A PSO Fuzzy-Expert System: As an Assistant for Specifying the Acceptance by NOET Measures, at PH.D Level

Seyed Muhammad Hossein Mousavi
Student
Department of Computer Engineering
Bu Ali Sina University
Hamedan, Iran, 65141
h.mosavi93@basu.ac.ir

S.Younes MiriNezhad
Student
Department of Computer Engineering
Bu Ali Sina University
Hamedan, Iran, 65141
y.mirinezhad93@basu.ac.ir

Mehrdad Shafeii Mosleh
Student
Department of Computer Engineering
Bu Ali Sina University
Hamedan, Iran, 65141
m.shafaei93@basu.ac.ir

Mir Hossein Dezfoulian
Professor
Department of Computer Engineering
Bu Ali Sina University
Hamedan, Iran, 65141
dezfoulian@basu.ac.ir

Abstract— **The intelligent decision making systems are useful tools for the assistance of human expert, and or as a perfect alternative for expert in a variety of auto-decision making fields. The use of such systems in education, agriculture, industry, fishery, animal husbandry etc., can decrease manpower errors or need of it; In the other hand, it can increase the quality and the pace of service giving. The interview at the PH.D level or even Master's degree, due to the high sensitivity in scoring to the candidates, is of high importance. Therefore, creating a system for storing these scores, and inferring the results can be beneficial when there is a large number of candidates. In this paper, the expert system has an educational use, and classifies the probability of acceptance or unacceptance of PH.D candidates in the exam and interview, based on the (National Organization of Educational Testing) NOET measures, also estimates scientific level of candidates. The proposed fuzzy-expert system takes advantage of the particle swarm optimization (PSO) evolutionary algorithm to specifying the score of each variable, and eventually the final condition of the candidate. The acquired results of evaluating the fuzzy-expert system proves its functionality. This system is also able to function well in scoring similar educational cases to specify acceptance.**

Keywords- PH.D Level; NOET Measures; Classification; Fuzzy-Expert System; Evolutionary Algorithms; Particle Swarm Optimization (PSO)

I. INTRODUCTION AND PRIOR WORKS

In recent years, the use of fuzzy-expert systems in different fields has been developed to a high extent. Scoring, and intelligent decision-making systems are of the most useful fields of fuzzy-expert systems. So far, a variety of different approaches of artificial intelligence field such as: neural networks, decision tree, logistic regression analysis, linear discriminant analysis etc., has been used for evaluation, scoring and finally decision-making. This paper also uses an evolutionary fuzzy-expert system, for evaluation, scoring and decision-making. Here, some of recent works are presented: in 2003, E.W.T Ngai, F.K.T Wat designed a fuzzy-expert system for assisting tourists in choosing proper hotels for themselves. This system evaluated the quality of hotels using customer's feedback [1]. In 2010, Mehdi Fesanghari and Gholam-Ali Montazer designed a fuzzy-expert system for choosing the top stock, in order to face the uncertainty conditions in Tehran stock market [2]. In 2012, Verdú Elena, María J. Verdú proposed a fuzzy-expert system using genetic algorithm [3], which was able to classify the hardness level of educational questions in competitive environment. This system, after obtaining the feedback of students' answers, classified the questions into three levels of easy, normal and hard. They used the genetic algorithm in order to specify the lower and upper bounds of the input variables' range [4]. Also [19] and [20] are related to previous item. In 2014, Ali Bazmara and Soheila Sardar devised a new fuzzy-expert system for scoring the customers' credit [5]. This study presents a fuzzy-expert system for specifying the acceptance at PH.D level, by the Iranian (National Organization of Educational Testing) NOET measures with the help of evolutionary PSO algorithm. In section II problem definition, and in the section III, the perfect model of fuzzy-expert system are discussed. Section IV discusses the acquired results of the tests and section V winds up and presents conclusion, discussion and suggestions.

II. PROBLEM DEFINITION

The acceptance at PH.D level includes two main sections of theoretical test and interview, which theoretical test forms 30

