Robot path planning in a dynamic and unknown environment based on Colonial Competitive Algorithm (CCA) and Fuzzy Logic

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Abstract - *Robot path planning has been one of the favorite areas for many Machine Learning researchers from the past up to date. The trajectory designed for a robot can be simple or complex. The robot must pass through obstacles which are either movable or fixed. One of the considerable ways for robot path planning in the dynamic and unknown environment is a combination of Evolutionary algorithm and Fuzzy logic. There are different kinds of evolutionary algorithms such as Genetic algorithm, Ant Colony algorithm, Colonial Competitive algorithm, etc. A new approach has been proposed in this paper for robot path planning in the dynamic and unknown environment based on both the Colonial Competitive algorithm and fuzzy rules. The implemented results of the proposed method present its superiority over previous methods which used only fuzzy logic method.*

Key Words: Colonial competitive Algorithm, Dynamic and unknown environment, Fixed and movable obstacles, Fuzzy Logic, Robot path planning

1. INTRODUCTION

Robot path planning in a trajectory has been one of the interesting areas for many Machine Learning and Pattern Recognition researchers from the past till date. Robot path planning can be simple and somewhat complex. The obstacles which are passed by the robot are either movable or fixed. Automated robot path planning for only one environment is one of the unsolved robotic challenges. Several methods that have been presented to solve these issues should be considered in two: classic and heuristic categories [1]. In the first twenty years of the advent of this field, scientists generally used classic routing method. But, this method had a notable problem named NP-Complete for robot path planning [2]. Thus, in order to overcome this issue, evolutionary method was designed. Evolutionary method is not performable in spite of its popularity because, in the beginning, all the paths are not accessible for the unknown environment with a movable obstacle. The method based on fuzzy logic is much appropriate for this type of problem. On the other hand, the table of the fuzzy rules has many rows in most of the cases.

This paper presents a method for detecting a trajectory in a dynamic and unknown environment. In this technique, colonial competitive algorithm has been carried out to optimize a number of the rules in the fuzzy table. This project also has been used another new method presented in [3, 4] to obtain the number of optimized fuzzy rules. Path planning has been defined offline just once in the mentioned environment by using these optimized rules. Section 2 is the first stage of this project which reviews the previous studies. In addition, studied environment for path planning has been introduced in section 3. Moreover, in section 4, brief descriptions of the required colonial competitive algorithm and fuzzy logic have been mentioned. Eventually, the simulation results of the proposed method will be dedicated.

2. PREVIOUS STUDIES

Robot path planning research began in 1960. Over the last few years, numerous studies have been conducted on control and path planning of robots [5-7]. After 30 years, robot path planning method can be classified into two: classic and heuristic categories [8, 9]. In other words, path planning method is grouped into four main classifications. 1- Path planning in a known environment with fixed obstacles, 2- An unknown environment with fixed obstacles, 3- A known environment with dynamic obstacles, 4- An unknown environment with dynamic obstacles. It is obvious that path planning in an unknown environment with dynamic obstacles is a much more real environment [10]. On the other hand, some of the most important methods in the classic category are Cell Decomposition, Voronoi diagram, and Reaction method, and Collocation method [11]. In cell decomposition algorithm, the environment is divided into a number of cells and then an appropriate path is created by using a graph-searching method. Moreover, in reaction method, a proper path is determined based on the local and current information. In addition, path planning has NP-complete problem in the classic technique [2]. Thus, several methods have been given attention in order to solve this problem. Generally, heuristic methods include Neural networks, Genetic algorithm, Colonial Competitive algorithm, Ant Colony, Particle Swarm Optimization, and Fuzzy logic [12-17]. Environmental factors can have a significant effect on some systems such as the mobile robot. The effect of different environmental factors on photovoltaic systems have been studied with the experimental system in [18, 19] and then, optimum tilt angles of the photovoltaic system are obtained. Gracia et al, presented a method based on ant colony algorithm for complex environments. In that paper, the track of the ants' movement will be kept for determination of path planning [1]. However, there are some studies use classic method to solve the optimization problems [20, 21]. In addition, all of the classic methods are not capable of path planning in this environment due to a lot of calculations. Likewise, the methods based on the evolutionary algorithm are offline and cannot be performed for online path planning because the whole path should be known from the beginning. On the other hand, path planning methods based on fuzzy logic are not appropriate because of its many rules [22]. In this project, a method based on a combination of colonial competitive algorithm and fuzzy logic will be presented for online path planning in the dynamic and unknown environment.

