. در این روش از تعاریف متنی کلمات و اصطلاحات که در لغت‌نامه یا شبکه واژگان یافت می‌شوند جهت تعیین جهت‌گیری کلمات استفاده شده است فرضیه اصلی آن است که اگر یک کلمه از لحاظ معنایی در یک جهت قرار گیرد در آن صورت کلماتی که در تعریف آن هستند در همان جهت قرار می‌گیرند. او همچنین [۱۱] با استفاده از لغت‌نامه وردنت و با استفاده از یک روش باناظر لغت نامه احساسی سنتی وردنت را بر پایه میزان ارتباط کلمات در وردنت ایجاد نمود. جهت این کار ابتدا سه کلاس مثبت، منفی و خنثی را تعریف کرد و با استفاده از میزان قرارگیری هر کلمه در این سه کلاس گرایش احساسی کلمات مشخص گردید.

۲-۲- رویکرد مبتنی بر مجموعه

این رویکردها بر این فرض استوار هستند که کلمات با گرایش احساسی یکسان با هم درون مجموعه ظاهر می‌شوند و از روش‌ها و اندازه‌گیری‌های آماری جهت محاسبه گرایش احساسی کلمات استفاده می‌نمایند.

اولین مطالعه صورت گرفته در این حوزه مطالعه مکیون [۲۴] که از ویژگی‌های زبان انگلیسی برای تعیین قطبیت صفات بهره گرفته است و با استفاده از دو کلمه ربط «and» و «but» میان صفات موجود ابتدا گرافی را ایجاد کرد و سپس با استفاده از روش خوشه‌بندی لیستی از صفات با گرایش مثبت و منفی ایجاد شد. ترنی [۱۶] با استفاده از معیار وابستگی اطلاعات متقابل گرایش احساسی کلمات و عبارات را تعیین نمود. در این مطالعه ابتدا عبارت‌های نحوی که شامل قید و صفت هستند، بر طبق برچسب بخش‌های سخن، از جملات مختلف استخراج شدند و سپس با استفاده از هم‌رخدادی عبارات ایجاد شده با دو کلمه پارادایم «excellent » با قطبیت مثبت کلمه «poor» با قطبیت منفی گرایش احساسی هر کلمه و عبارت تعیین گردید. ترنی و لیتمن [۱۳] با استفاده از روش باناظر ضعیف و استفاده از دو تکنیک اطلاعات متقابل نقطه‌ای و روابط معنایی به تعیین جهت‌گیری معنایی کلمات پرداختند در این مطالعه از ۱۴ کلمه پارادایم به عنوان کلماتی با گرایش از پیش تعیین شده جهت تعیین گرایش احساسی استفاده نمودند. گامن [۲۵] روش ترنی را گسترش داد و فرضیه جدیدی مبنی بر اینکه کلمات احساسی با جهت‌گیری مخالف با هم در یک جمله رخ نمی‌دهند را به روش ترنی اضافه کرد. دینگ و لیو [۱۴] به بررسی کلمات و ویژگی‌هایی که چند احساسی هستند پرداختند و از قوانینی برای تعیین گرایش کلمات استفاده نمودند آنها با جداسازی جملات و تعیین ویژگی‌های محصول و سپس علامت گذاری کلمات احساسی موجود در اطراف ویژگی های تعیین شده و دادن امتیاز به این کلمات و استفاده از ربط دهنده هایی مانند but و and قطبیت کلماتی که دارای گرایش‌های احساسی متفاوت هستند را تعیین نمودند. دیو و همکارانش [۲۶] علاوه بر در نظر گرفتن ارتباط کلمات موجود در یک دامنه، ارتباط کلمات را با کلمات خارج از مجموعه داده شده بدست آوردند تا لغت‌نامه احساسی را برای دامنه‌های مختلف ایجاد نمایند. تان و همکارانش [۷] روشی را با ایجاد گرافی جهت تعیین ارتباط کلمات با کلمات موجود در دامنه و کلمات خارج از دامنه و ارتباط آنها با اسناد موجود در دامنه‌ای خاص را طراحی نمودند و براساس آن جهت‌گیری کلمات را با در نظر گرفتن دامنه به کار رفته مشخص کردند.

مطالعات بسیار کمی در زبان فارسی در حوزه نظرکاوی و تجزیه و تحلیل احساسات به دلیل فقدان منابع مورد نیاز مانند لغت‌نامه جامعی از واژگان احساسی و نبود مجموعه داده جامع از نظرات مشتری که دارای برچسب مثبت و منفی باشد صورت گرفته است. برخی از مطالعات جهت ایجاد و ساخت واژگان احساسی از رویکرد ترجمه منابع موجود در زبان انگلیسی استفاده نموده‌اند. شمس [۲۷] از مجموعه واژگان نظری موجود در زبان انگلیسی و بصیری [۲۸] از منبع واژگانی موجود که شامل واژگان مثبت و منفی همراه با امتیاز آنها است استفاده کردند و این واژگان را به زبان فارسی ترجمه کردند و به عنوان لغت‌نامه‌ای جهت تجزیه و تحلیل احساسات از آن استفاده نمودند. تنها مطالعه‌ای که در زبان فارسی به ساخت واژگان احساسی در زبان فارسی پرداخته مطالعه‌ای است که توسط علیمردانی انجام شده است [۲۱] در این مطالعه جهت ساخت واژگان احساسی از وردنت موجود در زبان فارسی استفاده شده است که شامل ۱۷۰۰۰ مدخل واژگانی در مقوله اسم، صفت و فعل می باشد. که در آن برای هر کلمه بخش نحوی و مثالی که آن کلمه در آن به کار رفته می باشد و معادل انگلیسی هر کلمه در وردنت انگلیسی را در نظر گرفته است و سپس هر واژه بدست آمده را به معادل آن در سنتی وردنت در زبان انگلیسی ترسیم کرده و جهت گیری معنایی آن را مشخص نموده است . در مقایسه با روش پیشنهادی در این مقاله، این روش به طور کلی متکی به وجود لغت‌نامه‌ای قوی می‌باشد همچنین گرایش احساسی هر کلمه را مستقل از متن تعیین می‌نماید. از طرف دیگر با مشکل مقیاس‌پذیری مواجه است و قادر به تعیین گرایش کلماتی که در لغت‌نامه وجود ندارند نمی‌باشد [۷, ۱۴, ۲۶, ۲۹]. از آنجا که کلمات احساسی مثبت و منفی می‌توانند در دامنه‌های مختلف دارای جهت‌گیری احساسی متفاوت باشند [۱۶] در این مقاله از روش مبتنی بر مجموعه جهت بدست آوردن شباهت معنایی کلمات و ساخت واژگان احساسی در زبان فارسی استفاده شده است.

