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A Fuzzy-Genetic Approach for Microcytic Anemia Diagnosis in Cyber Medical Systems

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Abstract Microcytic anemia is the most common type of anemia in the different age groups of people. Diagnosis in the early stages could increase the chance of the treatment. Fuzzy Expert System (FES) is one of the excellent methods employed for diagnosis of different diseases because of its tremendous potential in the management of uncertainty sources that exist in the real medical systems. In this article, a Genetic Algorithm (GA) has been used for optimizing the parameters of the Membership Function (MFs) of the proposed FES for diagnosis of microcytic anemia (IDA and BTT). The proposed hybrid system was implemented in Matlab and evaluated by real dataset from patients and healthy people. High accuracy of the proposed system confirms that this method can help physicians make more accurate decisions for the diagnosis of this type of anemia.

Keywords: *expert system, microcytic anemia, diagnosing, cyber medical systems*

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1. Introduction

The two most common types of microcytic anemia are iron deficiency anemia (IDA) and beta-thalassemia trait (BTT) that 1.5% of the people in the world have BTT. Each year 60000 children are born by BTT and most of them are from Southeast Asia [1]. Carrier rate of 5% for Beta thalassemia in Pakistan [2] 2 milliard people in the world suffer from IDA that 1 million people of them kill in each year [3]. Over the past years, there have been significant advances in the medical field, major improvements in the preventions and diagnosis of the disease [4]. Expert systems as a kind of decision making systems had an important role in the medical field [5].

There are some related works in diagnosing anemia using artificial intelligence technical. Some related works for instance, in this study represented Expert Fuzzy System (FES) to diagnose anemia that used a fuzzy logic model for diagnosing 3 case of anemia such as IDA, folic acid DA, sickle cell A [6] and A hybrid expert system combining rule-based and artificial neural network (ANN) models was constructed to evaluate some types of anemia in a 3-layered program [7].

In this article, a hybrid expert system for diagnosis of microcytic anemia has been designed using Fuzzy inference systems and GA (Fuzzy-GA). This paper is organized as follow: An overview of other related works explains in section 2. In section 3 try to show, how to diagnose iron deficiency anemia (IDA) from beta-thalassemia trait (BTT), explaining about designing of the FES and about what are Inputs/Outputs of proposed system. The results of performance of proposed Fuzzy-GA, explaining about data, and accuracy are presented in the section 4. and finally section 5 is about conclusions.

2. Review of Related Intelligent Models for Diagnosis of Anemia

There were some models for diagnosing anemia for example, diagnosis of anemia in children (<18) via Artificial Neural Network (ANN) by using feed forward multilayer perceptron with 3 layers architecture. 100 neurons used in hidden layer, activation functions: TANSIG, in toolbox of Matlab. Its inputs are HGB, HCT, MCV, MCH, MCHC (in C.B.C test). In this system just detected being anemia or not and can't diagnose common type of anemia but the proposed system in addition to diagnose being anemic or healthy, microcytic anemia also diagnose. As well as on how to recognize, the symptoms were not used that this is intended in the proposed system and enhance system reliability in diagnosis. The system can use just for helping doctors and can't work lonely. It used not enough real data [8]. There is another expert system that designed a fuzzy logic model to diagnose 3 case of anemia such as IDA, folic acid DA, sickle cell A with 5 symptoms of anemia. Its membership functions were triangular. It diagnosed 3 types of anemia such as IDA, folic acid DA, sickle cell A. Although with using FIS, the system takes advantages of managing uncertainty, in the system only the symptoms of anemia detection is used which reduces system reliability. Unlike the system, the proposed system has benefited both of them (blood test and anemia symptoms). The system can use just for helping doctors and can't work lonely, because of not having facility of check signs of patients. The system can't work for healthy people and just rely on symptoms of illness. It didn't regard other types of anemia in proposed system [6] but the proposed system in addition to detection in healthy subjects to investigate suspicious cases also pays and an expert system to diagnose anemia using (ANN) models to evaluate it in a 3-layered program. The inputs were HCT, MCV, and RDW (in C.B.C test). The diagnosed were 3 types of anemia: iron deficiency anemia (IDA), hemoglobinopathy (HEM) and anemia of chronic disease (ACD). It didn't regard other common types of anemia in proposed system and also healthy people [7]. A FIS presented which is used to simulate a prediction model for determining the likelihood of (SCA). It did in MATLAB software. The inputs of the system are 3 symptoms of sickle cell anemia (SCA) disease such as: the level of fetal hemoglobin, genotype and the degree of anemia. The output of system is diagnosis of SCA: No, likely, yes. Results showed that fuzzy logic based model will be very useful in this aim. It just works on especial case of anemia and patients. It considered inputs that aren't acceptable for all [15]. In the Table 1 provides an overview of comparison of studies that worked in this field with proposed system.

The proposed system can help experts for making decision for diagnosis of 2 types of microcytic anemia (IDA/BTT) from healthy and it shows good results and accuracy after evaluating. In our study by regarding some symptoms of anemia, C.B.C test, knowledge of experts and use of reliable relations after discussing for detecting some common types of anemia can diagnose more reliable of other research. All materials that need to diagnose illness are available for all.

3. Methodology

3.1. Diagnosing of Iron Deficiency Anemia (IDA) and Beta-Thalassemia Trait (BTT)

Iron deficiency anemia (IDA) is most common in development countries especially in Iran and beta-thalassemia trait (BTT) saw in especially areas more such as in Mediterranean area. There are more than 25000 thalassemia patients in Iran, is an important reason for diagnosing it in the early steps is necessary to design this system [9]. Detecting it in the early steps of the anemia development can increase the chance of improvement patients more. Iron deficiency anemia (IDA), is one of the most common type of anemia that patients with it are in different age groups and mostly women (20%) and children (80%) but treatment is different for them. It is caused by appearance of low count of blood cells in the patient's blood and high RDW. Normally, count of blood cells is an important part of the body's healthy [3,6,8].

