JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Fuzzy Expert System for detection of nutritional deficiency Anemia

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Abstract: Anemia is very common blood disorder worldwide. Iron and B12 deficiency type of anemia are mostly observed with similar symptoms. A system is needed to diagnose anemia so that patient will get proper treatment on time. Fuzzy expert system, assisted by concern domain expert, provide effective means for conflict resolution of multiple criteria and better assessment of options. This paper presents fuzzy expert system for detection of nutritional deficiency anemia with all possible combinations. The system takes four lab parameters as input and gives output as anemia type divided into twelve different categories. Rule base is developed under the guidance of expert physician. Mamdani inference mechanism with Best of Maxima as defuzzification method is used. The system is implemented in Matlab and tested on 150 patient's data. Results of system are compared with diagnosis of expert.

Keywords**: Fuzzy expert system, Anemia, MCV, Iron, B12.**

I. INTRODUCTION

Expert System (ES), one of the applications of Artificial Intelligence (AI), attempt to emulate thinking pattern of expert [1]. More specifically, ES is a computer program using expert knowledge to attain high level of performance in a narrow problem area [2]. According to activities performed ES are categorized as diagnosis, prediction, design & planning, debugging/repair and monitoring & control. Based on application areas, ES are categorized as Agriculture, Science (Physics, Maths and Chemistry), Engineering (Computer science and Electronics), Geology, Law, Manufacturing, Medicine, Military, Process control and Space technology etc. Since medicine domain is quiet natural for diagnosis applications, recent trends show increase in development of medical diagnosis expert system as mentioned in [3].

Fuzzy logic enables us to work with linguistic terms that human can understand for example-cool temperature, low speed etc. Ambiguities, vagueness and uncertainties are easily handled by fuzzy systems. Fuzzy combined with ES becomes Fuzzy Expert System (FES). FES is most popular area of Artificial Intelligence with wide future scope. An advantage of fuzzy expert systems is that the rules can be written in language that the expert can directly understand, such as "if age is about 40" or "if patient is very old", rather than complicated computer-programming statements. Thus, communication between domain expert and knowledge engineer is greatly eased.

Organization of rest of the paper is as follows. Section II clarify why anemia is selected as problem domain. Literature review is presented in section III. Details of proposed FES to detect Anemia such as input and output parameters, their relationships, rule base are elaborated in section IV. Section V throws a light on testing results of FES. Conclusion is presented at the end.

II. SELECTION OF PROBLEM DOMAIN AS ANEMIA

Anemia is a condition in which healthy red blood cells (RBC) are less to carry enough oxygen to tissues of body and carry CO_2 return to lungs. In India 68.4% children and 66.4% women suffer from anemia as per the survey in 2019. As symptoms of anemia are common such as over fatigue, pale skin, shortness of breath, weakness etc.; person is unaware that he/she is suffering from anemia. Unawareness of being suffered from anemia, increasing patients in hospitals, unavailability of specialists create more delay in diagnosis process.

Anemia is of several types such as nutritional deficiency anemia which include iron and folic acid/B12 deficiency, hemolytic anemia in which RBC destroy include sickle cell and thalassemia, other types in which less RBC generated in body include aplastic and fanconi anemia. Among all, iron and folic/B12 deficiency anemia is most commonly seen.

Waterman [2] said that build ES only if ES development is possible, justified and appropriate. As task does not require common sense, experts can articulate their methods of diagnosis, experts agree on solutions, the task is not too difficult; ES development for anemia is possible. ES development is also justified as human experts are scarce, too busy and require high payoff. ES development is appropriate as task has practical value, task is not too easy and of manageable size.

III. LITERATURE REVIEW

ES is a knowledge-based system that matches the knowledge and reasoning capabilities of human expert [4]. Previous systems for detection of anemia are reviewed and details are as follows.

Javad and Hamed [5] designed symptom-based FES. They considered symptoms- irritability, Tachycardia, memory weakness bleeding and chronic fatigue. Based on these symptoms, they investigated iron deficiency, B-12 deficiency and sickle cell anemia; with 42 rules in rule-base. The system was tested on sample data of 30 people with 86% of accuracy.