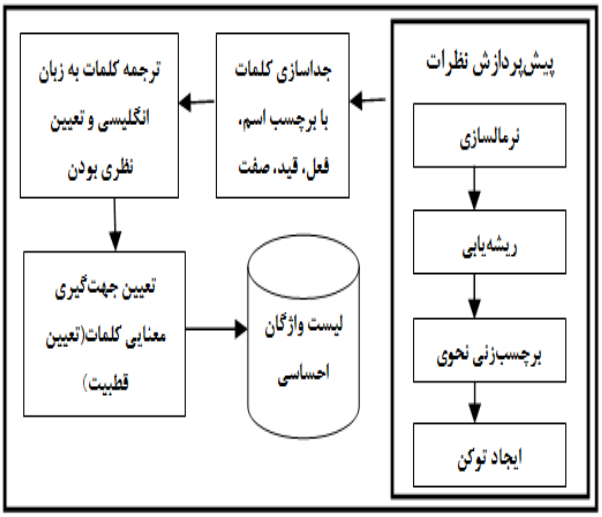
۳- مدل پیشنهادی

در این بخش روش ساخت لغت‌نامه احساسی برای زبان فارسی تشریح می‌گردد . شکل ۱ چارچوب کلی روش را ارائه می‌دهد.

۳-۱- پیش‌پردازش متن

بر خلاف زبان‌های دیگر از جمله زبان انگلیسی، متن‌کاوی در زبان فارسی به دلیل پیچیدگی بسیار با مشکلات متعددی روبه‌رو است. این مشکلات به دلیل کمبود ابزارهای مختلف، وجود پسوندهای متفاوت، فاصله‌گذاری کلمه‌ها و استفاده از کلمه‌های غیر رسمی و محاوره‌ای شکل می‌گیرد. از آنجا که ایجاد لغت‌نامه به پیش‌پردازش نیاز دارد، کلمه‌ها از داده‌های پیش‌پردازش شده استخراج می‌شوند. [۳۰]

پیش‌پردازش داده، فرایند پاکسازی و آماده‌سازی متن برای طبقه‌بندی است [۳۱, ۳۲]. در این مقاله، این فرایند شامل مراحل نرمال‌سازی، ریشه‌یابی، برچسب‌زنی بخش‌های سخن و در انتها تبدیل متن نظرات به برداری از کلمات می‌باشد.



شکل ۱: چارچوب پیشنهادی جهت ساخت لغت‌نامه احساسی

۳-۲- انتخاب ویژگی

استخراج ویژگی یکی از گام‌های اساسی در طبقه‌بندی احساسات است. صفات، قیدها، فعل‌ها و اسم‌ها به عنوان ویژگی‌هایی هستند که بیان‌کننده نظرات می‌باشند [۱۴]. در این مرحله جهت ساخت واژگان احساسی کلمات با برچسب نحوی فعل، صفت، قید و اسم از میان کلمات موجود استخراج می‌شوند.

۳-۳- تعیین نظری بودن ویژگی

این فرایند شامل ترجمه کلمات فارسی به زبان انگلیسی و جستجوی کلمات ایجاد شده در لیست واژگان احساسی نظری رایج در زبان انگلیسی [۳۳] می‌باشد. تنها کلمات موجود در لیست در مرحله بعد مورد استفاده قرار می‌گیرند.

۳-۴- تعیین جهت‌گیری معنایی کلمات

جهت تعیین جهت‌گیری معنایی عبارات و کلمات، این مطالعه از تئوری اندازه‌گیری شباهت مبتنی بر روش اطلاعات متقابل نقطه‌ای استفاده می‌کند. روش اطلاعات متقابل نقطه‌ای یک روش بسیار ساده در حوزه تئوری اطلاعات می‌باشد [۳۴]:

$$I(x,y)=\log_2\frac{p(x,y)}{p(x)p(y)} \qquad (۱)$$

در عمل $p(x)$ به عنوان احتمال تعداد دفعاتی است که در مجموعه ظاهر می‌شود، $p(y)$ به عنوان احتمال تعداد دفعاتی که در مجموعه ظاهر می‌شود و $p(x,y)$ به عنوان احتمال تعداد دفعاتی که هر دو کلمه با یکدیگر در متن و یا سند ظاهر می‌شوند تخمین زده می‌شود. جهت تعیین قطبیت کلمات معادله بالا به فرم زیر تغییر می‌یابد:

$$A(word,pos)=\log_2\frac{p(word,pos)}{p(word)p(pos)} \qquad (۲)$$

$$A(word,neg)=\log_2\frac{p(word,neg)}{p(word)p(neg)} \qquad (۳)$$

در معادلات بالا $p(word,pos)$ احتمال هم‌رخدادی کلمه در اسناد مثبت، $p(word,neg)$ احتمال آنکه کلمه در اسناد منفی قرار گیرد و $p(word)$ ، $p(pos)$ و $p(neg)$ به ترتیب احتمال رخداد کلمه، اسناد مثبت و اسناد منفی به تنهایی می‌باشد. در نهایت جهت گیری معنایی کلمه از رابطه زیر محاسبه می‌شود:

$$So(word)=A(word,pos)-A(word,neg) \qquad (۴)$$

اگر مقدار $So(word)$ که بیانگر جهت‌گیری معنایی کلمه است مثبت باشد کلمه دارای جهت‌گیری مثبت است و اگر مقدار منفی باشد کلمه دارای جهت‌گیری منفی است. و اگر مقدار صفر باشد کلمه هیچ قطبیت مثبت و منفی ندارد و خنثی است.