There are many symptoms for different types of anemia. At the earlier steps, symptoms of anemia are in the low level. Common symptoms for anemia include fatigue, pale skin, irritability, tachycardia, and dizziness. Most people with iron deficiency anemia (IDA) have low Hemoglobin, not enough red blood cells (RBC), low MCV, low MCH and high RDW and symptoms of anemia such asirritability, tachycardia [6]. Although, most people with beta-thalassemia trait (BTT) won't show any symptoms, they have low Hemoglobin, not enough red blood cells or enough (RBC), low MCV, low MCH and high RDW. For detecting IDA from BTT blood tests of patients, the relations in Table 2 have been used that achieved good result in the studies of the researches [3,6,8,9].

Table 1. An Overview of the Related Works

Designer's name	Methodology	Inputs	Outputs	Advantages	Disadvantages
[8]	It used perceptron NN.	HGB, HCT, MCV, MCH, MCHC (in C.B.C test)	(healthy):0/(anemia):1	It takes advantages of training NN.	the system can't work lonely. not enough real data.
[6]	Using a fuzzy logic model.	Irritability, Tachycardia, Memory Weakness, Bleeding, Chronic fatigue	3 types of anemia: IDA, folic acid DA, sickle cell A	It takes advantages of FES such as: managing uncertainty .	It can't work lonely.
[7]	A hybrid expert system combining rule-based and artificial neural network.	HCT, MCV, RDW	iron deficiency anemia (IDA), hemoglobinopathy (HEM), anemia of chronic disease(ACD)	training and not tired, improve.	Regarding low feature for classifying cases of anemia.
[15]	A prediction FIS for determining the likelihood of (SCA)	3 symptoms of sickle cell disease	SCA: No, likely, yes	Results showed that fuzzy logic based model will be very useful in this aim.	Just work on especial case of anemia and patients use inputs that aren't acceptable for all.
[16]	Some FES for applications in some medical area.	For every application is different.	The risk of prostate cancer, risk of coronary heart disease, degree of child anemia, determination the level of iron deficiency anemia, diagnosis of periodontal dental disease, determination of drug dose and etc	As a tool can help doctors and takes Advantages of FES.	All designed FES just can help in support decision process of physicians and can't work lonely.
The proposed hybrid Fuzzy-GA system	Diagnosis of microcytic anemia from healthy using hybrid Fuzzy-GA.	Hb, MCV, MCH, RDW and RBC and 4 symptoms of IDA	Diagnosis: Healthy, IDA, BTT.	As a tool can help doctors and takes Advantages of the FES (won't tired, can improve, managing uncertainty) and Work on real data	Not suggestion has provided for treatment yet.

Table 2. Relations for Separating BTT from IDA [2]

Index	Relations	BTT	IDA
England & Fraser	MCV-(5xHb)-RBC	<0 (neg)	>0 (pos)
Mentzer	MCV/RBC count	<13.0	>13.0
Srivastava	MCH/RBC count	<3.8	>3.8
Shine & Lal	MCVxMCVxMCH/100	<1530	>1530
Green & King	MCVxMCVxRDW/(Hbx100)	<72	>72
Ricerca	RDW/RBC count	<3.3	>3.3
RDWI	MCVxRDW/RBC	<220	>220

The main reason of the Anemia is malnutrition. The human body tissues needed to receive oxygen from the RBC. As a result of decreasing it, people (he or she) may develop anemia. People should report all possible anemia symptoms to the related experts very fast.

Experts need to look at the people's C.B.C test to diagnose Anemia. This test is a test that most people have had periodically and then Cells must be counted [3].

3.2. The Proposed Fuzzy Expert System

The proposed FES has been implemented in the following steps: there is a step before main steps to study the issue and collecting relevant data, then [10].

1) Partitioning input space of the system
2) Extracting related rules (if-then rules)
3) Choosing an appropriate inference model

The knowledge of experts was used in the proposed fuzzy expert system to diagnose the microcytic anemia in the early steps. After gathering information from reliable references and related experts, the inputs and outputs of proposed system for diagnosis of microcytic types of anemia determined. As show in Table 3 the C.B.C tests and some symptoms of anemia in the preliminary conditions of disease have been considered in the input of the proposed system. Because of high precision of the Mamdani model it has been utilized in the proposed FES. The proposed FES fuzzy rules are shown in Table 4.

Table 3. Inputs of the Proposed System

Inputs	Explain
Hb	Hemoglobin
MCV	Mean corpuscular volume
MCH	Mean Corpuscular Hemoglobin
RDW	red cell mean distribution width regard as a third index in diagnosing microcytic anemia is a measure of variability in red cell size
RBC	It carries oxygen to the human body.
Irritability	Easily made angry
Tachycardia	An abnormally rapid heart rate
Dizziness	Feeling dizziness
Fatigue	Feeling weakness and weariness

