

A fuzzy logic approach for determining appropriate doses in medical decision support systems

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Abstract

Optimizing treatment dosage is challenging because patient characteristics and clinical measurements are inherently variable and imprecise. This study presents a fuzzy logic approach for treatment dosage recommendation in medical decision support systems. The proposed framework uses patient age, symptom severity, laboratory test results, and heart rate as input variables and represents these variables through linguistic terms and membership functions. A rule-based fuzzy inference structure converts the combined input conditions into low, normal, or high treatment-dosage recommendations. Fuzzification and defuzzification enable the system to translate crisp clinical measurements into interpretable dosage outputs while retaining the uncertainty present in medical data. The study defines input and output ranges, linguistic variables, membership functions, and a 28-rule knowledge base, and demonstrates estimated dosage values together with three-dimensional surface plots illustrating the relationships between input variables and treatment dosage. The framework is intended to support transparent and adaptable clinical decision-making and to provide healthcare professionals with an interpretable basis for dosage recommendations. The results illustrate the potential of fuzzy logic to model uncertain treatment conditions and to contribute to individualized decision support. Clinical validation with real-world data and expert review of the rule base are required before practical deployment.

Keywords: fuzzy logic, treatment dosage, clinical decision support, membership functions, precision medicine

Introduction

Dosage determination is a hard and crucial process in today's ever-changing healthcare system. The inherent uncertainties and variability associated with individual patient circumstances and reactions are difficult for conventional approaches to capture. Based on observations of human thought processes, fuzzy logic offers an alternative to traditional binary reasoning. It allows for some degree of imprecision and ambiguity, providing a more accurate reflection of the intricate and sometimes nebulous character of medical data. The Fuzzy Logic Method takes this adaptability and applies it to the field of treatment dose in an effort to improve the accuracy and versatility of medical decision-making. The foundation of the Fuzzy Logic Approach is the creation of fuzzy rules based on existing clinical evidence and developed in tandem with healthcare professionals. Patient features are translated into dose recommendations based on these guidelines. Importantly, the system incorporates flexibility, allowing it to continuously learn from patient responses and dynamically change recommendations over time. This novel framework is expected to promote precision medicine and usher in a new era of adaptive and patient-specific treatment decisions as we delve into the study of the fuzzy logic technique for dose. Because of its openness to uncertainty, the fuzzy logic approach has the potential to dramatically alter the process of dosing, leading to better health results and more satisfied patients.

Saritas et al. developed a fuzzy expert system using clinical indicators to estimate salazopyrine dosage for chronic intestinal inflammation [1]. Zarei et al. modeled HIV infection by means of a linear fuzzy

differential-equation system that represents uncertainty in immune-cell levels and viral load [2]. Mauseth et al. reported a fully automated closed-loop insulin dosing controller based on fuzzy logic [3]. Choudhury and Baruah proposed a fuzzy expert system for determining patient health-risk levels [4], while Gorgulu and Akilli discussed fuzzy-logic-based decision support applications in medicine and reported an average success level of 90% [5]. Al-Dmour et al. designed a fuzzy-logic warning system for patient classification [6]. Improta et al. presented a fuzzy-logic-based clinical decision support system for evaluating renal function in post-transplant patients [7]. Ekong et al. developed an integrated fuzzy decision support system for disease management [8]. Wantoro et al. used fuzzy profile matching to support antidiabetic drug recommendations, including dosage and administration frequency [9]. More recently, Xu et al. emphasized the importance of interpretability in artificial-intelligence-based clinical decision support systems [10].

Materials and Methods

Ranges of input and output variables

In the context of therapeutic dosage recommendations, a common technique is to employ fuzzy logic, wherein the input and output variables are typically characterized by language terms and fuzzy sets. Fuzzy logic proves to be highly advantageous in scenarios characterized by ambiguous borders between distinct levels or states, hence encompassing a certain degree of uncertainty.