$$wordpolarity=\begin{cases} positive \rightarrow so(word)\succ 0 \\ negative \rightarrow so(word)\prec 0 \\ neutral \rightarrow so(word)=0 \end{cases} \qquad (۵)$$

۴- آزمایشات و یافته‌های پژوهش

در این بخش به پیاده‌سازی مدل پیشنهادی بر روی داده‌های واقعی پرداخته می‌شود و نتایج حاصل از هر گام مدل بیان می‌گردد. همچنین به ارزیابی لغت‌نامه احساسی ایجاد شده پرداخته می‌شود.

۴-۱- جمع‌آوری مجموعه داده

برای انجام آزمایشات موجود در این پژوهش از مجموعه داده‌های زیر استفاده شده است:

مجموعه نظرات جمع‌آوری شده از یک سایت خرده فروشی آنلاین: مجموعه‌ای شامل ۷۵۰۰ سند از نظرات فارسی نوشته شده در حوزه‌های دوربین دیجیتال، لپ تاپ، تلویزیون، تبلت و تلفن همراه که به صورت دستی جمع‌آوری شد. از این مجموعه جهت انتخاب ویژگی برای ساخت لیستی از واژگان احساسی استفاده کردیم.

مجموعه نظرات موجود دارای برچسب مثبت و منفی در زبان انگلیسی: در این مطالعه از مجموعه نظرات جمع‌آوری شده توسط آقای بلیتزر [۳۵] استفاده شده است. مجموعه جمع‌آوری شده دارای نظراتی با برچسب مثبت و منفی به صورت جداگانه در هر یک از زمینه‌های پوشاک، اتومبیل، دوربین دیجیتال، تلفن همراه، کامپیوتر، فیلم، DVD ، وسایل الکترونیکی و .... می‌باشد. که از این مجموعه ۳۱۳۳۵ نظر انتخاب شد. از این مجموعه جهت تعیین جهت‌گیری معنایی کلمات استفاده شد.

۴-۲- آماده‌سازی و پیش‌پردازش نظرات

جهت نرمال‌سازی، ریشه‌یابی و برچسب‌زنی نحوی متن نظرات از ابزار پردازش زبان طبیعی [۳۶] ایجاد شده در آزمایشگاه فناوری وب مشهد استفاده شده است. جهت استخراج واژه‌ها و کلمات از مجموعه اسناد، از نرم‌افزار متن‌باز Rapidminer استفاده شد. این نرم‌افزار به کمک ویژگی vector creation اسناد را به مجموعه‌ای از واژه‌ها تبدیل می‌نماید. به طور کلی تعداد ویژگی‌های زبانی ایجاد شده ۱۲۶۰۸ ویژگی بودند که از بین آنها تنها ویژگی‌هایی با برچسب نحوی صفت، قید، اسم و فعل جداسازی شدند که تعداد کلمات موجود با هر یک از این برچسب‌ها به ترتیب ۱۵۴۳، ۱۰۶، ۷۶۲۱ و ۳۹۰۴ عدد می‌باشد. از میان کلمات موجود تنها ۳۰۰۵ کلمه نظری بودند که از آنها به عنوان ورودی مرحله بعد استفاده شد. جدول ۱ نمونه نظر پیش‌پردازش شده و جدول ۲ نمونه کلمات نظری موجود در زبان فارسی را نشان می‌دهد.

جدول ۱: نمونه نظر پیش‌پردازش شده

متن نظر	نظر پیش‌پردازش شده
حرفی واسه گفتن ندارم فقط میتونم بگم عالیه!!!	نرمال‌سازی: حرفی برای گفتن ندارم فقط می‌توانم بگویم عالی هست!!!
	ریشه‌یابی: حرف برای گفت نداشت فقط توانست گفت عالی هست!!!
	برچسب‌زنی: حرف<N> برای<PREP> گفت<N> نداشت<V> فقط<ADV> توانست<V> گفت<N> عالی<ADJ> هست<V>!!! ا<PUNC>ا

جدول ۲: نمونه‌ای از کلمات نظری در زبان فارسی

کلمه	معادل انگلیسی	برچسب نحوی کلمه
آبروریزی	Scandal	N
آرام	calm	ADJ
آزار	abuse	N
آزاردهنده	Annoying	ADJ
آسان	easy	ADJ
آسیب	Damage	N
آسیب‌دیده	hurt	ADJ
آسیب‌دیدگی	Injury	N

۴-۳- ساخت لغت‌نامه

جهت محاسبه جهت‌گیری معنایی کلمات میزان ارتباط آن‌ها با مجموعه نظرات انگلیسی که دارای برچسب مثبت و منفی هستند، بدست آمد که در جدول ۳ برخی از این کلمات ارائه شده‌اند. در جدول ۴ تعداد کلمات مثبت و منفی در لغت‌نامه ایجاد شده به صورت آماری نشان داده شده است.