Sonu Malu et.al. [6] presented fuzzy system to diagnose iron deficiency and B-12 deficiency anemia. They considered input parameters as HB, MCV and MCHC.

Nidhi Mishra and P. Jha [7] proposed FES for assessing severity of hemolytic anemia. Parameters considered were level of HB and five other symptom-based parameters. The system with 11 rules tested on 15 patient's data with 80% of accuracy.

Tuba Karagül Yıldız et.al. [8] presented artificial learning methods for classifying anemia types on real patient data. Methods used include- Bagged decision tree (with highest accuracy of 85.6%), Artificial Neural network, Support Vector Machines and Naïve Bayes. Parameter selection out of 25 different parameters is done by applying different methods. The study considered 12 different types anemia. [9] , [10] also presented machine learning based approaches for predicting anemic condition.

Here, we must differentiate FES verses Machine Learning (ML) approach. The major difference is that FES are rule based systems which need process of knowledge acquisition from human expert, while ML approaches are based on statistical modeling of data. The FES can give explanation to the inference process as it is highly structured to simulate the steps and decision-making processes whereas ML is less structured and more complex, allowing the machine to make data-driven decisions, instead of specifying what to do and how to do it. In both cases, expert diagnosis is needed to test accuracy of system.

It can be concluded that existing FES are not up to the mark. Accuracy of symptom-based FES is less. Testing were not done on sufficient patient data. Output indicating types of anemia detected were limited.

IV. PROPOSED FES TO DETECT ANEMIA

4.1 Input Parameters & membership functions

We have considered following pathological parameters as input to FES as per the discussion with domain expert. Membership value intervals of input parameters are as shown in table 1.

- HB: Hemoglobin (HB) is a protein found in the red blood cells that transport oxygen in the body. Normal range of HB varies for male (12 to 16 g/dl) and female (11 to 15 g/dl).
- MCV: It is mean corpuscular volume. An MCV blood test measures the average size of your red blood cells. If MCV is low (MCV<80 μm^3) then it might be iron deficiency. If MCV is high (MCV<80 μm^3) then it might be B12 deficiency.
- Iron: Iron is a part of hemoglobin and an essential mineral found in foods we eat. Iron helps your body make new red blood cells.
- B12: Vitamin B12 is a nutrient that helps keep the body's blood and nerve cells healthy. Symptoms of iron & B12 deficiency are too similar to distinguish.

Table 1: Membership value intervals of input parameters

Inputs	Low	Normal	High
HB (g/dl)	<12 (for male) <11 (for female)	12-16(for male) 11-15 (for female)	>16 (for male) >15 (for female)
MCV (μm^3)	<80	80-97	>97
Iron (µg/dL)	<37	37-145	>145
B12 (pg/mL)	<187	187-883	>883