Table 1. Ranges of input variables

Input variables	Ranges	Attributes
Age	0-30 years	Young
	20-50 years	Middle
	40-100 years	Old
Symptoms severity	0-3	Mild
	2-6	Moderate
	5-10	Severe
Laboratory test results	0-50	Low
	40-70	Normal
	60-100	High
Heart rate	0-50 bpm	Low
	40-100 bpm	Normal
	90-150 bpm	High

Table 2. Ranges of output variable

Output variable	Ranges	Attributes
Treatment dosage	0-50 mg	Low
	10-100 mg	Normal
	90-150 mg	High

Definition of linguistic variables

Table 3. Definition of input variables

Age (A)	Symptoms severity (SS)	Laboratory test results (LTR)	Heart rate (HR)
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Young (Y)	AY	Mild (MIL)	SSMIL	Low	LTRL	Low	LHR
Middle (MID)	AMID	Moderate (MOD)	SSMOD	Normal	LTRN	Normal	NHR
Old (O)	AO	Severe	SSS	High	LTRH	High	HHR

Table 4. Definition of output variable

Treatment dosage (TD)	
Low	LTD
Normal	NTD
High	HTD

Membership functions of input and output variables

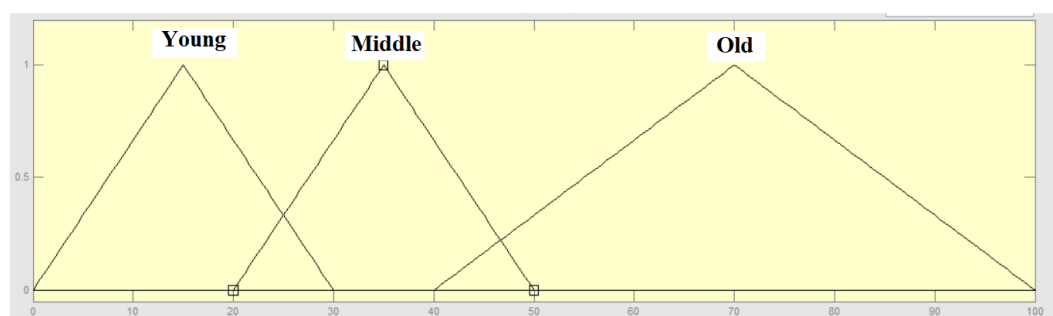


Figure 1. Membership function for age (input variable 1)

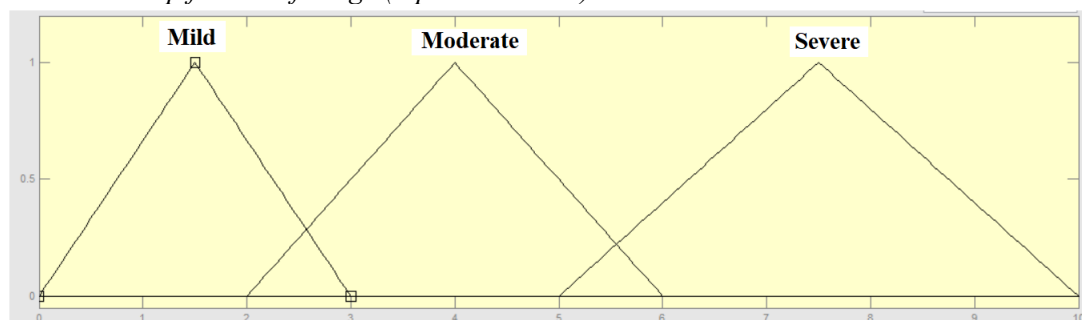


Figure 2. Membership function for symptoms severity (input variable 2)

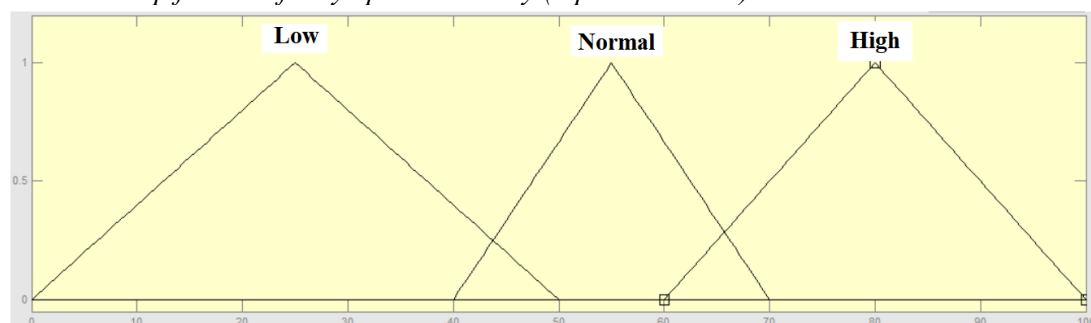


Figure 3. Membership function for laboratory test results (input variable 3)