Table 4. Fuzzy Rules of the Proposed System

Rules Numbers	**Rules**
1.	If (HB is VERY-LOW) and (MCV is LOW) and (MCH is LOW) and (RDW is HIGH) and (RBC is LOW) and (Irritability is YES) and (Tachycardia is YES) and (Dizziness is YES) and (Fatigue is YES) then (DIAGNOSIS is IDA)
2.	If (HB is LOW) and (MCV is VERY-LOW) and (MCH is LOW) and (RDW is MIDDLE) and (RBC is MIDDLE) and (Irritability is NO) and (Tachycardia is NO) and (Dizziness is NO) and (Fatigue is NO) then (DIAGNOSIS is BTT)
3.	If (HB is LOW) and (MCV is VERY-LOW) and (MCH is LOW) and (RDW is MIDDLE) and (RBC is HIGH) and (Irritability is NO) and (Tachicardia is NO) and (Dizziness is NO) and (Fatigue is NO) then (DIAGNOSIS is BTT)
4.	If (HB is MIDDLE) and (MCV is MIDDLE) and (MCH is MIDDLE) and (RDW is MIDDLE) and (RBC is MIDDLE) and (Irritability is NO) and (Tachicardia is NO) and (Dizziness is NO) and (Fatigue is NO) then (DIAGNOSIS is HEALTHY)
5.	If (HB is VERY-LOW) or (MCV is LOW) or (MCH is LOW) or (RDW is HIGH) or (RBC is LOW) then (DIAGNOSIS is NEEDTOMORECHECK)
6.	If (HB is LOW) or (MCV is VERY-LOW) or (MCH is LOW) or (RDW is MIDDLE) or (RBC is MIDDLE) then (DIAGNOSIS is NEEDTOMORECHECK)
7.	If (HB is LOW) or (MCV is VERY-LOW) or (MCH is LOW) or (RDW is MIDDLE) or (RBC is HIGH) then (DIAGNOSIS is NEEDTOMORECHECK)
8.	If (HB is HIGH) or (MCV is HIGH) or (MCH is HIGH) or (RDW is LOW) or (RBC is HIGH) then (DIAGNOSIS is NEEDTOMORECHECK)
9.	If (HB is HIGH) or (MCV is HIGH) or (MCH is HIGH) or (RDW is LOW) or (RBC is HIGH) or (Irritability is YES) or (Tachicardia is YES) or (Dizziness is YES) or (Fatigue is YES) then (DIAGNOSIS is NEEDTOMORECHECK)
10	If (HB is MIDDLE) and (MCV is MIDDLE) and (MCH is MIDDLE) and (RDW is MIDDLE) and (RBC is MIDDLE) then (DIAGNOSIS is HEALTHY)