جدول ۳: نمونه کلمات احساسی همراه با قطبیت آنها

کلمه	ارتباط با اسناد مثبت	ارتباط با اسناد منفی	جهت‌گیری معنایی	قطبیت
آبروریزی	-0.5373	0.3894	-0.9267	negative
آرام	0.5197	-0.8164	1.3361	positive
آزار	-0.0805	0.0759	-0.1564	negative
آزاردهنده	-0.7456	0.4877	-1.2333	negative
آزرد	-0.8304	0.5222	-1.3526	negative
آسان	0.6186	-1.1003	1.7189	positive
آسوده	0.4095	-0.5715	0.981	positive
آسیب	-0.2369	0.2028	-0.4397	negative
آسیب‌دیده	-0.1799	0.1594	-0.3393	negative

negative	-1.3039	0.5084	-0.7955	آسیب‌دیدگی

جدول ۴: تعداد و درصد کلمات مثبت و منفی در لغت‌نامه احساسی

دسته کلمات	تعداد	درصد
کلمات مثبت	۲۰۰۷	٪۵۵
کلمات منفی	۱۶۹۸	٪۴۵

۴-۴- معیارهای ارزیابی

جهت ارزیابی لغت‌نامه احساسی ایجاد شده به شیوه کیفی، قطبیت واژگان با استفاده از لغت‌نامه سنتی وردنت مورد مقایسه قرار گرفت. این تجزیه و تحلیل در دو گام صورت گرفت: ابتدا کلماتی که در هر دو لغت‌نامه مشترک بودند استخراج شدند. که تعداد کلمات مشترک ۲۰۲۲ کلمه بود سپس قطبیت کلماتی که در سنتی وردنت دارای چندین حس بودند از طریق میانگین‌گیری میان مقادیر موجود بدست آمد. در گام دوم ۹۷ کلمه در سنتی وردنت دارای قطبیت خنثی بودند این کلمات از دو لیست مشترک استخراج شده و حذف شدند و تنها کلمات مشترکی باقی ماندند که دارای قطبیت مثبت و منفی بودند. پس از آن با توجه به ماتریس درهم ریختگی زیر سه معیار دقت، صحت و فراخوانی محاسبه گردید:

جدول ۵: ماتریس درهم ریختگی

	رکوردهای تخمینی	
	کلمات مثبت	کلمات منفی
کلمات مثبت واقعی	TP = نمونه‌های به درستی مثبت تشخیص داده شده	FN = نمونه‌های به غلط منفی تشخیص داده شده
کلمات منفی واقعی	FP = نمونه‌های به غلط مثبت تشخیص داده شده	TN = نمونه‌های به درستی منفی تشخیص داده شده

در این مقاله از سه معیار دقت، صحت و فراخوانی جهت ارزیابی استفاده شده است:

$$Accuracy = \frac{TP + TN}{TP + FP + TN + FN} \quad (۶)$$

$$precision^{+} = \frac{Tp}{TP + FP}, precision^{-} = \frac{TN}{TN + Fn} \quad (۷)$$

$$recall^{+} = \frac{TP}{TP + FN}, recall^{-} = \frac{TN}{TN + FP} \quad (۸)$$

در جدول زیر قطبیت کلمات در هر دسته در دو لغت‌نامه مشخص شده است از میان ۱۹۲۵ کلمه مشترک در هر دو لغت‌نامه تعداد کلمات با قطبیت مثبت و منفی به شرح زیر است:

جدول ۶: مقایسه روش پیشنهادی با سنتی وردنت

طبقه کلمات	تعداد کلمات در سنتی وردنت	تعداد کلمات به درستی تعیین قطبیت شده با استفاده از مدل پیشنهادی	درصد تعداد کلمات به درستی برچسب خورده
کلمات با برچسب مثبت	۱۰۸۷	۸۸۱	٪ ۸۱
کلمات با برچسب منفی	۸۳۸	۶۷۲	٪ ۷۹

جدول ۷: ارزیابی روش پیشنهادی

دسته کلمات	Precision	recall	Accuracy
کلمات مثبت	٪۸۴	٪۸۱	٪۸۰
کلمات منفی	٪۷۶	٪۷۹	

همانطور که در جدول مشاهده می‌کنید روش پیشنهادی در این مقاله دارای دقت قابل قبولی در تعیین گرایش احساسی کلمات می‌باشد و دقت کلی روش در تعیین گرایش احساسی واژگان موجود در مجموعه نظرات ۸۰ درصد می‌باشد.

۵- نتیجه‌گیری و پیشنهادات آتی

در این مقاله روشی با ناظر جهت ساخت لغت‌نامه احساسی برای زبان فارسی ارائه گردید. که با استفاده از برچسب ادات سخن و معیار وابستگی متقابل جهت تعیین گرایش احساسی کلمات موجود در مجموعه نظرات بهره گرفته است همچنین از آنجا که روش پیشنهادی روشی مبتنی بر مجموعه می‌باشد می‌تواند ویژگی‌های مورفولوژیکی و زبانی موجود در نظرات را پوشش دهد. نتایج حاصل از ارزیابی واژگان احساسی ایجاد شده حاکی از مناسب بودن واژگان احساسی ایجاد شده جهت طبقه‌بندی نظرات می‌باشد. روش پیشنهادی شامل محدودیت‌هایی می‌باشد: از جمله اینکه محدودیت روش مبتنی بر مجموعه را یعنی پوشش ندادن تمامی کلمات را دارد . همچنین روش اطلاعات متقابل جهت تعیین گرایش معنایی کلمات از نظر پیاده‌سازی آسان است و محدود به مجموعه صفات نمی‌شود اما نیازمند به مجموعه بزرگی می‌باشد تا عملکرد بهتری

داشته باشد. از این رو ما قصد داریم تا در آینده به توسعه و بهبود واژگان احساسی ایجاد شده با ترکیب رویکردهای مبتنی بر لغت‌نامه و مبتنی بر مجموعه بپردازیم و روش اطلاعات متقابل را با روش‌های دیگر جهت اندازه‌گیری میزان وابستگی کلمات به دسته مثبت و منفی ترکیب نماییم.