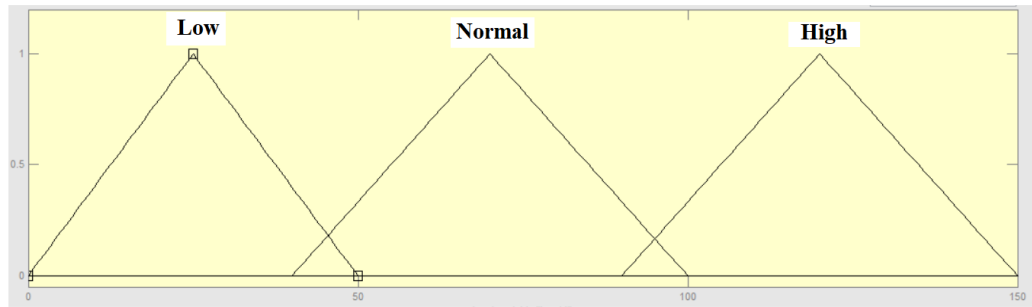


Figure 4. Membership function for heart rate (input variable 4)

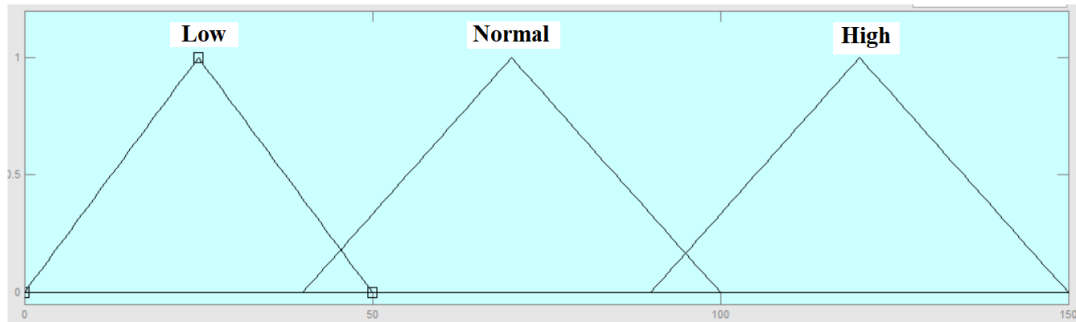


Figure 5. Membership function for treatment dosage (output variable)

Rule base

The establishment of rules serves as a fundamental framework for the fuzzy logic system to determine appropriate treatment dosages by considering a combination of input variables. It is important to note that the linguistic variables and membership functions pertaining to each variable would require coordination with medical practitioners for their definition. Furthermore, it is imperative to employ real-world data in order to validate and enhance the rule base, hence achieving heightened levels of accuracy.

1. IF (Patient Age is Young) AND (Symptoms severity is Mild) AND (Laboratory test results is High) AND (Heart rate are Low) THEN (Treatment dosage is Low)
2. IF (Patient Age is Middle-aged) AND (Symptoms severity is Moderate) AND (Laboratory test results is Normal) AND (Heart rate is Normal) THEN (Treatment dosage is Normal)
3. IF (Patient Age is Old) AND (Symptoms severity is severe) AND (Laboratory test results is low) AND (Heart rate is high) THEN (Treatment dosage is High)
4. IF (Patient Age is Young) AND (Symptoms severity is Moderate) AND (Laboratory test results is High) AND (Heart rate is Normal) THEN (Treatment dosage is Normal)
5. IF (Patient Age is Middle-aged) AND (Symptoms severity is Mild) AND (Laboratory test results is High) AND (Heart rate is Low) THEN (Treatment dosage is Low)
6. IF (Patient Age is Young) AND (Symptoms severity is Mild) AND (Laboratory test results is low) AND (Heart rate is low) THEN (Treatment dosage is Low)
7. IF (Patient Age is Old) AND (Symptoms severity is Severe) AND (Laboratory test results is high) AND (Heart rate is High) THEN (Treatment dosage is High)
8. IF (Patient Age is Young) AND (Symptoms severity is Moderate) AND (Laboratory test results is high) AND (Heart rate is Normal) THEN (Treatment dosage is Normal)
9. IF (Patient Age is Old) AND (Symptoms severity is Mild) AND (Laboratory test results is normal) AND (Heart rate is High) THEN (Treatment dosage is High)