978-1-5386-2585-9/17/$31.00 ©2017 IEEE

TABLE I. ACCEPTANCE FACTORS AT PH.D LEVEL, ACCORDING TO THE IRANIAN NOET MEASURES BY THE END OF 2016

	Type of Activity	Maximum Score	Evaluation
*	**Research Scores**	**Maximum 40 Scores**	**-**
1	1-1: Journal articles (international and domestic) related to the field of study 1-2: Patent accepted by Industrial Scientific Research Institute of Iran 1-3: Chosen at a prestigious festival	22 scores	-Each article up to 7 scores, according to the upgrade regulation -International patent, up to 7, and domestic up to 5 scores -Domestic chosen up to 3, and international up to 7
2	Scientific extension papers, related to the field of study	6 scores	Each article up to 2 scores, according to the upgrade regulations
3	Published articles in the prestigious conferences (international and domestic)	4 scores	International up to 2, and domestic up to 1 scores
4	Book compilation or translation, related to the field of study	4 scores	-
5	The quality of masters' dissertation or thesis	4 scores	Excellent up to 4, and very good up to 2 scores
-	**Sum**	**40**	**-**
*	**Educational Scores**	**Maximum 30 Scores**	**-**
6	The average and quality of bachelor's university	Up to 6 scores	According to the opinion of interview committee
7	The average and quality of the university of M.Sc. education place	Up to 5 scores	According to the opinion of interview committee
8	Education length at bachelor period	up to 3 scores	According to the opinion of interview committee
9	Education length at M.Sc. period	3 scores	According to the opinion of interview committee
10	The winners of student scientific Olympiads	5 scores	Rank 1 to 3, 5 scores Rank 4 to 6, 4 scores Rank 7 to 9, 3 scores Rank 10 to 12, 2 scores Rank 13 to 15, 1 score
11	Credible language certification	8 scores	According to the English language skill table (Table II)
-	sum	30 scores	-
*	**The Score of Scientific Test of Second Level**	**Maximum 30 Scores**	**-**
12	The total number of the specialized test or interview	30 scores	Base on the call (released announcement)

TABLE II. THE LANGUAGE CERTIFICATION SCORE (ALIGNMENT OF THE DOMESTIC AND INTERNATIONAL ENGLISH LANGUAGE TEST)

Specialized Scores	TOFEL:IBT+TOLIMO	TOFEL:CBT	TOFEL:IBT	IELTS	MSRT
8	677-637	300-270	120-110	8 and upper	100-80
7	636-607	269-253	101-102	7.5	79-75
6	606-587	252-240	101-94	7	74-70
5	586-550	239-213	93-79	6.5	69-65
4	549-495	212-168	78-60	6	64-60
3	494-450	166-137	59-46	5.5	59-55
2	449-420	136-108	45-35	5	54-50
1	419-393	107-93	34-29	4.5	49-45

percent, and the interview 70 percent of coefficient acceptance. The interview, except the scientific level test, includes some other factors, which are converted to the fuzzy-expert system. The factors which are considered in interview for accepting the candidates are shown in Table I and II. The acquired scores of Table I and II, and theoretical test are the final criterion of acceptance.

III. THE PSO FUZZY-EXPERT SYSTEM MODEL

A. Expert System

Expert systems are a special group of software, which are used to aid human experts, or for being as a total or partial alternative for them to be used in the specialized fields. These systems are in fact the early and simpler types of the knowledge base technology, which with gathering, processing and analyzing data are able to infer and resolve problems in the cases, which usually need the knowledge of a human expert in a special field of study. These systems usually store data as facts and rules in the knowledge base, and then using as special inference methods, needed results will be produced. Expert systems have application in a variety of fields; some of them: medicine, accountancy, industry, education, process control, human resources, financial services, archeology, radiography, engineering consultancy in architecture, juridical consultancy etc. In each

of these fields, with the aid of experimental systems, more quickly and easily, it is possible to do works such: guidance, processing, classification, consultation, design, recognition, decision-making, analysis, scoring, foretelling, concept-making, detection, justification, learning, management, planning, scheduling and test [6].

In this study, the estimation of acceptance or unacceptance takes place in two phases. In the first phase, fuzzy model generator commences learning from fact base, and automatically generates the classification rules and fuzzy sets from input variables for specific data. In the second phase, fuzzy-expert system infers the acceptance conditions for each candidate. Computing factors are performed in Table III. Initial values are inside Fact base, and based on the acquired data of human expert. PSO in each level and for each candidate uses the initial pattern inside Fact Base, and converts them to Crisp sets. The fuzzy model generator uses these Crisp sets, and generates the rules and fuzzy sets related to the knowledge base. When the rules and fuzzy models generated, then inference engine will be able to infer candidates' conditions, which are stored as patterns in the Fact base. Eventually, such a patter will be updated under the title of accepted pattern, rejected pattern, or in queue, and in later uses, without the need for a human expert will be used in the same cases. Figure 1 indicates a perspective of an expert system, and Figure 2 a general view of the proposed evolutionary fuzzy-expert system. For more information on expert systems, refer to [7].

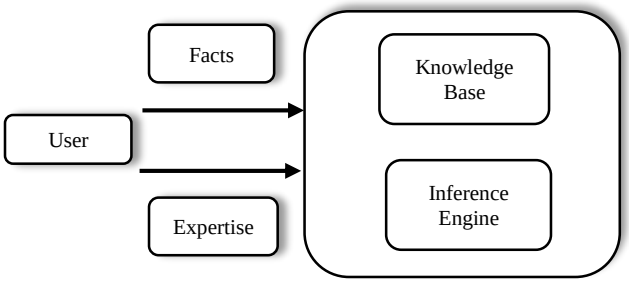

Figure 1. General view of an expert system

B. Particle Swarm Optimization (PSO)

PSO is of the most important intelligent optimization algorithms, which is placed in the range of Swarm Intelligence. This algorithm was introduced in 1995 by J.Kennedy and R. Eberhart, and was inspired of the social treatment of animals such as fish and the birds, which live in small and large groups [8]. In PSO, members of the answer population are related to each other directly, and with information exchange and remembering the good past memories, resolve the problems. PSO is suitable for a variety of discrete and continuous problems, and provides very proper answers for resolving different optimization problems.