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تشخیص ناهنجاری پرواز در عملیات فرود یک هواپیما با استفاده از مدل پنهان مارکف

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چکیده - صنعت حمل ونقل هوایی به طور جدی مدیریت خطر در سفرهای هوایی را دنبال می‌کند. که هدف اصلی آن تشخیص رفتارهای غیرعادی در موقعیت‌های مختلف پرواز است. روش‌های موجود، دارای محدودیت و مبتنی بر مطالعه‌ی خطرات و اندازه‌گیری پارامترهای مؤثر بر آن هستند. این پارامترها حقیقت وابستگی فرایند پرواز به تصمیمات انسانی و زمان را پوشش نمی‌دهند. در این مقاله از روشی بر اساس مدل پنهان مارکف *(HMM)* که از روش‌های اصلی ارزیابی موقعیت درتلفیق داده محسوب می‌شود، استفاده شده است. این روش شامل دو سطح خوشه‌بندی مبتنی بر داده و مبتنی بر مدل است. آزمایش‌ها با داده های هواپیمای *B_777* و متغیرهای پیش‌بینی شده در نسل آینده سیستم پخش اطلاعات پروازی *(ADS_B)* انجام شده است. سرعت و حساسیت بسیار بالای این روش در تشخیص تغییرات غیر عادی و مؤثر در پارامترهای پرواز هنگام فرود، در نتایج این مقاله به خوبی دیده می‌شود. مدل‌سازی پویا مسئله وابستگی به زمان و شرایط را حل کرده است و با توجه به تطابق این روش با سایر سیستم‌های کنترل ترافیک هوایی، توسعه‌ی آن برای تمام موقعیت‌های پرواز به راحتی امکان‌پذیر است.

کلید واژه- الگوریتم پیشرو[۱]، سیستم پخش اطلاعات وابسته به نظارت خودکار ADS_B[۲] ، مدل مارکف پنهان HMM[۳]

۱. مقدمه

در طول تاریخ بهبود ایمنی سفرهای هوایی توسط شرکت‌های هواپیمایی از سخت‌ترین مباحث علمی و تکنولوژی بوده است. و پس از هر پیشرفت در استراتژی‌های کاهش خطرات، حوادث هوایی باز هم رخ داده‌اند[۱] . امروزه صنعت هوایی به سمت روش‌هایی برای ایمنی پرواز حرکت می‌کند که خطرات را قبل از وقوع شناسایی و اقدام لازم را انجام دهد. اطلاعات دیجیتال ضبط کننده داده‌های پرواز[۴](FDR) به طور معمول در بسیاری از شرکت‌های هواپیمایی در پردازش‌های تشخیص خطر استفاده می‌شود. تمامی روش‌ها قابلیت استفاده از بخشی از ده‌ها پارامتر پرواز موجود در FDR را دارند.

برنامه ضمانت کیفیت فعالیت‌های پروازی[۵](FOQA) که در اروپا با نام نظارت بر داده‌های پروازی[۶](FDM) شناخته شده است از معروف‌ترین این تلاش‌ها است. در برنامه‌های تجاری کنونی از روش تشخیص تجاوز از حدود[۷](ED) استفاده شده است که برای تعداد معینی از پارامترهای پرواز، عبور از محدوده مجاز تشخیص و اعلام خطر می‌کند. این اعلام خطر در وقایع از قبل مطالعه شده نتیجه درست می‌دهد و نه برای تمام وقایع ممکن[۲]. دیگر کارهای انجام شده در ذیل آمده است.

از آخرین تلاش‌ها برای تشخیص رفتار غیر عادی با استفاده از داده‌های FDR ، بسته نرم‌افزاری گزارش صبح[۸]است[۳]. کارهای بعدی در زمینه روش‌های داده کاوی برای تشخیص رفتار غیر عادی در سیستم‌های هوافضا بوده است. بعضی از روش‌های مبتنی بر آموزش استفاده می‌کنند، مانند سیستم نظارت قیاسی[۹] (IMS) که قابلیت کمی در به کارگیری الگوهای وابسته به زمان دارند[۴]. و بقیه رویکرد غیر نظارتی دارند و بر روی کاربرد الگوریتم رشته کاوی برای داده‌های گسسته FDR تمرکز دارند

[۱] Forward algorithm
[۲] Automatic Dependent Surveillance – Broadcast
[۳] Hidden Markov Model
[۴] Flight Data Recorder
[۵] Flight Operations Quality Assurance
[۶] Flight Data Monitoring
[۷] Exeedance Detection
[۸] Morning report software package
[۹] Inductive Monitoring System

مانند سیستم تلنگر تعویض کابین خلبان[۵][۵]. آقای داس و همکارانش در سازمان ناسا تشخیص ناهنجاری چند هسته‌ای (MKAD) [۱۱]را توسعه داده‌اند که از نوع تک کلاسه الگوریتم SVM [۱۲]استفاده می‌کند[۶]. آقای Srivastava و همکارانش روشی بر پایه داده معرفی کرده‌اند که با استفاده از خوشه‌بندی به تشخیص رفتار غیر عادی می‌پردازد[۷]. اخیراً در مقاله‌ای اطلاعات الگوریتم‌های بالا به اختصار جمع‌آوری شده است[۸].

ضرورت وجود یک سیستم با رویکرد واحد در تمام شرایط و موقعیت‌های پرواز برای تشخیص رفتار غیر عادی به شدت احساس می شود مخصوصاً اینکه حمل و نقل هوایی و به صورت عمومی و خصوصی به شدت در حال گسترش است. چرا که متخصصان در مراکز کنترل ترافیک هوایی فرودگاه‌ها با پارمترهای فراوان کار می‌کنند و امکان بروز خطا و وجود سیستم‌های خودکار برای هشدار به موقع خطر یک چالش مهم است. این نیاز در فرودگاه ها و دیگر نقاط پر ترافیک خطوط هوایی دو چندان است. یک چالش اساسی ماهیت متغیر با زمان بودن موقعیت‌های یک پرواز است بنابراین سیستم باید قابلیت تشخیص رفتار پویا را داشته باشد. و همچنین تطابق با سیستم پخش اطلاعات وابسته به نظارت خودکار (ADS_B) که در نسل آینده سیستم حمل و نقل هوایی پیش‌بینی شده است، بسیار اهمیت دارد.