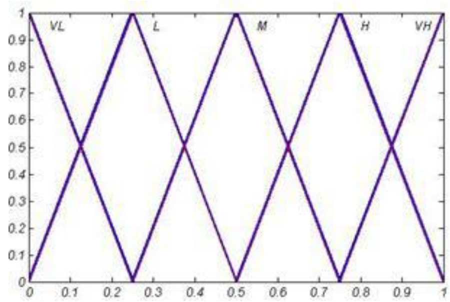
3. PROPOSED METHOD

3.1 Explanation of Issue in Fuzzy Logic

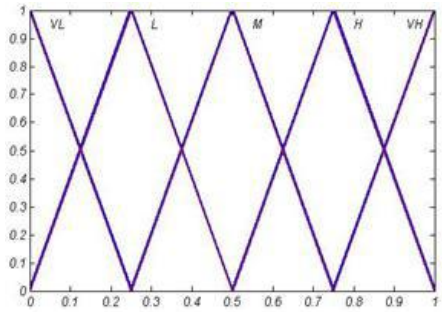
Fuzzy theory was first introduced by Zade in 1965 [23]. There are three significant steps in fuzzy logic. The first step is fuzzification of input, the Second step is creating fuzzy rules table which is usually determined by specialists and the final step is called the defuzzification step [24]. For Path planning in fuzzy logic, at any moment, the next node will be selected from among the eight available options by using the angle difference to the target and its distance to the nearest obstacle. Afterward, a selective preference coefficient is obtained as the next node, for each of those eight available nodes. After applying fuzzy logic, a defuzzified or final output is created for the inputs of each node. Eventually, when the node has the most defuzzification preference coefficient, it will be the next selective node in that procedure. Membership functions have been demonstrated in Fig. 1 for two inputs and fuzzy output (selective preference coefficient). In addition, a number of fuzzy rules for this issue are specified in Table I.

Table -1: A number of fuzzy rules for path planning

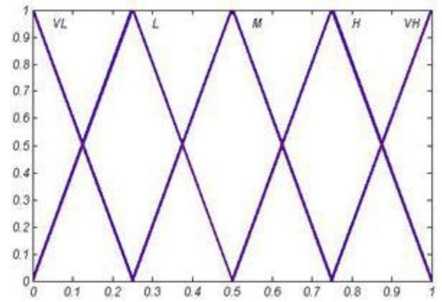
Preference Coefficient	Angle difference to target	Distance to the nearest obstacle
Extremely low	Very high	Very low
High	Very low	Low
⁞	⁞	⁞
Extremely high	Extremely high	Extremely high



(a)



(b)



(c)

Fig -1: (a) Fuzzy functions for input of the angle difference, (b) Fuzzy functions for input of the distance to the nearest obstacle, (c) Fuzzy functions for output (selective preference coefficient)

Table I shows the fuzzy rules for selecting the next node in the momentum path planning that is regulated via node by node. In this table, generally for every node, if the distance to the nearest obstacle is much higher and also the angle difference to the target is much lower, that node will be more likely to be chosen as a next node along the path. This paper utilized weighted average method to create a final and defuzzified output [25, 26].

3.2 Colonial Competitive Algorithm

Colonial competitive algorithm was inspired by the idea of the socio-political evolution of humans via E. Atashpaz-Gargari and C. Lucas in 2007 [3, 27]. This algorithm began with a random primary population that each member of this population is only one country. The position of each country in the N-dimensional space represents a possible solution for optimization issue and "N" is the number of optimization variables. After evaluation of primary population, the number of population members with the least amount of cost function is considered as colonial countries which are equivalent to parents in genetic algorithm. Other members of the population are colonies that each of them belongs to an empire. In this research, a possible solution for this issue is defined as a string with N length that is considered as a country. In addition, N is the total number of fuzzy rules and its numerical value is 5. According to Fig 2, if to find a possible solution, the j-th membership function is specified for the i-th rule, then "i" element is equal to the value of "j" in the corresponding string.