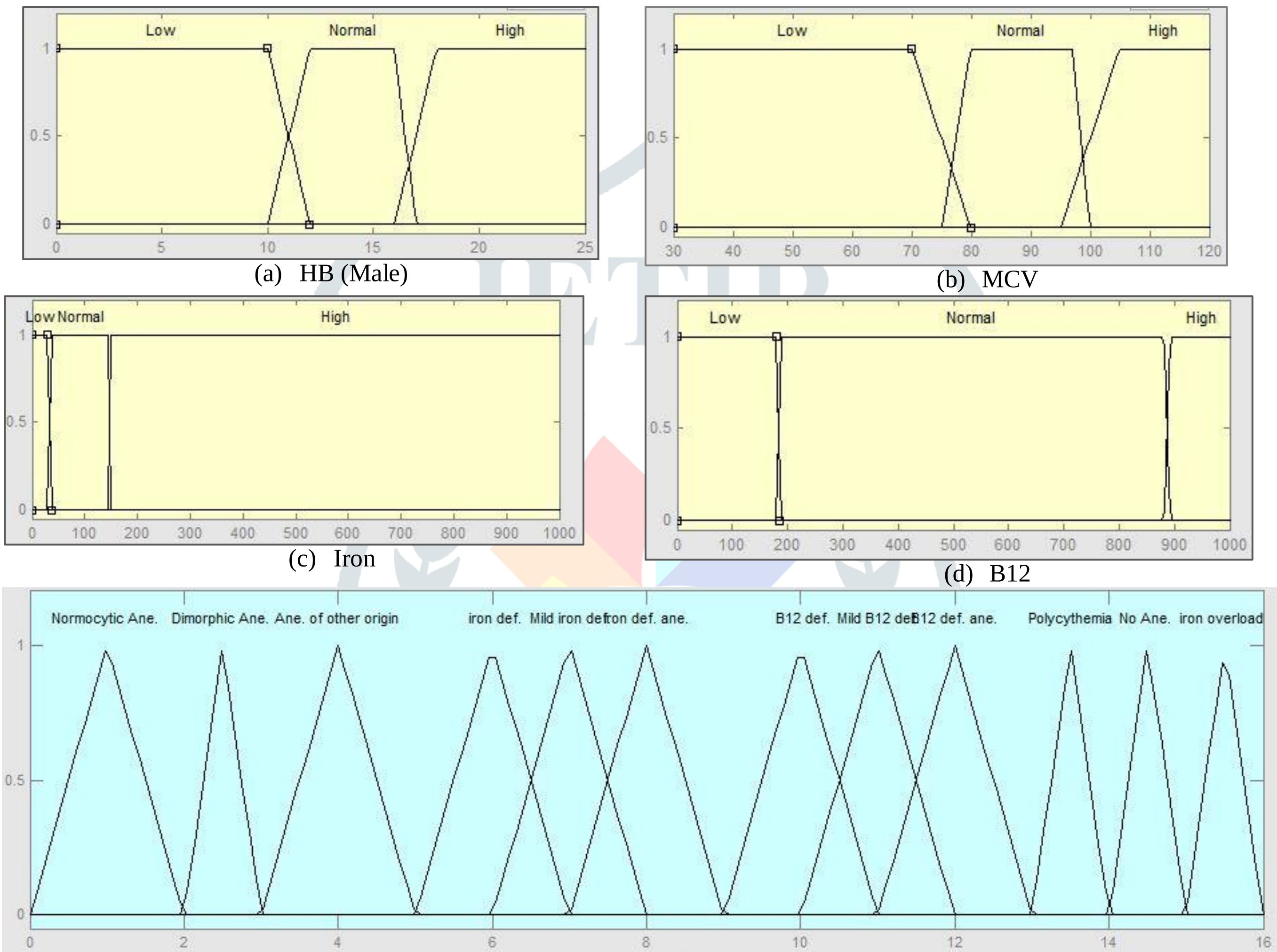
4.2 Output Parameters & membership functions

Output specifies the type of anemia detected. Here we have considered many variations of anemia as shown in table2. Iron and B12 deficiencies are further divided in 3 categories- deficiency not causing anemia, mild deficiency and (strong) deficiency. Cases of Normocytic anemia (having normal-sized red blood cells, but low in numbers) and Dimorphic anemia (MCV is normal, but having both Iron and B12 deficiency) are also considered. Polycythemia (may cause due to high HB) and Iron overload or Hemochromatosis (due to high iron) are also very problematic cases which can be detected based on input parameters (even though these are not directly related to anemia). Apart from these, patient can have "Anemia of other origin"-other than iron and B12 deficiency. Membership value intervals of output parameters are as shown in table 2. Fig.1 shows membership function graphs for input and output parameters.

Table2: Membership value intervals of output parameters.

Anemia type (number)	Anemia type (Description)	Membership value intervals
1	Normocytic anemia	0-2
2	Dimorphic anemia	2-3

3	Anemia of other origin	3-5
4	Iron deficiency not causing anemia	5-7
5	Mild iron deficiency	6-8
6	Iron deficiency Anemia	7-9
7	B12 deficiency not causing anemia	9-11
8	Mild B12 deficiency	10-12
9	B12 deficiency Anemia	11-13
10	Polycythemia	13-14
11	No anemia	14-15
12	Iron overload	15-16



(a) HB (Male)

(b) MCV

(c) Iron

(d) B12

(e) Anemia type

Fig.1: Membership function graphs for input and output parameters.