در این مقاله برای تشخیص رفتار غیر عادی پرواز از متغیرهای پیش‌بینی شده در ADS_B استفاده شده است و با استفاده از مدل پنهان مارکف (HMM) رفتار عادی فرایند فرود مدل‌سازی شده و با استفاده از آن بروز هر نوع تغییر غیر عادی در متغیرهای پرواز حین فرود به سرعت تشخیص داده می‌شود و می‌تواند در هشدار قبل از وقوع حادثه برای امداد رسانی بهتر استفاده شود. این روش در مدل‌سازی فرایندهای تصادفی و پویا کارایی خیلی خوبی دارد. در واقع این کار، تلاش برای ایجاد یک چارچوب در زمینه ایجاد یک سیستم به منظور تشخیص رفتار غیر عادی پرواز بر پایه HMM است. چرا که HMM با ساختارهای متنوع و الگوریتم‌های مناسب خود به خوبی با دیگر پردازش‌ها تطبیق‌پذیر است.

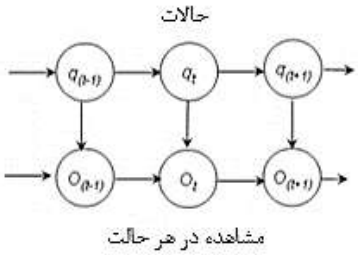
در این مقاله ابتدا توضیحی برای سطح کاربرد HMM در تلفیق داده در بخش ۲، سپس بررسی نظری HMM و کاربرد در زمینه تشخیص رفتار غیر عادی فرود هواپیما در بخش ۳و۴ و مدل‌سازی و نتایج در بخش ۵ گفته می‌شود و بحث و کارهای آینده در بخش ۶ بیان می‌شود.

۲. جایگاه HMM در تلفیق داده[۱۳]

یکی از معروف‌ترین مدل‌های استفاده شده در مبحث تلفیق داده، مدل JDL[۱۴]می‌باشد[۹]. تعریف زیر توسط گروه JDL برای تلفیق داده ارائه شده است: " تلفیق داده، فرایند ترکیب داده‌ها برای بهبود تخمین و پیش‌بینی حالات است." تلفیق داده در سطوح مختلف انجام می شود. و کاربرد HMM مربوط به سطوح ۲ و ۳ است که برای ارزیابی وضعیت و تهدید استفاده می‌شود[۹, ۱۰]. کار ارائه شده در این مقاله در واقع ارزیابی وضعیت در کاربرد فرود هواپیما است.

۳. مدل مارکف پنهان HMM[۱۱]

HMM نوعی از فرایند تصادفی مارکف دو تایی حالت[۱۵] محدود است. که از دو فرایند مارکف (زنجیره مارکف) تشکیل شده است. یک فرایند با ماتریس گذر حالت و دیگری در هر حالت با یک توزیعی از مشاهدات به صورت ماتریس احتمالات مشاهدات بیان می شود. در واقع سیستم با توزیع احتمالات گذر حالت از یک حالت به حالت دیگر می‌رود و در هر حالت شرایط سیستم به صورت سمبل‌های مشاهدات با استفاده از توزیع احتمالات مشاهدات در خروجی دیده می‌شود. بدین معنا که حالات سیستم پنهان است اما شرایط و وضعیت سیستم با مشاهدات دیده می‌شود (شکل ۱).



شکل ۱: ساختار HMM استاندارد. حالت پنهان (qt) و مشاهده (Ot)

[۱۰]Cockpit switch flips
[۱۱]Multiple Kernel Anomaly Detection
[۱۲]Suport Vector Machine
[۱۳]Data Fusion
[۱۴]Joint Director of Laboratories
[۱۵]State

۳،۱. اجزای یک HMM[۹]

یک HMM گسسته، λ، با تعداد حالات N و تعداد سمبل مشاهدات M بیان می‌شود. فضای حالات به صورت $S=\{s_1,s_2,\ldots,s_N\}$ و فضای مشاهدات به صورت $V=\{v_1,v_2,\ldots,v_M\}$ است. مدل λ با پارامتر های زیر توصیف می‌گردد.

$$\lambda = (\pi, A, B, N, M) \quad (۱)$$

$$\pi = \{\pi_i\} = \{ p(q_i = s_i)\} \quad (۲)$$

$$A = \{ a_{ij}\} = \{ p(q_{t+1} = s_j \mid q_t = s_i)\} \quad (۳)$$

$$B = \{ b_j(k)\} = \{ p(O_t = v_k \mid q_t = s_j)\} \quad 1 \le i,j \le N, 1 \le k \le M \quad (۴)$$

که در روابط فوق A بیان‌گر احتمالات گذر حالات است، B بیان‌گر توزیع احتمال سمبل‌های گسسته در همه حالت‌ها و π بیان‌گر توزیع احتمالات اولیه حالات است. a_{ij} احتمال تغییر حالت سیستم از i به j و $b_j(k)$ توزیع احتمال سمبل‌ها برای حالت j است. و حالت لحظه t با q_t و مشاهده همان لحظه با O_t نمایش داده شده است.