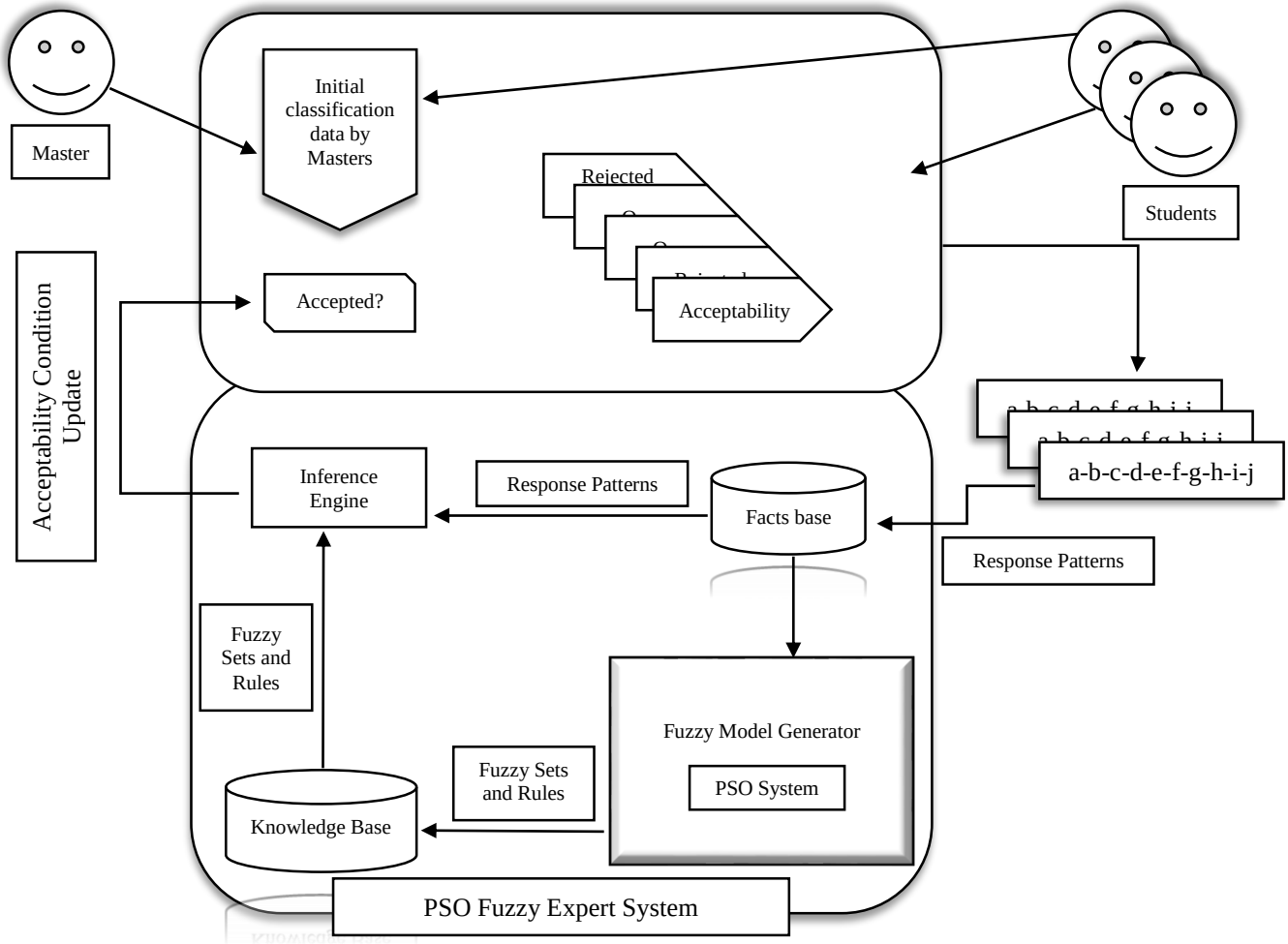

Figure 2. The proposed evolutionary fuzzy-expert system

Here, the initial population namely particle, which in the simplest form enjoys two variables of Position and Velocity, shown as a vector of real numbers. This evolutionary algorithm does not possess Recombinition operator, but Mutation operator. In the simplified sample of this algorithm, mutation is performed as with adding the acceleration vector. Choosing the parents is Deterministic, meaning each parent generates an Offspring via mutation. Choosing offspring occurs as Generational, meaning the next generation or offspring replaces the prior generation or parent. For more information on this, refer to [8] and [9].