4.3 Rule Base

Patient is anemic only if HB is low. There can be various combinations of low HB and various values of other parameters. If HB is low, MCV is low then iron must be low causing iron deficiency. It is also called as microcytic anemia. If HB is low, MCV is high then B12 must be low causing B12 deficiency. It is also called as macrocytic or megaloblastic anemia. If HB is low and MCV is normal then there are two possibilities- dimorphic amenia (low iron and low B12, some blood cells are small and some are large, so average is normal, hence MCV is normal) and normocytic anemia (both iron and B12 normal). If HB is normal, then patient is non-anemic. Even if in non-anemic case, there is possibility of iron or B12 based deficiency depending on values of MCV, iron and B12. If HB is high then it may be polycythemia depending on RBC value. Classification of anemia is as shown in fig.2.

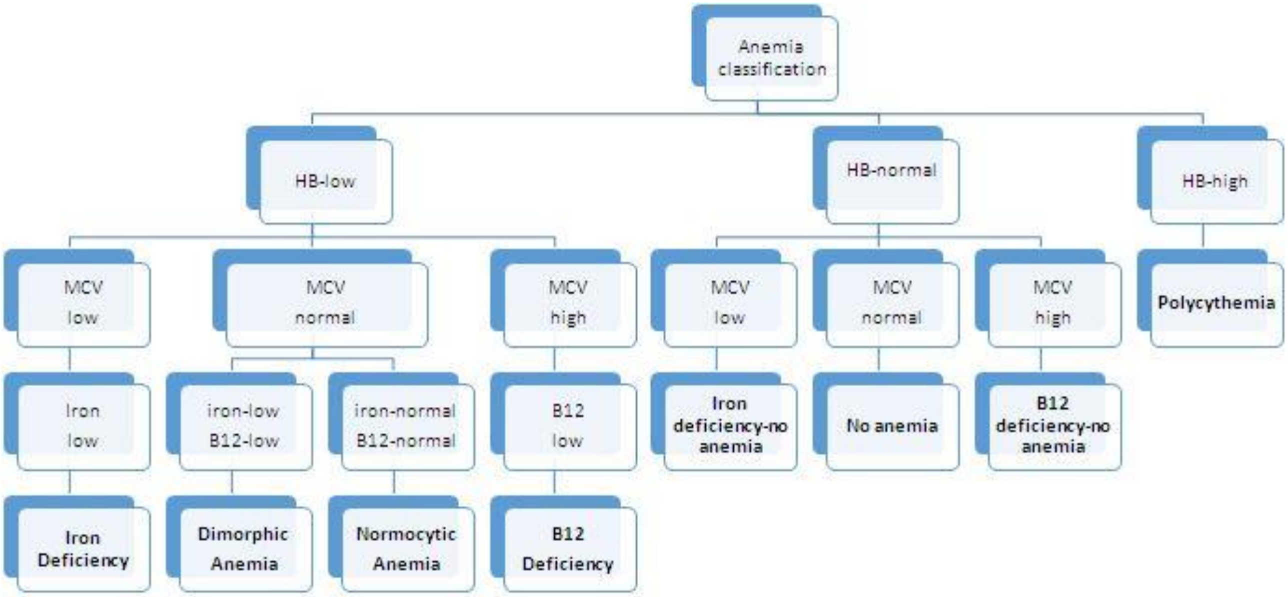


Fig.2: Classification of anemia

The FES with rule base consisting of 25 rules based on relationship between input and output parameters as discussed with domain expert are as shown in fig.3.