پارامتر های A, B, π با آموزش مدل بدست می‌آید در این مقاله آموزش با استفاده از الگوریتم حداکثر امید ریاضی[۱۶](EM) که با نام بام ولچ[۱۷]مشهور است انجام شده است. زمانی که λ و پارامتر های آن مشخص شد. می‌توان برای محاسبه راستی آزمایی[۱۸](L) از یک رشته مشاهدات استفاده شود که مقدار آن از رابطه(۵) بدست می‌آید.

$$L = p(O \mid \lambda) \quad (۵)$$

۴. الگوریتم پیشرو[۹]

$O=(o_1,o_2,\ldots,o_T)$ رشته مشاهدات در مدت زمان T است در یک مسئله تشخیص، هدف مقایسه O با یک مدل و یافتن میزان تشابه به آن است. برای محاسبه L از الگوریتم پیشرو استفاده می‌شود.

$$\alpha_t(i) = p(O_1 O_2 \ldots O_t, q_t = s_i \mid \lambda) \quad (۶)$$

$\alpha_t(i)$ در الگوریتم پیشرو مقدار احتمال مشاهده یک زنجیره مشاهده $(O_1,O_2,\ldots,O_t)$ را در حالت i و زمان t بیان می‌کند. برای λ و O_1 ، α_1 به صورت زیر بدست می‌آید.

$$\alpha_1(i) = \pi_i b_i(O_1) \quad 1 \le i \le L \quad (۷)$$

برای بقیه مشاهدات α که متغیر پیشروگفته می‌شود به صورت زیر محاسبه می‌شود.

$$\alpha_{t+1}(j) = \left[\sum_{i=1}^{L} \alpha_t(i) a_{ij}\right] b_j(O_{t+1}) \quad \begin{matrix} 1 \le t \le T-1 \\ 1 \le j \le L \end{matrix} \quad (۸)$$

رابطه(۸) مشخص می‌کند که چگونه به حالت s_j در زمان t+1 از میان N حالت ممکن می‌رسیم. محاسبات برای تمام حالت‌ها در زمان t انجام می‌شود و برای تمام زمان های t = 1,2,..,T تکرار می شود. جواب نهایی با جمع متغیر پیشرو[۱۹]پایانی برای تمام حالات بدست می‌آید رابطه(۹).

$$p(O|\lambda) = \sum_{i=1}^{N} \alpha_T(i) \quad (۹)$$

در طی محاسبات تعداد زیادی عمل ضرب بین احتمالات کمتر از یک رخ می‌دهد که باعث می‌شود جواب نهایی به صفر نزدیک شود و مشکل وقتی حادتر می‌شود که جواب نهایی از مقدار قابل نمایش کامپیوتر کمتر شود. مشکل با استفاده از یک فاکتور مقیاس c_t توسط رابطه(۱۰) قابل حل است.

$$c_t = {}^{1}/_{\sum_{i=1}^{N} \alpha_T(i)} \quad (۱۰)$$

و رابطه‌ای که برای محاسبات مفید است به شکل زیر است.

$$\log[\, p(O|\lambda)\,] = -\sum_{t=1}^{T} log\, c_t \quad (۱۱)$$

۵. آزمایش و نتایج

در این مقاله از بانک اطلاعاتی ۳۶۵ پرواز هواپیمای B_777 استفاده شده است، که در پروژه MKAD در سازمان ناسا نیز به کار رفته است. این داده‌ها در کنترل و هدایت پرواز توسط برج مراقبت پرواز و سیستم‌های ناوبری کاربرد دارد. داده‌ها شامل موقعیت، ارتفاع، فاصله افقی، سرعت افقی و سرعت عمودی است. در استفاده از HMM برای مدل‌سازی پدیده‌های پویا مبحث

[۱۶] Expectation Maximization
[۱۷] Baum_Welch
[۱۸] Likelihood
[۱۹] Forward variable

آموزش مدل اهمیت بسیاری دارد. بنابراین در HMM گسسته روش ایجاد سمبل از داده‌های پیوسته مهم می‌باشد. همچنین تعداد این سمبل‌ها در حساسیت مدل موثر است. در این مقاله از مقدار متغیرها استفاده کردیم و با استفاده از الگوریتم K_means به ۱۰۰ خوشه تقسیم شد و سمبل ها به صورت 1,2,3,…,99,100 است.

در این مقاله از داده‌های فرایند فرود استفاده شد که شامل ۲۰ فرود موفق و ۱۰ فرود ناموفق است. مدل شامل دو حالت است، s_1 : عدم تغییر یا تغییرات کم در متغیرهای پرواز، s_2 : تغییر قابل توجه در متغیرهای پرواز. علت انتخاب این حالت‌ها ضرورت وجود ارتباط منطقی ولی پنهانی با سمبل‌ها است. بعد از ساخت سمبل‌های مشاهدات، داده های فرود موفق توسط الگوریتم baum_welch برای آموزش مدل استفاده شد. ماتریس‌های مدل در رابطه‌های (۱۱و۱۲و۱۳) قرار گرفته است.

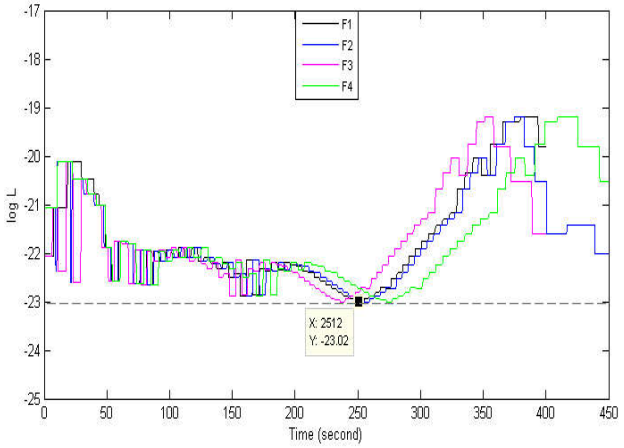
$$\pi = \begin{bmatrix} 0.55 \\ 0.45 \end{bmatrix} \qquad (۱۲)$$

$$A = \begin{bmatrix} 0.45 & 0.55 \\ 0.61 & 0.39 \end{bmatrix} \qquad (۱۳)$$

$$B = \begin{bmatrix} 0.01 & 0.011 & \cdots & 0.125 & \sim 0 \\ 0.01 & 0.011 & \cdots & 0.124 & \sim 0 \end{bmatrix} \qquad (۱۴)$$