	1	2	3	4	5	6	7	....	N
Solution	4	1	3	1	2	4	3	....	1

Fig -2: The structure of a country for path planning

Initially, the random primary population is generated from countries in the N-dimensional space where N is the total number of fuzzy rules. The values of parameters are continuously determined in the [0, Nout], where Nout is the number of membership functions considered for fuzzification of output. The suitability (power) evaluation of each country and overall power of each empire have been assessed by using (1). In other words, in this level, the power of the created solution via i-th country is evaluated by using (1).

$$fit_i = \frac{1}{L_i} \quad (1)$$

In the above equation, Li is the length of the traversed path via dynamic robot by using fuzzy rules table for i-th country and $\frac{1}{L_i}$ is the power of i-th country. The total power of every empire in each repetition is equal to the sum of the power (suitability) of colonial countries and power average of the dominated countries in that empire. Therefore, after determining the power of all countries, the power of k-th empire will be obtained as stated by (2).

$$(Power)_k = fit(imp)_k + mean(fit(empire)_k) \quad (2)$$

In the above equation, $fit(imp)_k$ is the colonial suitability in k-th empire and $mean(fit(empire)_k$ is an average of the colonial countries suitability in k-th empire. Meanwhile, to update the colonial countries and after determination of all current countries power in each empire, if one of the colonies has more power than colonialism, then that colony will be specified as a new colonialism in the empire. The total power of k-th empire is obtained by (3).

$$N_{imp-k} = \frac{(power)_k}{\sum_{j=1}^{M}(power)_j} \quad (3)$$

In the above equation, $N_{imp\text{-}k}$ states the number of dominated countries of k-th empire. In addition, $(power)_k$ is the power of the k-th empire and $\sum_{j=1}^{M}(power)_j$ represents the total powers of all empires. The study of the termination condition for the above steps will be repeated as long as the termination condition is established. In this project, the end of number of algorithmic repetitions is considered as the termination condition of colonial competitive. Fig. 3 shows the main schematic of the proposed system.

4. SIMULATION

4.1 Introducing the Workspace

A 2D environment of the dynamic robot's workspace is created, which includes the dimension of 500×500 square network with the same length. There are fixed obstacles with a variety of shapes, numbers, and coordinates. Moreover, movable obstacles are demonstrated with different speeds and directions via blue circles [28]. The target and starting points are also located in different positions. These diversities are selected due to the fact that the robot's workspace becomes the same as the real world. According to a number of the fixed and movable obstacles, a workspace can be considered simple or complex. Therefore, in this paper, a complex environment with a robot as a moveable point has been designed. The starting point and end point are in the lower left corner and the upper right corner, respectively. The following Figure shows an example of a complex workspace with a number of fixed and movable obstacles at various speeds. In Fig. 4, the black and blue shapes represent fixed and moveable points at different speeds, respectively.

4.2 Simulation Results

When the path is known from the beginning, evolutionary algorithm will have an appropriate performance. In this article, the trajectory is unknown, so this algorithm will not work properly. On the other hand, fuzzy logic method which is fast and greedy will be performed as the best option. The fuzzy rules table is a critical point of fuzzy logic method that is often determined by specialists. But rows of the fuzzy rules table are not optimal and the use of colonial competitive algorithm solves this problem. In other words, colonial competitive algorithm is proposed to optimize a number of rows in the fuzzy rules table which are used for effective path planning. Likewise, colonial competitive algorithm has been used once as an offline path planning to optimize rows of the fuzzy rules table. According to Fig. 5, path planning using fuzzy logic is indicated and also, the rules of the table are defined manually.