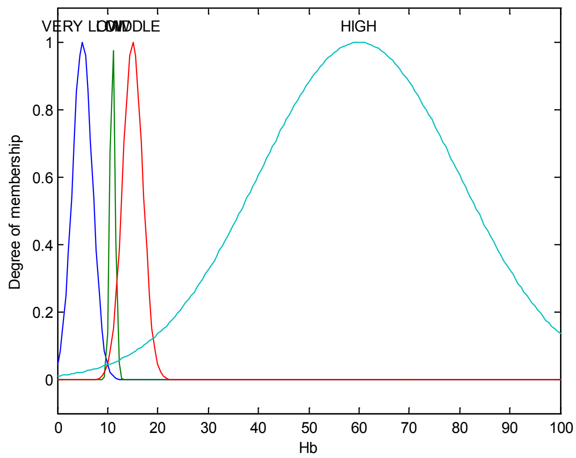

Figure 1. MFs of input1 of the proposed FES before optimization

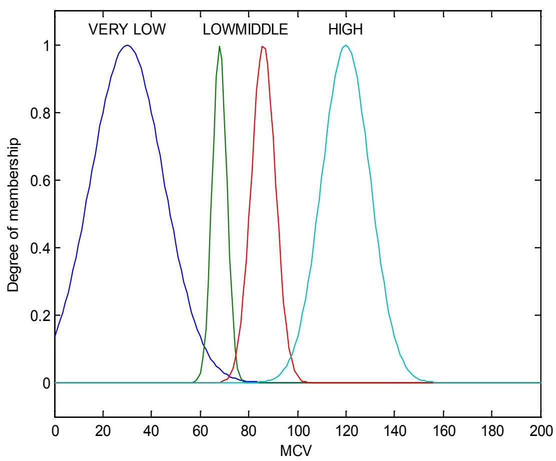

Figure 2. MFs of input2 of the proposed FES before optimization

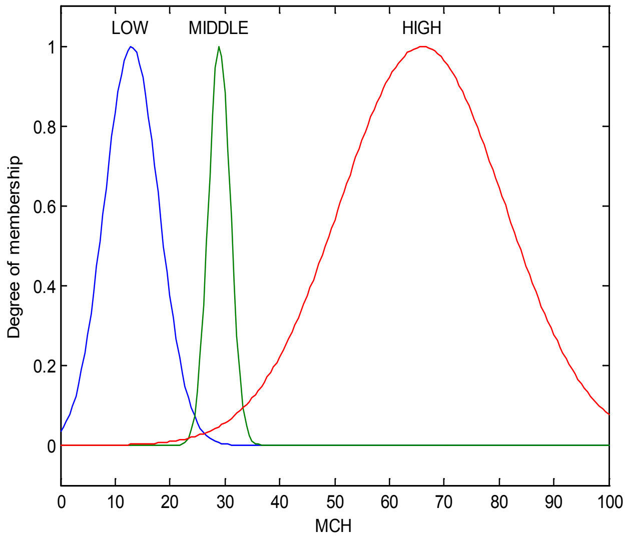

Figure 3. MFs of input3 of the proposed FES before optimization

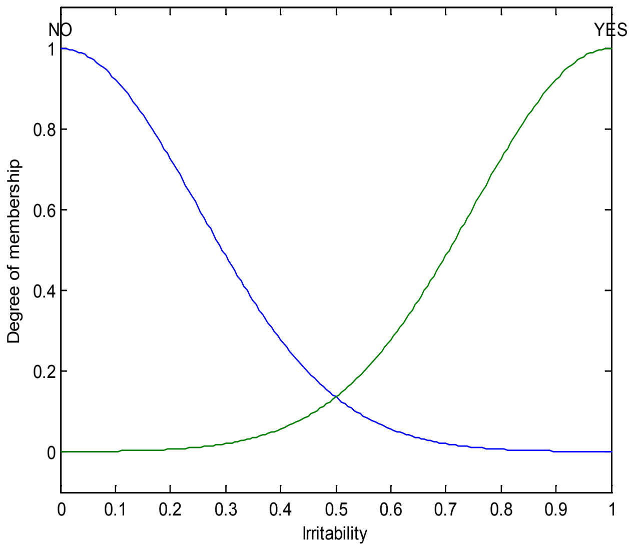

Figure 6. MFs of input6 of the proposed FES before optimization

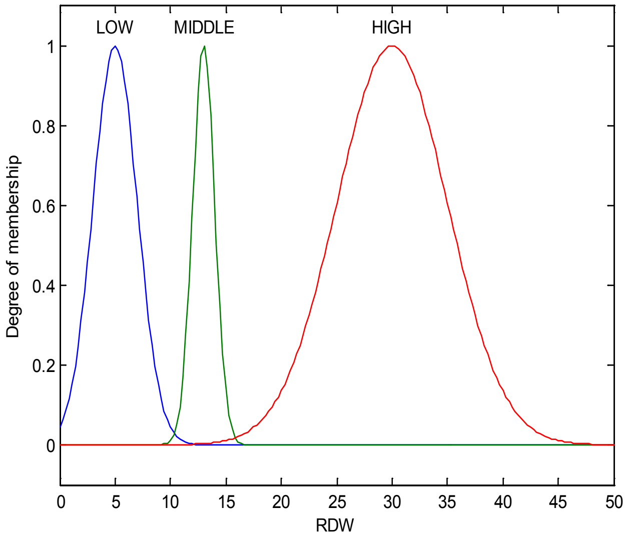

Figure 4. MFs of input4 of the proposed FES before optimization

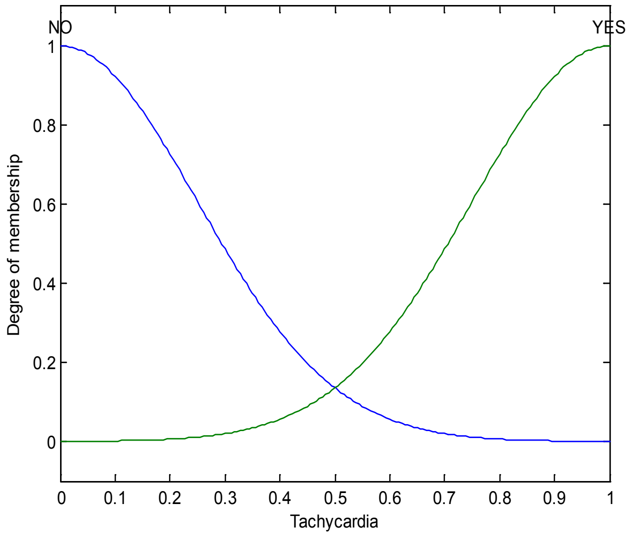

Figure 7. MFs of inputs7 of the proposed FES before optimization

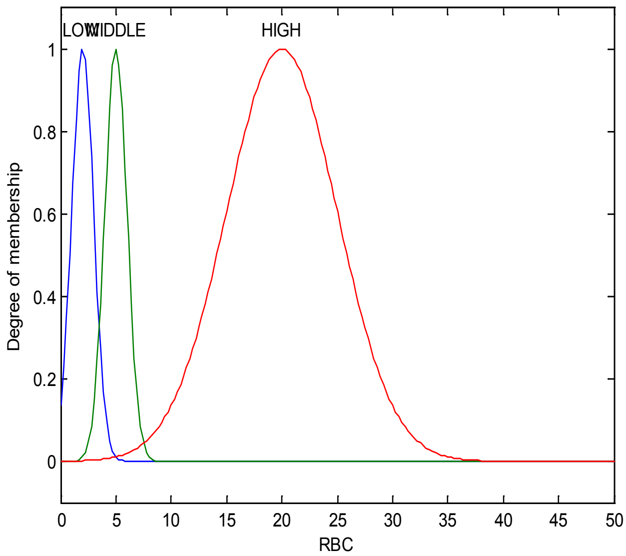

Figure 5. MFs of input5 of the proposed FES before optimization

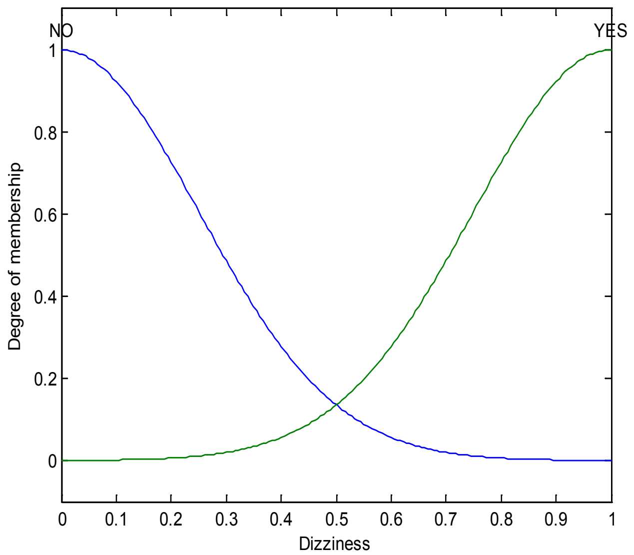

Figure 8. MFs of input8 of the proposed FES before optimization

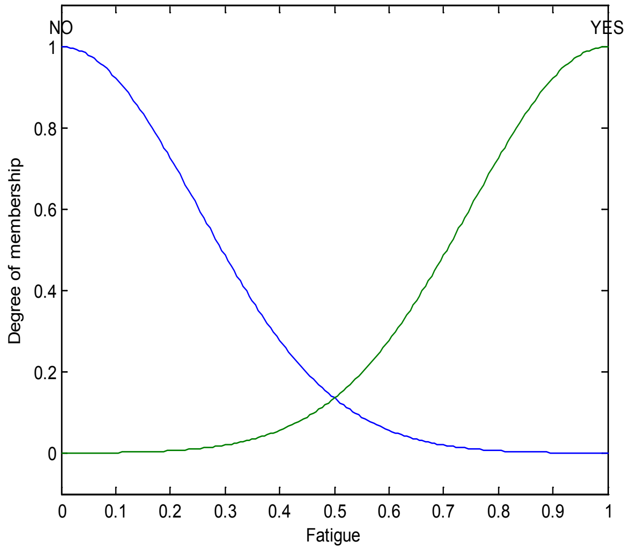

Figure 9. MFs of input9 of the proposed FES before optimization

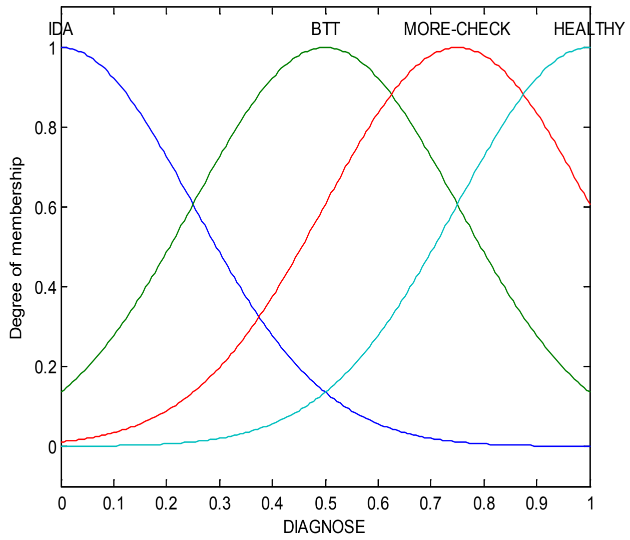

Figure 10. MFs of output1 of the proposed FES before pptimization

The Membership Functions (MFs) figures related to each input/output of the proposed FES before optimization is shown in Figure 1 to Figure 10.

3.3. The Proposed Hybrid Fuzzy-GA

The parameters of the MFs of the proposed FES were tuned with the genetic algorithm in this study that is done in the following steps, are shown in Figure 11:

1. Determine the proposed FES structure as an objective function.
2. Find the MFs parameters of the FES and used them as a chromosome for GA.
3. Set the GA parameter values.
4. Apply the necessary constraints to product valid chromosome.
5. Run the GA for evolving the FES.

The real values of the MFs parameters has been sort for building a chromosome and all knowledge that is used in the system has been gathered from related experts. The values of the GA operations such as crossover and mutation must determine [11,12,13,14] that all of them within the allowed amounts have been selected (mutation and crossover were considered with low amount because of keeping good genes and high for composition and use of superior genes, prospectively). This study has been considered the benefits and capabilities of a combination of both methods (the FES and GA) such as natural evolution and management of uncertainty and working with imprecise and uncertain data.

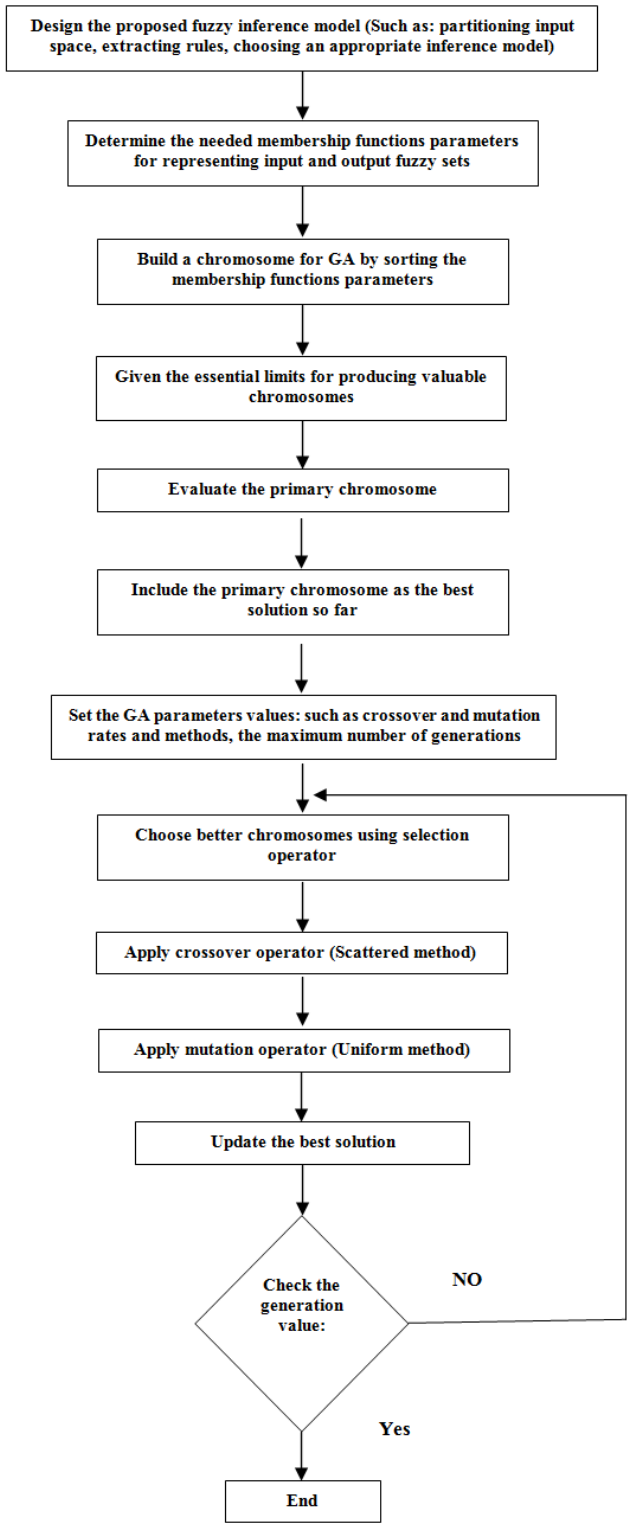

Figure 11. Implementation steps of the proposed hybrid system

4. Experimental Results

This section describes the data and the results of evaluating proposed system.

4.1. The Data That Used in the Proposed System

In the proposed Fuzzy-GA system used 51 real data from valid laboratory in Tehran. Data based includes 27 healthy data, 24 unhealthy data (Count Blood Cells (C.B.C) tests).