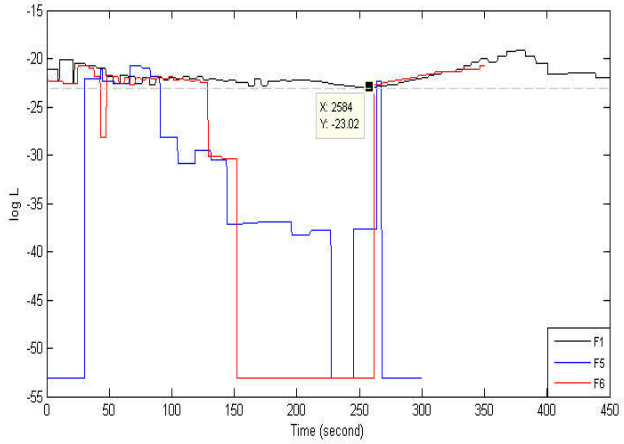
بعد از ساخت مدل رفتار عادی فرایند فرود، حال باید با استفاده از داده های فرود موفق و ناموفق به تشخیص رفتار غیر عادی پرداخت برای این کار از الگوریتم پیشرو استفاده شد به این صورت که سمبل‌های هر فرود به عنوان ورودی به مدل داده شد و خروجی الگوریتم (L) میزان شباهت این فرود به مدل فرود موفق است. با بررسی متوجه شدیم که یک روش مناسب برای محاسبه و نمایش L استفاده از یک پنجره ۵ سمبلی بر روی داده‌ها است که بر روی سمبل‌ها تک تک حرکت کند بنابراین الگوریتم پیشرو برای ۵ سمبل اجرا شد . این کار، سرعت پردازش ها را نیز بیشتر کرد.

نتایج برای ۴ فرود موفق و متفاوت رسم شد و در شکل ۲ می‌بینید . با بررسی تمام داده‌های فرود موفق یک حد برای میزان log(L) بدست آوردیم، بنابراین L<-23.02 بیان‌گر رفتار غیر عادی و L>-23.02 بیان‌گر رفتار عادی در هنگام فرود است.



شکل ۲: لگاریتم L بر حسب زمان برای چهار فرود موفق و میزان حد مجاز برای L

نتایج برای ۲ فرود ناموفق و متفاوت محاسبه شد و در شکل ۳ نشان داده شده است



شکل ۳: لگاریتم L بر حسب زمان برای یک فرود موفق (F1) و دو فرود نا موفق متفاوت (F5 , F6)

فرود شماره F5 در ابتدا سرعت عمودی نسبت به افقی غیر عادی بوده است و سپس تنظیم شده و دوباره از کنترل خارج شده است. که مدل به درستی تشخیص داده است. و فرود شماره F6 ابتدا با وجود داشتن ارتفاع کمتر اما با سرعت‌های عمودی و افقی همخوانی داشته و سپس سرعت عمودی آن از مقدار صحیح بیشتر شده و مدل آن را به درستی تشخیص داده است. زمان محاسبات به صورت آفلاین برای هر فرود بدین صورت است : F1: ۰,۲۵۸۱ و F5: ۰,۲۲۶۵ و F6: ۰,۲۲۸۳ ثانیه و زمان محاسبه الگوریتم پیشرو برای ۵ سمبل به طور میانگین ۰,۰۰۰۲۸۶ثانیه است و باتوجه به سرعت تشخیص بسیار بالا پردازش برخط در عمل به راحتی امکان‌پذیر است.

اصـــلی ترین تمایز این روش با روش MKAD و ED و روش خو شه‌بندی آقای Srivastava و همکاران ا ستفاده از مدل سازی پویا در کنار خو شه‌بندی داده‌ها ا ست که علاوه بر بالا بردن دقت و ســـرعت، امکان آموزش مدل به صـــورت برخط و بهبود آن نیز وجود دارد. هم‌چنین دقت این مدل به نوع پیوســـته یا گســـســـته بودن داده‌ها وابسته نیست.

۶. بحث و نتیجه گیری

اســـتفاده از HMM برای مدل‌ســـازی رفتار غیر عادی پرواز مو ضوع ا صلی این مقاله ا ست. این روش با توجه به کاربردش در پردازش‌های گفتار و ویدئو و مدل سازی پدیده‌های پویا همان‌طور که انتظار می‌رفت از دقت و حســـاســـیت بالایی در این کاربرد نیز برخوردار ا ست. با توجه به کاربرد ا صلی HMM در مدل سازی و تشخیص پدیده‌های پویا و تصادفی، نتایج نشان می‌دهد این مدل برای مســـئله‌ی تشـــخیص فرایند پرواز که پویا و وابســـته به زمان ا ست، بسیار مناسب ا ست. و با توجه به ماهیت کاربرد که مسئله خوشـــه بندی اســـت در مقایســـه با کارهای پیشـــین از دو ســـطح خوشـــه‌بندی اســـتفاده می‌کند در ســـطح داده علاوه بر تبدیل داده‌های زیاد به یک ر شته سمبل، حدود پارامترهای پرواز را نیز مشـــخص می‌کند و در ســـطح مدل با ایجاد مدل احتمالاتی و پویا از فرود موفق، قابلیت بالایی در به کارگیری الگوهای وابســـته به ز مان دارد. ســـر عت بالای الگوریتم ها اجرای عملی پروژه را امکان‌پذیر می‌کند. این مدل برای بخش‌های مختلف یک پرواز و مطابق با شـــرایط مختلف آب وهوایی و نوع هواپیما قابل توســـعه است.

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