The aim of PSO for the proposed system is to generate a group of Crisp sets, which are marking the upper and lower bounds of input variables for this algorithm in relation to the values of human expert. As mentioned before, values of Table III contains the input of PSO. Each Particle is containing the following vector:

[a1,a2, b1, b2, c1, c2, d1, d2, e1, e2, f1, f2, g1, g2, h1, h2, i1, i2, j1, j2]

Which shows the operators of Table III from up to down respectively. A view of general process of this algorithm is available in Figure 3.

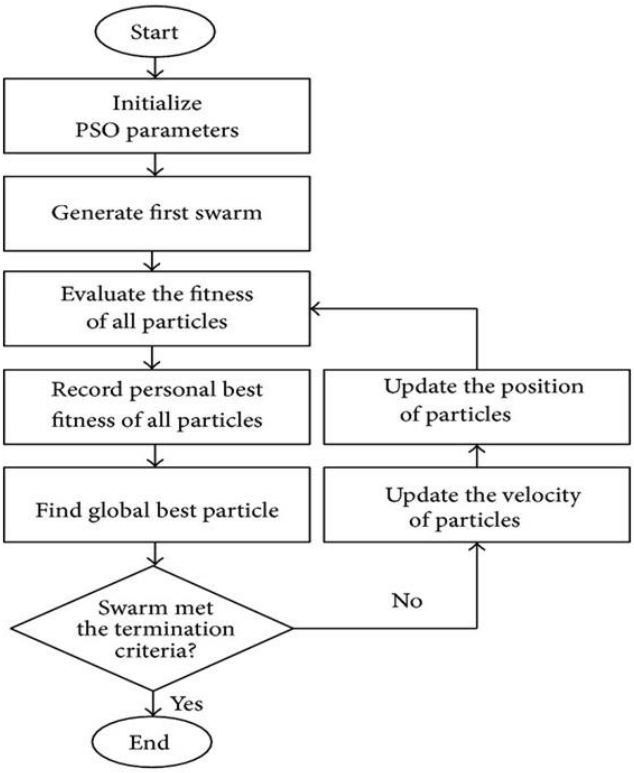

Figure 3. Flowchart of the PSO Evolutionary algorithm

TABLE III. TEST TABLE

	Type of Activity	Points	Inputs in Matlab	Particle Variables
1	Education length at bachelor period	1 to 6	Ex-uni-Length	a
2	The average of the university of M.Sc. education place	12 to 20	Ex-uni-Average	b
3	The winners of student scientific Olympiads	0 to 5	Olympiad-Chosen	c
4	The quality of the university of M.Sc. education place	1 to 11	Ex-Uni-Quality	d
5	Credible language certification	4 to 10	IELTS	e
6	Scientific extension papers, journal articles and prestigious conferences papers	0 to 17	Papers	f
7	Chosen at a prestigious festival	0 to 7	Festival-Chosen	g
8	Book compilation or translation, related to the field of study and patent accepted by Industrial Scientific Research Institute of Iran	0 to 11	Book-Invention	h
9	The quality of masters' dissertation or thesis	1 to 4	Msc-Thesis-Quality	i
10	The total number of the specialized test or interview	1 to 30	Interviews-Test	j
-	Result	Class(1, 2, 3)	Qualification	-

Figure 4 presents the output generated by PSO for 100 Iterations for three classes. As presented the cost function converges with optimized values.

C. Generating the fuzzy model

Based on Prof Lotf-Ali Asgarzade, founder of fuzzy logic and fuzzy sets [10], as complexity increases, exact sentences lose their meaning, and meaningful sentences their precision. Following this rule, there is a need for converting the absolute results to the results possessing range. The fuzzy hypothesis is also based on this. Considering the similarity of fuzzy concept and probabilities, it can never be possible to say that these two concepts are one. For instance, in crisp problems, we say: "an accident occurred", but in a similar fuzzy case, we say: "how much the damage was", and for instance the intensity of it is shown as between a range of 0 and 1 [11], [12]. A view of a fuzzy model is available in Figure 5.