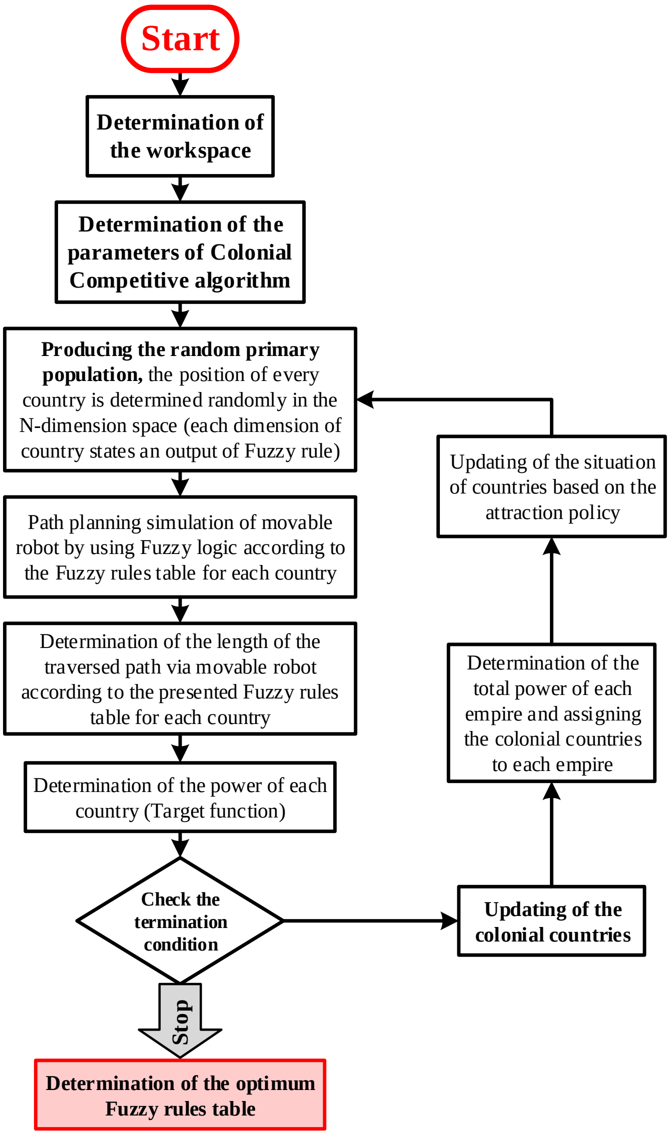


Fig -3: General schematic of the proposed system

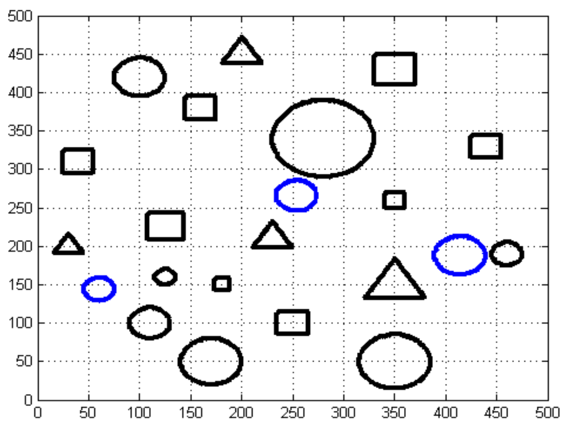


Fig -4: A view of the workspace

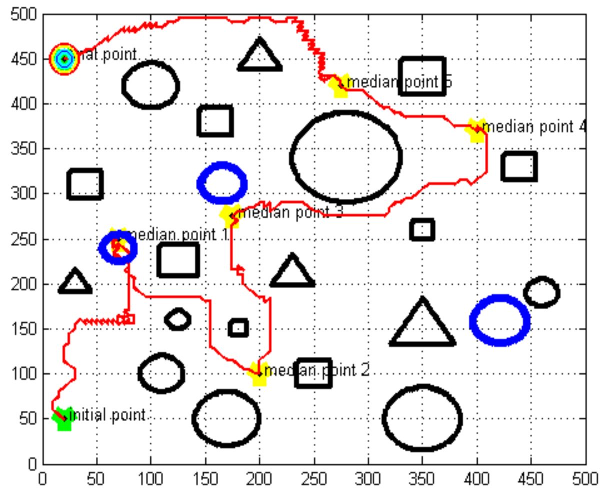


Fig -5: Path planning by using fuzzy logic

In Fig. 5, the length of the traversed path is 965.35 cm. But this length decreased to 925.5 cm by using a combination of colonial competitive algorithm and fuzzy logic.

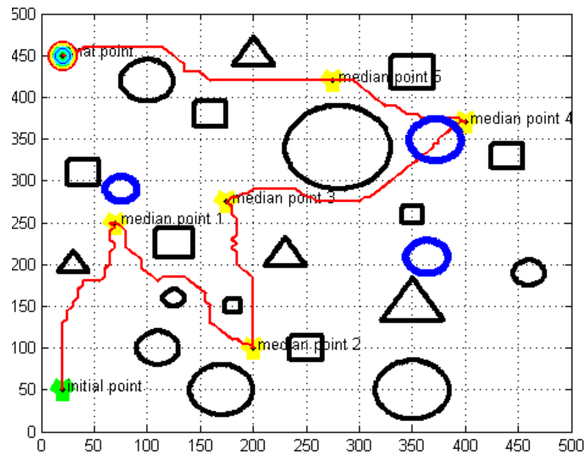


Fig -6: Path planning by using combination Colonial Competitive algorithm and Fuzzy logic

Finally, the system has been repeated 15 times. Moreover, colonial competitive algorithm has been implemented in each level and then optimal fuzzy rules are extracted. Fig. 7 shows the process of obtaining the cost function in these 15 levels. All other parameters of colonial competitive algorithm have been defined like [3]. In Fig. 7, the vertical axis is final value of the best cost function and the horizontal axis is a number of the algorithm repetitions.