4.2. Results of Performance of Proposed Fuzzy-GA

The proposed study introduced a system to diagnose different types of microcytic anemia from healthy using a hybrid Fuzzy-GA system in the early steps of this disease.

The values of the mutation and crossover rate have been determined heuristically as are shown in Table 5. Table 6 shows the parameters of the GA that have been set for optimizing the proposed system and the system performance comparison is in Table 7. The Membership Functions (MFs) figures related to each input/output of the proposed FES after optimization using Fuzzy-GA system are shown in Figure 12 to Figure 21.

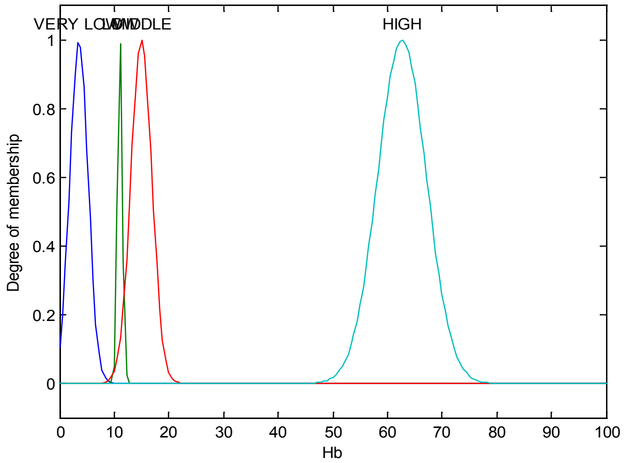

Figure 12. MFs of input1 of the proposed FES after optimization

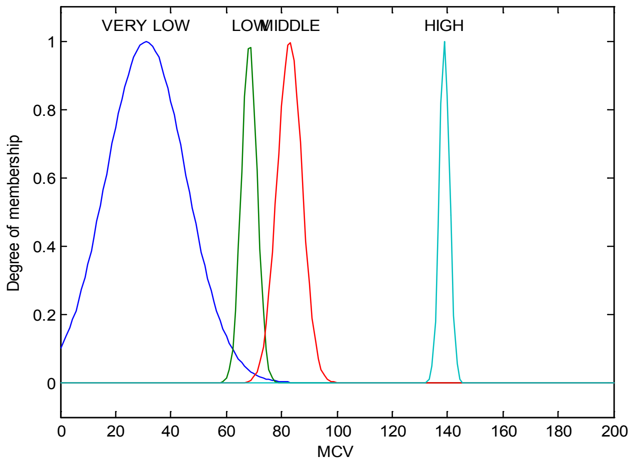

Figure 13. MFs of input2 of the proposed FES after optimization

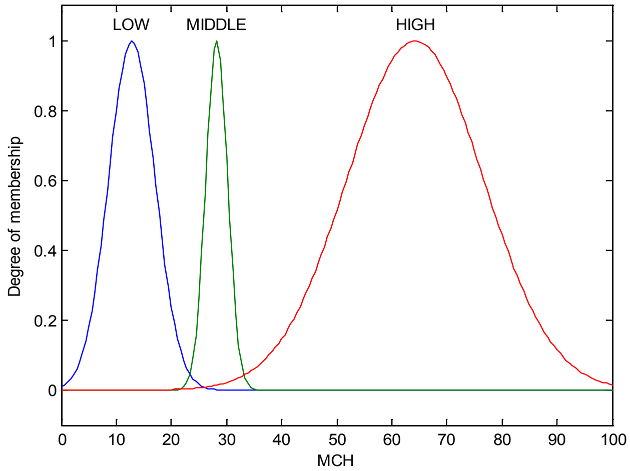

Figure 14. MFs of input3 of the proposed FES after optimization

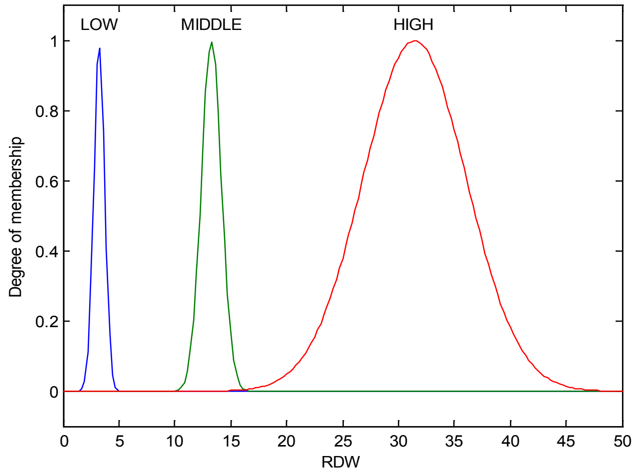

Figure 15. MFs of input4 of the proposed FES after optimization

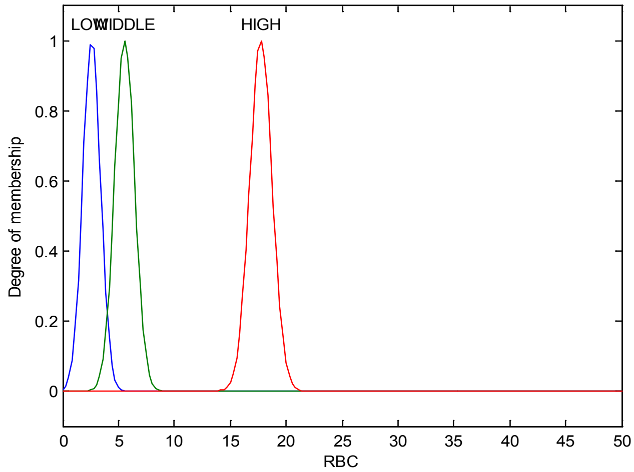

Figure 16. MFs of input5 of the proposed FES after optimization

Table 5. Comparison of the GA Parameters

Mutation Rate	Cross Over Rate	Fitness (MSE%)
0.05	0.5	88.2
0.001	0.88	93.6
0.15	0.7	80.6
0.1	0.9	79.4
0.001	0.99	90.1