1. If (HB is Low) and (MCV is Normal) and (Iron is Normal) and (B12 is Normal) then (health_status is Normocytic Ane.) (1)
2. If (HB is Low) and (MCV is Normal) and (Iron is Low) and (B12 is Low) then (health_status is Dimorphic Ane.) (1)
3. If (HB is Low) and (MCV is Normal) and (Iron is High) and (B12 is High) then (health_status is Ane. of other origin) (1)
4. If (HB is Low) and (MCV is Normal) and (Iron is Normal) and (B12 is Low) then (health_status is Mild B12 def.) (1)
5. If (HB is Low) and (MCV is Normal) and (Iron is Normal) and (B12 is High) then (health_status is Ane. of other origin) (1)
6. If (HB is Low) and (MCV is Normal) and (Iron is High) and (B12 is Normal) then (health_status is Ane. of other origin) (1)
7. If (HB is Low) and (MCV is Normal) and (Iron is High) and (B12 is Low) then (health_status is Mild B12 def.) (1)
8. If (HB is Low) and (MCV is Normal) and (Iron is Low) and (B12 is Normal) then (health_status is Mild iron def.) (1)
9. If (HB is Low) and (MCV is Normal) and (Iron is Low) and (B12 is High) then (health_status is Mild iron def.) (1)
10. If (HB is Low) and (MCV is Low) and (Iron is Low) and (B12 is Normal) then (health_status is Iron def. ane.) (1)
11. If (HB is Low) and (MCV is High) and (Iron is Normal) and (B12 is Low) then (health_status is B12 def. ane.) (1)
12. If (HB is Low) and (MCV is High) and (Iron is Normal) and (B12 is Normal) then (health_status is Ane. of other origin) (1)
13. If (HB is Low) and (MCV is High) and (Iron is High) and (B12 is Normal) then (health_status is Ane. of other origin) (1)
14. If (HB is Normal) and (MCV is Normal) and (Iron is Normal) and (B12 is Normal) then (health_status is No Ane.) (1)
15. If (HB is Normal) and (MCV is Low) and (Iron is Low) and (B12 is Normal) then (health_status is iron def.) (1)
16. If (HB is Normal) and (MCV is High) and (Iron is Normal) and (B12 is Low) then (health_status is B12 def.) (1)
17. If (HB is Normal) and (MCV is High) and (Iron is High) and (B12 is Low) then (health_status is B12 def.) (1)
18. If (HB is High) and (MCV is Low) and (Iron is Low) and (B12 is Normal) then (health_status is Polycythemia) (1)
19. If (HB is High) and (MCV is Normal) and (Iron is Normal) and (B12 is Normal) then (health_status is Polycythemia) (1)
20. If (HB is High) and (MCV is High) and (Iron is Normal) and (B12 is Low) then (health_status is Polycythemia) (1)
21. If (HB is Normal) and (MCV is Normal) and (Iron is Normal) and (B12 is Low) then (health_status is B12 def. no ane.) (1)
22. If (HB is Normal) and (MCV is Normal) and (Iron is Low) and (B12 is Normal) then (health_status is iron def. no ane.) (1)
23. If (HB is Low) and (MCV is Low) and (Iron is Low) then (health_status is Iron def.) (1)
24. If (HB is Low) and (MCV is High) and (B12 is Low) then (health_status is B12 def.) (1)
25. If (HB is Normal) and (MCV is Normal) and (Iron is High) and (B12 is Normal) then (health_status is iron overload) (1)

Fig.3: Rule base for the anemia detection system.

V. TESTING AND RESULTS

The system developed was tested on data of 150 patients with variations in gender. Some of the data is obtained from pathology and some data is taken from dataset available online. The system results with BOM [17] as defuzzification method were obtained for the entire dataset. Expert diagnosis was also obtained by consulting the Expert. The system with BOM/PM as defuzzification method gives 93.33% accuracy for the data of 150 patients. Some sample test cases with system output and expert diagnosis are shown in table 3.

Table3: Sample test cases with system output and expert diagnosis.

Sex	Hemoglobin	MCV	Iron	B12	System output	Expert diagnosis
Male	13.8	99	140	182	B12 Def. no anemia	mild B12 def.
Male	12.2	81	31	194	iron Def. no anemia	mild iron def.
Male	11.2	97	80	175	B12 Def. no anemia	mild B12 def.
Male	8.2	91	150	192	anemia of other origin	anemia of other origin

Female	10.3	84	42	200	Normocytic	Normocytic
Female	12.8	76	35	192	iron Def. no anemia	iron Def. no anemia
Female	10.5	90	34	204	iron Def. no anemia	iron def.
Female	9	99	86	181	B12 deficiency	B12 deficiency
Female	8	79	34	411	mild iron def.	mild iron def.
Female	13	78	33	347	iron def. no anemia	iron def. no anemia
Female	10	79	34	374	mild iron def.	mild iron def.