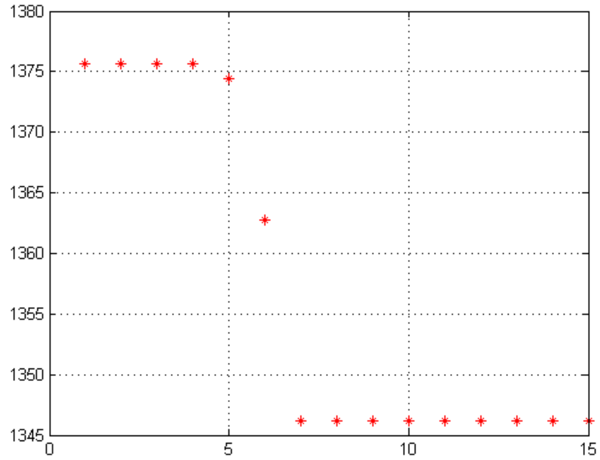


Fig -7: 15 different level of the system

5. CONCLUSION

The application of evolutionary algorithm for path planning in an unknown environment with movable obstacles has been widely considered. Evolutionary method is not capable of path planning in the unknown environments, because in the beginning, roadmap must be specified [1, 2]. Furthermore, the number of rules in path planning is much when using Fuzzy logic method. Thus, this method is not qualified alone to be used in path planning. Afterward, a method which is a combination of colonial competitive algorithm and fuzzy logic was presented for online path planning in a dynamic and unknown environment. The implementation results of the proposed method states that colonial competitive algorithm for optimization of the fuzzy rules table reduced the length of the path and also this algorithm optimized a number of the fuzzy rules. Moreover, reduction of the number of fuzzy rules will diminish the computational complexity.

REFERENCES

[1] M. P. Garcia, O. Montiel, O. Castillo, R. Sepúlveda, and P. Melin, "Path planning for autonomous mobile robot navigation with ant colony optimization and fuzzy cost function evaluation," Applied Soft Computing, vol. 9, pp. 1102-1110, 2009.

[2] E. Masehian and D. Sedighizadeh, "Classic and heuristic approaches in robot motion planning-a chronological review," World Academy of Science, Engineering and Technology, vol. 23, pp. 101-106, 2007.

[3] E. Atashpaz-Gargari and C. Lucas, "Imperialist competitive algorithm: an algorithm for optimization inspired by imperialistic competition," in Evolutionary computation, 2007. CEC 2007. IEEE Congress on, 2007, pp. 4661-4667.

[4] F. Rahmani, F. Razaghian, and A. Kashaninia, "Novel Approach to Design of a Class-EJ Power Amplifier Using High Power Technology," World Academy of Science, Engineering and Technology, International Journal of Electrical, Computer, Energetic, Electronic and Communication Engineering, vol. 9, pp. 541-546, 2015.

[5] T. Lozano-Pérez and M. A. Wesley, "An algorithm for planning collision-free paths among polyhedral obstacles," Communications of the ACM, vol. 22, pp. 560-570, 1979.

[6] M. T. Andani and Z. Ramezani, "Robust Control of a Spherical Mobile Robot," 2017.

[7] Tahere Pourseif, M. T. Andani, Zahra Ramezani and Mahdi Pourgholi, "Model Reference Adaptive Control for Robot Tracking Problem: Design & Performance Analysis," International Journal of Control Science and Engineering, vol. 7, pp. 18-23, 2017.

[8] E. K. Chong and S. H. Zak, An introduction to optimization vol. 76: John Wiley & Sons, 2013.

[9] F. Najafi, M. Dadvar, A. Hosseini, S. Habibian, H. Haeri, M. Arvan, et al., "RoboCupRescue 2015-Robot League Team< MRL (Iran)."

[10] H. Mei, Y. Tian, and L. Zu, "A hybrid ant colony optimization algorithm for path planning of robot in dynamic environment," International Journal of Information Technology, vol. 12, pp. 78-88, 2006.

[11] A. F. Bastani, Z. Ahmadi, and D. Damircheli, "A radial basis collocation method for pricing American options under regime-switching jump-diffusion models," Applied Numerical Mathematics, vol. 65, pp. 79-90, 2013.