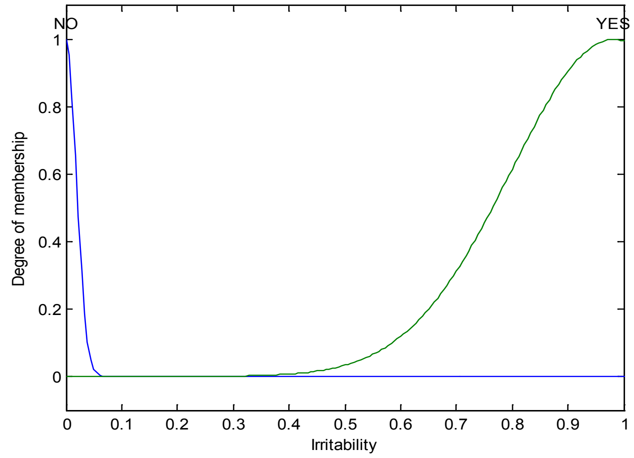

Figure 17. MFs of input6 of the proposed FES after optimization

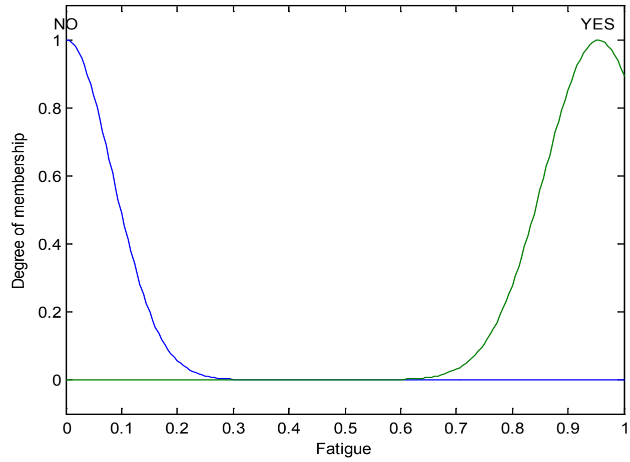

Figure 20. MFs of input9 of the proposed FES after optimization

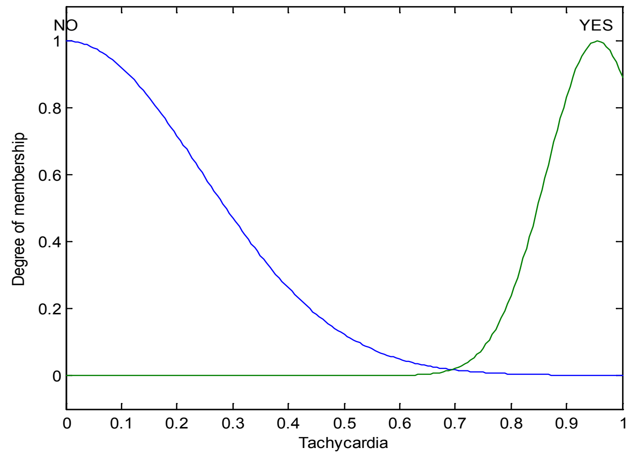

Figure 18. MFs of input7 of the proposed FES after optimization

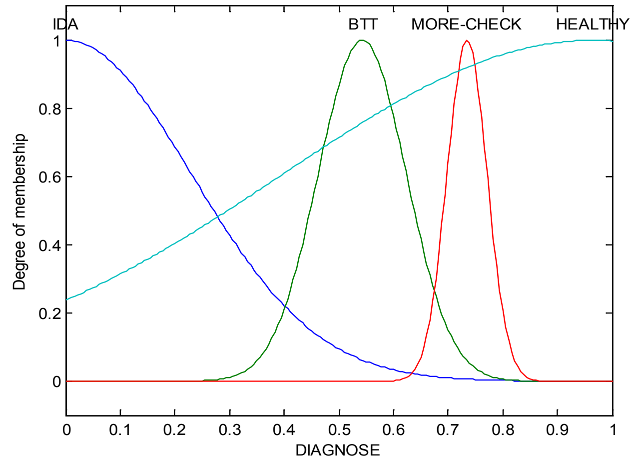

Figure 21. MFs of output1 of the proposed FES after optimization

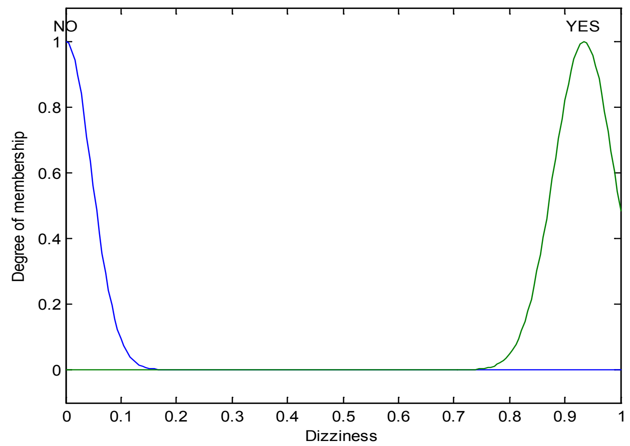

Figure 19. MFs of input8 of the proposed FES after optimization

Table 7. Comparison of the Performance of the System Evaluation Values Before and After Optimization

Methods name	MSE value	Accuracy (%)
FES (before optimization)	0.190	81.00
Fuzzy-GA(after optimization)	0.064	93.60