10. IF (Patient Age is Middle age) AND (Symptoms severity is Severe) AND (Laboratory test results is low) AND (Heart rate is high) THEN (Treatment dosage is high)
11. IF (Patient Age is Old) AND (Symptoms severity is Moderate) AND (Laboratory test results is Low) AND (Heart rate is Low) THEN (Treatment dosage is Low).
12. IF (Patient Age is Middle age) AND (Symptoms severity is Moderate) AND (Laboratory test results is Normal) AND (Heart rate is Normal) THEN (Treatment dosage is Normal).
13. IF (Patient Age is Young) AND (Symptoms severity is Mild) AND (Laboratory test results is Low) AND (Heart rate is High) THEN (Treatment dosage is Normal).
14. IF (Patient Age is Old) AND (Symptoms severity is Severe) AND (Laboratory test results is High) AND (Heart rate is Low) THEN (Treatment dosage is High).
15. IF (Patient Age is Old) AND (Symptoms severity is Mild) AND (Laboratory test results is Low) AND (Heart rate is High) THEN (Treatment dosage is Low).
16. IF (Patient Age is Young) AND (Symptoms severity is Mild) AND (Laboratory test results is Low) AND (Heart rate is High) THEN Treatment dosage is Low.
17. IF (Patient Age is Old) AND (Symptoms severity is Severe) AND (Laboratory test results is High) AND (Heart rate is Low) THEN Treatment dosage is High.
18. IF (Patient Age is Middle age) AND (Symptoms severity is Mild) AND (Laboratory test results is Low) AND (Heart rate is Low) THEN Treatment dosage is Normal
19. IF (Patient Age is Old) AND (Symptoms severity is Moderate) AND (Laboratory test results is Normal) AND (Heart rate is Normal) THEN Treatment dosage is High
20. IF (Patient Age is Young) AND (Symptoms severity is Severe) AND (Laboratory test results is High) AND (Heart rate is High) THEN Treatment dosage is Normal
21. IF (Patient Age is Old) AND (Symptoms severity is Mild) AND (Laboratory test results is Low) AND (Heart rate is Low) THEN Treatment dosage is Normal
22. IF (Patient Age is Young) AND (Symptoms severity is Moderate) AND (Laboratory test results is Normal) AND (Heart rate is Normal) THEN Treatment dosage is Low
23. IF (Patient Age is Middle age) AND (Symptoms severity is Severe) AND (Laboratory test results is High) AND (Heart rate is High) THEN Treatment dosage is High
24. IF (Patient Age is Middle age) AND (Symptoms severity is Mild) AND (Laboratory test results is High) AND (Heart rate is Low) THEN Treatment dosage is Normal
25. IF (Patient Age is Old) AND (Symptoms severity is Mild) AND (Laboratory test results is Low) AND (Heart rate is Low) THEN Treatment dosage is Normal
26. IF (Patient Age is Young) AND (Symptoms severity is Moderate) AND (Laboratory test results is Normal) AND (Heart rate is Low) THEN Treatment dosage is Normal
27. IF (Patient Age is Old) AND (Symptoms severity is Severe) AND (Laboratory test results is Normal) AND (Heart rate is Low) THEN Treatment dosage is High
28. IF (Patient Age is Old) AND (Symptoms severity is Severe) AND (Laboratory test results is High) AND (Heart rate is Normal) THEN Treatment dosage is High

Results and Discussion

Estimated values of treatment dosage

The determination of estimated values for treatment dosage in a Fuzzy Logic Approach relies on the utilization of a fuzzy inference system and the predefined rules inside the system. The process of fuzzy inference consists of three main steps: fuzzification of the input variables, application of fuzzy rules, and defuzzification of the output to derive a precise value for the dosage of treatment.