[12] A. F. Bastani and D. Damircheli, "An adaptive algorithm for solving stochastic multi-point boundary value problems," Numerical Algorithms, vol. 74, pp. 1119-1143, 2017.

[13] M. Rostaghi-Chalaki, A. Shayegani-Akmal, and H. Mohseni, "HARMONIC ANALYSIS OF LEAKAGE CURRENT OF SILICON RUBBER INSULATORS IN CLEAN-FOG AND SALT-FOG," in 18th International Symposium on High Voltage Engineering, 2013, pp. 1684-1688.

[14] M. Rostaghi-Chalaki, A. Shayegani-Akmal, and H. Mohseni, "A STUDY ON THE RELATION BETWEEN LEAKAGE CURRENT AND SPECIFIC CREEPAGE DISTANCE," in 18th International Symposium on High Voltage Engineering (ISH 2013), 2013, pp. 1629-1623.

[15] K. Yousefpour, "Placement of Dispersed Generation with the Purpose of Losses Reduction and Voltage

Profile Improvement in Distribution Networks Using Particle Swarm Optimization Algorithm," Journal of World's Electrical Engineering and Technology, vol. 2322, p. 5114, 2014.

[16] K. Yousefpour, S. J. H. Molla, and S. M. Hosseini, "A Dynamic Approach for Distribution System Planning Using Particle Swarm Optimization," International Journal of Control Science and Engineering, vol. 5, pp. 10-17, 2015.

[17] T. Agarwal, D. Kumar, and N. R. Prakash, "Prolonging network lifetime using ant colony optimization algorithm on LEACH protocol for wireless sensor networks," Recent Trends in Networks and Communications, pp. 634-641, 2010.

[18] H. Pourgharibshahi, M. Abdolzadeh, and R. Fadaeinedjad, "Verification of computational optimum tilt angles of a photovoltaic module using an experimental photovoltaic system," Environmental Progress & Sustainable Energy, vol. 34, pp. 1156-1165, 2015.

[19] A. Rouholamini, H. Pourgharibshahi, R. Fadaeinedjad, and G. Moschopoulos, "Optimal tilt angle determination of photovoltaic panels and comparing of their mathematical model predictions to experimental data in Kerman," in Electrical and Computer Engineering (CCECE), 2013 26th Annual IEEE Canadian Conference on, 2013, pp. 1-4.

[20] M. H. Imani, P. Niknejad, and M. Barzegaran, "The impact of customers' participation level and various incentive values on implementing emergency demand response program in microgrid operation," International Journal of Electrical Power & Energy Systems, vol. 96, pp. 114-125, 2018.

[21] S. H. Imani, S. Asghari, and M. Ameli, "Considering the load uncertainty for solving security constrained unit commitment problem in presence of plug-in electric vehicle," in Electrical Engineering (ICEE), 2014 22nd Iranian Conference on, 2014, pp. 725-732.

[22] F. Rahmani, F. Razaghian, and A. Kashaninia, "High Power Two-Stage Class-AB/J Power Amplifier with High Gain and Efficiency," Journal of Academic and Applied Studies (JAAS), vol. 4, pp. 56-68, 2014.

[23] L. A. Zadeh, "Fuzzy sets," Information and control, vol. 8, pp. 338-353, 1965.

[24] A. Mashat, A. Karambakhsh, M. Rahmani, A. H. M. Hosseini, M. Mashat, B. Mahdikhani, et al., "RoboCupRescue 2013-Robot League Team MRL Rescue Robot (Iran)."

[25] M. Ma, A. Kandel, and M. Friedman, "A new approach for defuzzification," Fuzzy Sets and Systems, vol. 111, pp. 351-356, 2000.

[26] A. Rahimnejad and M. Mirzaie, "Optimal corona ring selection for 230 kV ceramic I-string insulator using 3D simulation," International Journal of Scientific & Engineering Research, vol. 3, pp. 1-6, 2012.

[27] E. Akbari, M. Mirzaie, A. Rahimnejad, and M. B. Asadpoor, "Finite Element Analysis of Disc Insulator Type and Corona Ring Effect on Electric Field Distribution over 230-kV Insulator Strings," International Journal of Engineering & Technology, vol. 1, pp. 407-419, 2012.

[28] P. Niknejad, T. Agarwal, and M. Barzegaran, "Using gallium nitride DC-DC converter for speed control of BLDC motor," in Electric Machines and Drives Conference (IEMDC), 2017 IEEE International, 2017, pp. 1-6.