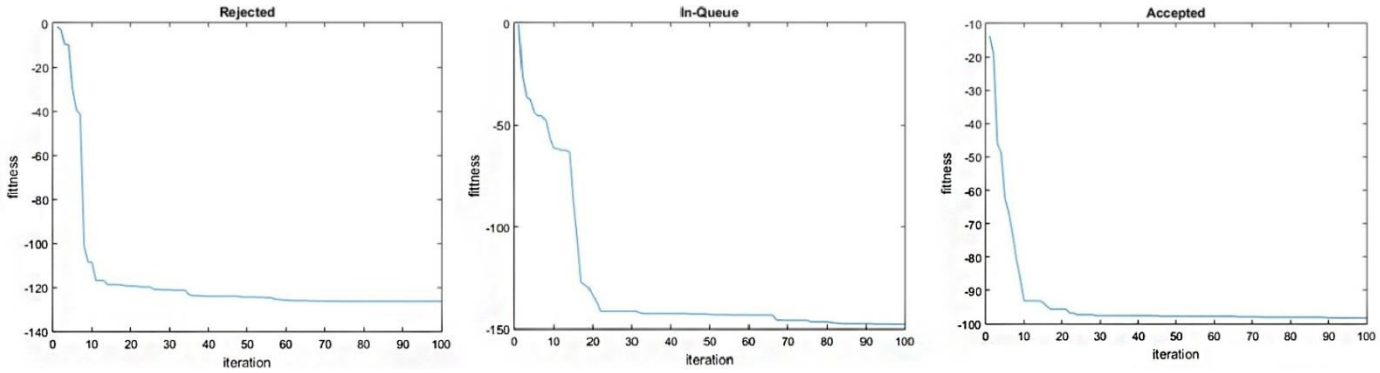

Figure 4. The generated output by PSO for three classes

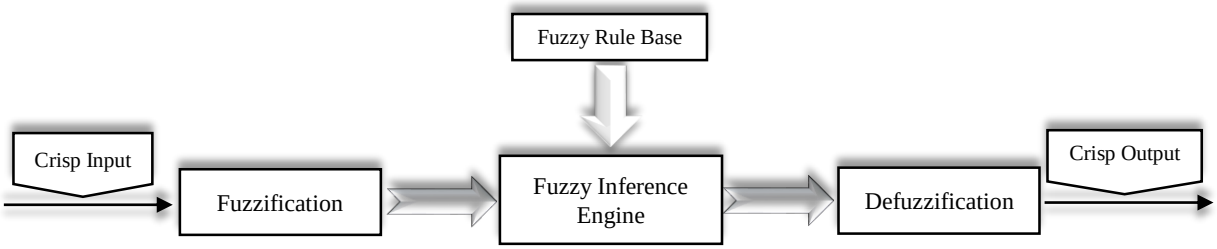

Figure 5. The structure of fuzzy model

PSO obtains a group of ranges for input variables for all three classes of acceptance, unacceptance and in queue. Afterwards, the fuzzy model generator uses a group of ranges for generating the membership functions and classification rules of fuzzy model. There are ten fuzzy sets, which each set includes three linguistic words of High, Medium and low, but these values are not always constant and depend on the number of fuzzy sets, generated by the fuzzy model generator, which classify each time for each student. These linguistic words are specified by PSO and input data.

The number of fuzzy rules is variable between 3 to 10. The final output variable is just a number, possessing Trapezoidal distribution. Also, this output variable possess three linguistic words namely Accepted, In-Queue, Rejected, which form classes of the system. All input distributions are considered Gaussian. The inference method has been specified as Mamdani, and Defuzzification method is also performed as Centroid. The fuzzy sets for input variables of Table III, are available in Table IV. The acquired fuzzy sets of Table IV, are available in Figure 6.

TABLE IV. A GROUP OF RANGES, ACQUIRED BY PSO, AND FORM THE RANG OF FUZZY SET VARIABLES

	Type of Activity	Rejected	In- Queue	Accepted
1	Education length at bachelor and M.Sc. period in year	[3 4] [3 6]	[2 4] [2 3]	[2 3] [2 2]
2	The average of the university of bachelor and M.Sc. education place	[12 15] [12 16]	[15 19] [16 18]	[17 20] [16 20]
3	The winners of student scientific Olympiads	[1 2] [1 1]	[1 4] [2 4]	[3 5] [2 5]
4	The average quality of the university of bachelor and M.Sc. education place	[3 8] [1 7]	[6 9] [7 8]	[7 11] [6 10]
5	Credible language certification	[1 5] [2 6]	[6 9] [5 9]	[7 9] [6 10]
6	Scientific extension papers, journal articles and prestigious conferences papers	[5 10] [2 7]	[10 14] [8 13]	[10 17] [12 16]
7	Chosen at a prestigious festival	[1 2] [1 3]	[3 5] [2 3]	[4 7] [5 7]
8	Book compilation or translation, related to the field of study and patent	[2 3] [1 5]	[6 10] [4 8]	[8 11] [6 9]
9	The quality of masters' dissertation or thesis	[1 2] [1 3]	[2 3] [2 4]	[3 4] [4 4]
10	The total number of the specialized test or interview	[9 16] [11 17]	[10 15] [11 21]	[15 30] [20 30]