VI. CONCLUSION

Anemia is a condition which is most common particularly in children and women. Being common symptoms it is ignored and not detected earlier. The FES with input parameters- HB, MCV, Iron and B12 is designed. The output indicates type of anemia such as iron & B12 deficiency, normocytic anemia, dimorphic anemia, polycythemia etc. The system with 25 rules in rule base is a Mamdhani fuzzy inference system with BOM as defuzzification method. When FES is tested on 150 patient's data, including male and female, 93.33% accuracy is obtained as compared to expert diagnosis. In future, we try to extend FES to detect other types of anemia on the basis of input parameters included in Complete Blood Count (CBC) only.

ACKNOWLEDGEMENT

I acknowledged to Dr. Rajesh Kate, Pathologist, Nidan Pathology, Akola, who spared time inspite of in busy schedule to determine input parameters, provided normal ranges of parameters and helped in designing rule base. I am also thankful to Dr. Shubhangi Jibkate, Pathologist who has given diagnosis for the dataset as an expert.

REFERENCES

[1] W. Siler and J. J. Buckley, Fuzzy expert systems and fuzzy reasoning, Wiley Online Library, 2005.

[2] D. Waterman, A Guide to Expert Systems, Pearson, 2008.

[3] M. Rajabi, S. Hossani and F. Dehghani, "A literature review on current approaches and applications of fuzzy expert systems," *arXiv preprint arXiv:1909.08794,* 2019.

[4] K. Gilda and S. Satarkar, "Review of Fuzzy Systems through various jargons of technology," *International Journal of Emerging Technologies and Innovative Research,* vol. 7, pp. 260-264, 7 2020.

[5] J. Aramideh and H. Jelodar, "Application of fuzzy logic for presentation of an expert fuzzy system to diagnose anemia," *Indian Journal of Science and Technology,* vol. 7, p. 933, 2014.

[6] S. Malu, B. L. Pal and S. Kumar, "Detection of anemia using fuzzy logic," *Int. J. Comput. Appl. Technol. Res,* vol. 4, p. 762–766, 2015.

[7] N. Mishra and P. Jha, "A Fuzzy Rule Based Expert System for Assessment of Severity of Hemolytic Anemia".

[8] d. Tuba Yıl, Y. Nilüfer and Ö. Birgül, "Classifying anemia types using artificial learning methods," *Engineering Science and Technology, an International Journal,* vol. 24, no. 1, pp. 50-70, 2021.

[9] M. Abdullah and S. Al-Asmari, "Anemia types prediction based on data mining classification algorithms," in *Communication, management and information technology*, CRC Press, 2016, pp. 629-636.

[10] N. B. Noor, M. S. Anwar and M. Dey, "Comparative Study Between Decision Tree, SVM and KNN to Predict Anaemic Condition," in *2019 IEEE International Conference on Biomedical Engineering, Computer and Information Technology for Health (BECITHCON)*, 2019.

[11] Elaine Rich, Kevin Knight and Shivashankar Nair, Artificial Intelligence, 3 ed., McGraw Hill Education, 2009.

[12] M. Tavana and V. Hajipour, "A practical review and taxonomy of fuzzy expert systems: methods and applications," *Benchmarking: An International Journal,* 2019.

[13] A. Yilmaz, M. Dagli and N. Allahverdi, "A fuzzy expert system design for iron deficiency anemia," in *7th International Conference on Application of Information and Communication Technologies*, 2013.

[14] S. N. Sivanandam, S. Sumathi and S. N. Deepa, Introduction to Fuzzy Logic using MATLAB, Springer, 2007.

[15] M. K. Choudhury and N. Baruah, "A Fuzzy Logic Based Expert System For Determination Of Health Risk Level Of Patient," *International Journal of Research in Engineering and Technology,* vol. 04, pp. 261-267, 2015.

[16] Ela Kumar, Artificial Intelligence, New Delhi: I. K. International , 2010.

[17] Kalpana Gilda, Shrikant Satarkar, " Defuzzification: Maxima methods with improved efficiency and their performance evaluation", 2022 IEEE Delhi Section Conference (DELCON), 2022.