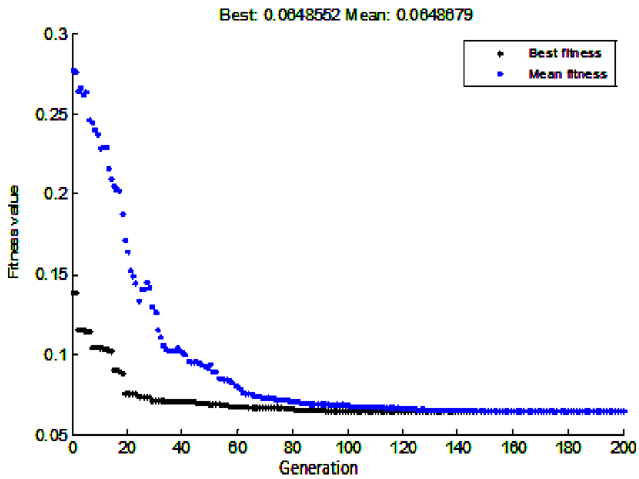

Figure 22. The best and average performance of the GA

Table 6. The Fuzzy-GA Parameters

Parameters names	Values
Population size	100
Crossover Rate	0.88
Mutation Rate	0.001
Crossover method	Scattered
Mutation method	Uniform
Select Strategy	Uniform
Number of generations	200

According to the figures (1 to 20) of membership functions of the proposed FES before and after optimization of their parameters, It can be noted that after optimization the membership functions has been set, as well as compare the results of the evaluation of the proposed FES before and after optimization using the evaluation criteria Mean Squared Error (MSE), indicates that the system performance is improved. The best and average performance of the Genetic Algorithm (GA) after evolving the proposed FES is shown in Figure 22.

As in the above figure is remarkable, system performance through optimization improved by reducing the amount of errors and this value from 140 generation to the next converged to a value. The average error after optimizing system parameters with the hybrid Fuzzy-GA system is 0.064 that is much less than the proposed FES before optimization (0.19).

5. Conclusion

This paper proposed a Fuzzy-GA to diagnose Microcytic Anemia (IDA and BTT) from healthy that they are common types of anemia using a combination of the FES and genetic algorithm. The proposed Fuzzy-GA was evaluated on real patents dataset.

The average error after tuning system parameters with the hybrid Fuzzy-GA approach is reduced from 0.19 to 0.064.Thetuned system can assist expert decision making for diagnosis of the anemia and healthy people. This approach is promising to assist early diagnosis of these types of anemia and takes advantages of fuzzy expert systems (won't tired, can improve, managing uncertainty) and genetic algorithm (natural evolution & not to need initializing). Our future work is to extend the FES for diagnosis of other types of the anemia or improve it. The results showed that the proposed Fuzzy-GA is able to diagnose the disease with high accuracy. There is different uncertainty in real system and the proposed system can manage them.

References

[1] Rathod, DA. Kaur, A. Patel, V. Patel, K. Kabrawala, R. Patel M, and Shah, P. (2007), "Usefulness of Cell Counter-Based Parameters and Formulas in Detection of ß-Thalassemia Trait in Areas of High Prevalence," American Society for Clinical Pathology, 128 (4), pp 585-589.

[2] Niazi, M. Tahir, M. e Raziq, F. and Hameed, A. (2010), "Usefulness of Red Cell Indices in Differentiating Microcytic Hypochromic Anemias," Gomal Journal of Medical Sciences, 8 (2), pp 125-129.

[3] Safari fard, AS. A. (1393), "Iron deficiency anemia", E-Health, Volume 6, Tehran, Iran.

[4] Shortliffe, E. H. and Cimino, J. J. (2006), "Biomedical informatics: computer applications in health care and biomedicine," Springer, New York, USA, Forth Edition.

[5] Durkin, J. (1994), "Expert Systems: Design and Development, Prentice Hall," New York, USA.

[6] Aramideh, J. and Jelodar, H. (2014), "Application of Fuzzy Logic for Presentation of an Expert Fuzzy System to Diagnose Anemia," Indian Journal of Science and Technology, 7(7), pp 933-938.

[7] Birndorf, N. I. Pentecost, J. O. Coakley, J. R. and Spackman, K. A. (1996), "An Expert System to Diagnose Anemia and Report Results Directly on Hematology Forms," Computers and Biomedical Research, 29 (1), pp 16-26.

[8] Kaya, E. Aktan, M. E. Koru, A. T. and Akdogan, E. (2014), "Diagnosis of Anemia in Children via Artificial Neural Network," International Journal of Intelligent Systems and Applications in Engineering, 3 (1), pp 24-27.

[9] Ghafouri, M. Mostaan Sefat, L. Sharifi, Sh. Hosseini Gohari, L. Attarchi, Z. (2006), "Comparison of cell counter indices in differentiation of beta thalassemia minor from iron deficiency anemia," volume 2, Issue 7, 385-389 special.

[10] Wang, L. Translators: Teshnehlab, M. Safarpoor, N. (2015), "A course in fuzzy systems and control," Tenth edition, Tehran, Iran.

[11] Cordona O., Gomideb F., Herreraa F., Hoffmann F., and L. Magdalenad. 2004. Ten years of genetic fuzzy systems: current framework and new trends. Fuzzy Sets and Systems 141: pp. 5-31.

[12] Casillas J., Cordón O., Del Jesus MJ., and F. Herrera. 2005. Genetic tuning of fuzzy rule deep structures preserving interpretability and its interaction with fuzzy rule set reduction. IEEE Transaction on Fuzzy Systems 13:13-29.

[13] Herrera, F. 2008.Genetic fuzzy systems: taxonomy, current research trends and prospects. Evolutionary Intelligence 1: 27-46.

[14] Ishibuchi, H., Nakashima, T. and T. Murata. 1996. A fuzzy classifier system that generates linguistic rules for pattern classification problems. Fuzzy Logic, Neural Networks, and Evolutionary Computation 1152:35-54.

[15] Idowu, AP. Aladekomo, TA. Williams, KO. and Balogun, JA. (2015), "Predictive Model for Likelihood of Survival of Sickle-Cell Anaemia (SCA) among Peadiatric Patients using Fuzzy Logic," Transactions on Networks and Communications, 3 (1), pp. 31-44.

[16] Allahverdi, N. (2014), "Design of Fuzzy Expert Systems and Its Applications in Some Medical Areas," International Journal of Applied Mathematics, Electronics and Computers, 2 (1), pp 1-8.