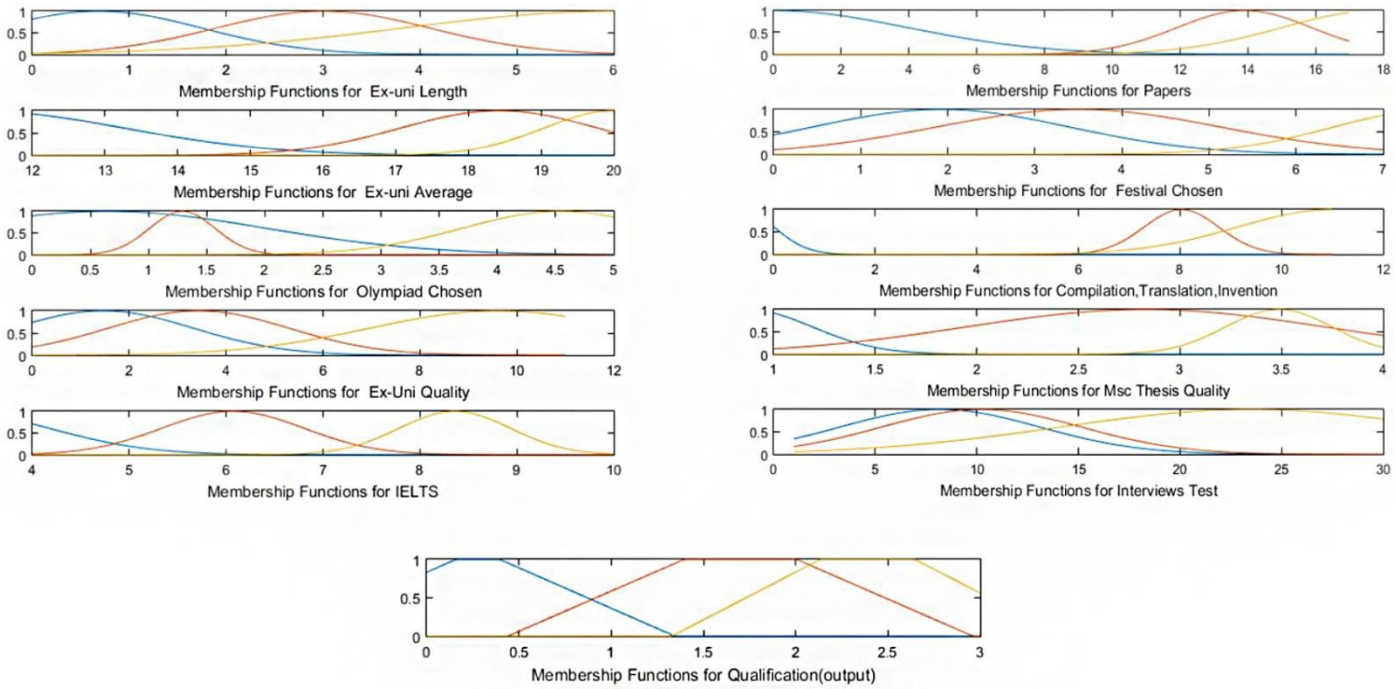

Figure 6. Fuzzy sets of the input and output variables

A fuzzy set of specified ranges are defined by PSO. For instance, if the fuzzy sets related to 10 input variable are present around Low linguistic variable, PSO puts them in the range of unacceptance, and if the variables are present in the range of Low, Med, or Med, High, then the system allocates a value between 0 and 1 for them. When fuzzy sets generated automatically, then fuzzy rules and contents of Table IV will be generate by fuzzy model generator. For instance, the following fuzzy rules for the acceptance situation is generated automatically:

IF Ex-uni-Length IS MED AND Ex-uni-Average IS HIGH AND Olympiad-Chosen IS MED AND Ex-Uni-Quality IS HIGH AND IELTS IS HIGH AND Papers IS HIGH AND Festival-Chosen IS LOW AND Book-Invention IS MED AND Msc-Thesis-Quality IS HIGH AND Interviews-Test IS HIGH THEN Qualification IS Accepted

IF Ex-uni-Length IS LOW AND Ex-uni-Average IS HIGH AND Olympiad-Chosen IS HIGH AND Ex-Uni-Quality IS LOW AND IELTS IS HIGH AND Papers IS HIGH AND Festival-Chosen IS HIGH AND Book-Invention IS HIGH AND Msc-Thesis-Quality IS HIGH AND Interviews-Test IS MED THEN Qualification IS Accepted

Also, for instance, for In Queue and unacceptance there are respectively:

IF Ex-uni-Length IS HIGH AND Ex-uni-Average IS MED AND Olympiad-Chosen IS LOW AND Ex-Uni-Quality IS MED AND IELTS IS MED AND Papers IS MED AND Festival-Chosen IS LOW AND Book-Invention IS MED AND Msc-Thesis-Quality IS MED AND Interviews-Test IS MED THEN Qualification IS In-Queue

IF Ex-uni-Length IS LOW AND Ex-uni-Average IS HIGH AND Olympiad-Chosen IS LOW AND Ex-Uni-Quality IS LOW AND IELTS IS MED AND Papers IS MED AND Festival-Chosen IS LOW AND Book-Invention IS LOW AND Msc-Thesis-Quality IS LOW AND Interviews-Test IS MED THEN Qualification IS Rejected

D. Inference Engine

The Mamdani method's [13] is employed for inferring acceptance condition of candidate from 10 input Crisp variable related to the Table III. The fuzzy logic toolbox of Matlab software is employed to implement total process [14]. Figure 7 presents fuzzy inference of acceptance condition with the following input values.

[14.73; 3.665; 7.932; 5.548; 16.1; 7.505; 5.324; 3.112; 19.4; 2.684]

Fuzzy inference takes place in four stages. Initially, Crisp input variables along the Fuzzification phase convert to fuzzy form; then, the phase of rule evaluation takes place. In Figure 7, fuzzy rule is employed. The method of Min is also used for AND operator. In the next phase, rules of results gather in a fuzzy set using Max composition method. Finally, in Difuzzification phase, a Crisp output using Centroid method will be achieved. For instance, in Figure 7, this value is equal to (2.07), which is at the acceptance range and in queue, and tends more to acceptance. The output is a number between 0 and 3, which if being greater than 2, means acceptance, and if being between 1.3 to 2.1, means in queue, and lower than 1.3 means unacceptance. For more information on fuzzy-expert systems, refer to [15].

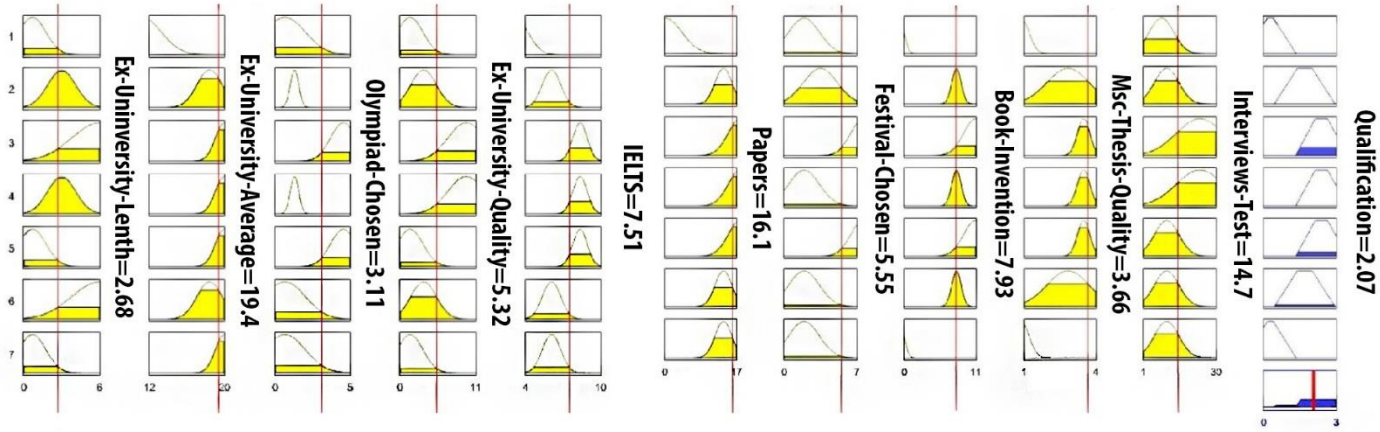

Figure 7. Fuzzy inference of acceptance condition on 7 fuzzy rules

I. TESTS, VALIDATIONS AND RESULTS

In order to simplification, Table III being the summarized of prior tables has been used in tests. It is clear that these values are variable and able to be used in the similar cases. All the tests were taken place on 15 samples of PH.D students by 3 human experts, and in 3 days; each day one hour. The acquired ranges, acquired by PSO, were employed by the fuzzy model generator, for generating the membership functions of input variables. As the same way, the PSO outputs and generated fuzzy sets have been used for generating the 7 fuzzy classification rules, as shown in Figure 7. After classification process, validation should take place against human expert. New acquired values, acquired by the system, undergo comparison with the initial generated values, generated by human expert, and in the case of conflict, the values update. Comparison of acquired values, acquired by the system and human expert, are available in Table V.

First column indicates the row number, and the second, the initial classification by human expert. The third column indicates acquired results of Crisp by the system, which are between the range of 0 and 3. The fourth column indicate the linguistic word related to Crisp output. The last three columns indicate the classification of human experts. The agreement level or the similarity of each pair of acquired results by the human experts and system are computed by Weighted kappa method in SPSS, and available in Table VI [16], [17], [18]. A strong connection in Kappa is shown with a number larger than 0.9, and a weak connection is lower than 0.6. As the Table indicates, the least of agreement level with the value of 0.61 is related to human expert of 1 and 2, and the highest agreement level with the value of 0.92 relates to the expert system and human expert 2.

TABLE V. THE DATA FOR VALIDATING THE EXPERT SYSTEM

	Initial Classification Data by Masters	Expert System Crisp Values	Expert System Linguistic Words	First Human Expert	Second Human Expert
1	Accepted	2.31	Accepted	Accepted	Accepted
2	Accepted	2.86	Accepted	Accepted	Accepted
3	Rejected	0.79	Rejected	Rejected	Rejected
4	In- Queue	1.90	In- Queue	Rejected	In- Queue
5	In- Queue	2.15	Between In-queue and accepted	In- Queue	Between In-queue and accepted
6	Rejected	1.47	Between Rejected and In-queue	Rejected	In- Queue
7	Accepted	2.20	Between Accepted and In-queue	In- Queue	Accepted
8	Accepted	2.76	Accepted	Accepted	Accepted
9	Accepted	2.11	Accepted	Accepted	Accepted
10	In- Queue	1.85	In- Queue	In- Queue	In- Queue
11	In- Queue	1.91	In- Queue	In- Queue	Between Rejected and In-queue
12	In- Queue	1.84	In- Queue	In- Queue	In- Queue
13	Accepted	2.13	Accepted	In- Queue	Accepted
14	Rejected	0.63	Rejected	Rejected	Rejected
15	Rejected	1.12	Rejected	Rejected	Rejected

TABLE VI. THE ACQUIRED VALUES BY THE WEIGHTED KAPPA METHOD

Agreement Level	First Human Expert	Second Human Expert	Expert System
First human expert	-	0.61	0.79
Second human expert	0.61	-	0.92
Expert system	0.79	0.92	-

I. CONCLUSION, DISCUSSION AND SUGGESTION

The university professors provide the initial input and basic classification, and then the evolutionary fuzzy-expert system with the aid of PSO adjusts again the initial input values, entered by professors. The system has been tested in real situations, and has been evaluated successfully for human expert. Table VI indicates that human expert has operated correctly only in one case, and other cases are accompanied by a few errors except in output of expert system. This system can work simply for other similar scoring cases in educational cases and other cases. It is suggested this system be employed for cases of discrete master's level degree, and also educational institutions. This system is also able to be employed to work as a referee in boxing and other sport fields which are held in an equal situation.

References

[1] Ngai, E. W. T. and F. K. T. Wat. "Design and development of a fuzzy expert system for hotel selection." Omega 31.4 (2003): 275-286.

[2] Fasanghari, Mehdi, and Gholam Ali Montazer. "Design and implementation of fuzzy expert system for Tehran Stock Exchange portfolio recommendation."Expert Systems with Applications 37.9 (2010): 6138-6147.

[3] Mitchell, Melanie (1996). "An Introduction to Genetic Algorithms". Cambridge, MA: MIT Press. ISBN 9780585030944.

[4] Verdú, Elena, et al. "A genetic fuzzy expert system for automatic question classification in a competitive learning environment." Expert Systems with Applications 39.8 (2012): 7471-7478.

[5] Bazmara, A. and S. Sardar Donighi. "Classification of Bank Customers for Granting Banking Facility Using Fuzzy Expert System Based on Rules Extracted from the Banking Data." Journal of Basic and Applied Research3.12 (2013): 379-384.

[6] Joseph, Giarratano, and Riley Gary. "Expert systems principles and programming." PWS Publishing Company 2 (1998): 321.

[7] J. Kennedy and R. Eberhart, "Particle swarm optimization. «Proc.» IEEE International Conf. on Neural Networks (Perth, Australia), IEEE Service Center, Piscataway, NJ, 1995 (in press).

[8] Coello, Carlos A. Coello, David A. Van Veldhuizen, and Gary B. Lamont. Evolutionary algorithms for solving multi-objective problems. Vol. 242. New York: Kluwer Academic, 2002.

[9] Zadeh, Lotfi A. "Outline of a new approach to the analysis of complex systems and decision processes." IEEE Transactions on systems, Man, and Cybernetics 1 (1973): 28-44.

[10] zimmermann h.j. "fuzzy set theory and its applications", 2nd edition,kluwer academic pub,(1991).

[11] Klir, G. J., & Folger, T .A., "Fuzzy sets,Uncertainty,and Information",Prentice-Hall,(1988).

[12] Mosqueira-Rey, E., Moret-Bonillo, V., & Fernández-Leal, Á. (2008). "An expert system to achieve fuzzy interpretations of validation data. Expert Systems with Applications", 35(4), 2089–2106.

[13] Akgun, Aykut, et al. "An easy-to-use MATLAB program (MamLand) for the assessment of landslide susceptibility using a Mamdani fuzzy algorithm." Computers & Geosciences 38.1 (2012): 23-34.

[14] Sivanandam, S. N., Sai Sumathi, and S. N. Deepa. Introduction to fuzzy logic using MATLAB. Vol. 1. Berlin: Springer, 2007.

[15] Kandel, Abraham. Fuzzy expert systems. CRC press, 1991.

[16] Viera, A. J., & Garrett, J. M. (2005). "Understanding interobserver agreement: The Kappa statistic. Family Medicine", 37(5), 360–363.

[17] Cohen, Jacob (1960). "A coefficient of agreement for nominal scales". Educational and Psychological Measurement. 20 (1): 37–46.

[18] Cohen, Jacob. "Weighted kappa: Nominal scale agreement provision for scaled disagreement or partial credit." Psychological bulletin 70.4 (1968): 213.

[19] Alexandrou-Leonidou, Vasso, and George N. Philippou. "TEACHERS'BELIEFS ABOUT STUDENTS DEVELOPMENT OF THE PRE-ALGEBRAIC CONCEPT OF EQUATION." International Group for the Psychology of M athematics Education (2005): 41.

[20] Anderson, Jonathan R. "On cooperative and competitive learning in the management classroom." Mountain Plains Journal of Business and Economics, Pedagogy 7 (2006): 1-10.