Table 5. *Estimated treatment dosage values*

Age	Symptoms severity	Laboratory test results	Heart rate	Treatment Dosage
50	5	50	75	120
35.3	4.28	41.4	45.4	70
42.5	4.78	49.2	118	75
49.7	2.73	44.2	95.4	76.5
44.2	4.23	60.3	80.4	84.3
38.8	5.28	48.1	92.1	80.8
90.3	5.61	34.7	27.1	25
20.3	2.13	23.1	101	49.7
5.28	2.02	88.1	55.4	69.7
56.9	2.79	12.5	35.4	39.7
21.9	2.4	13.6	37.1	38.9

3D surface plots for treatment dosage

The 3D surface plot, as depicted in figures 6-8, provides insights into the relationship between differences in the input factors and changes in dosage. Elevated regions on the surface correspond to increased dosages, whilst depressed regions correspond to decreased dosages. Distinct zones within the figure are indicative of various amalgamations of input values and their corresponding treatment dosages.

Through the analysis of the three-dimensional surface plot, professionals are able to visually evaluate the manner in which alterations in the input factors influence the suggested dosage for therapy. This facilitates comprehension of the operational characteristics of the fuzzy logic system and assists in the formulation of well-informed judgments.

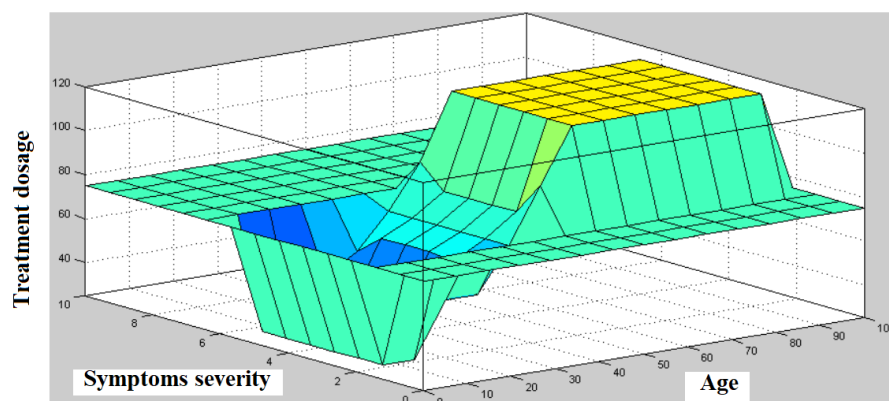


Figure 6. *Variations in treatment dosage for different age and symptoms severity*

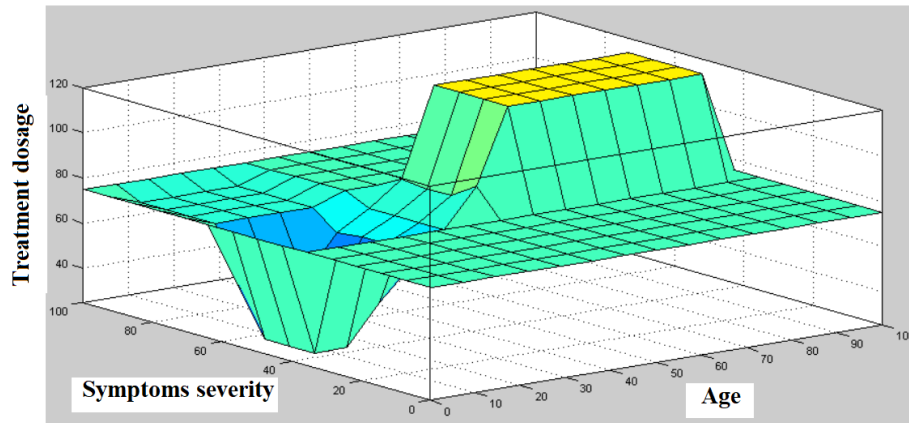


Figure 7. Variations in treatment dosage for different age and laboratory test results

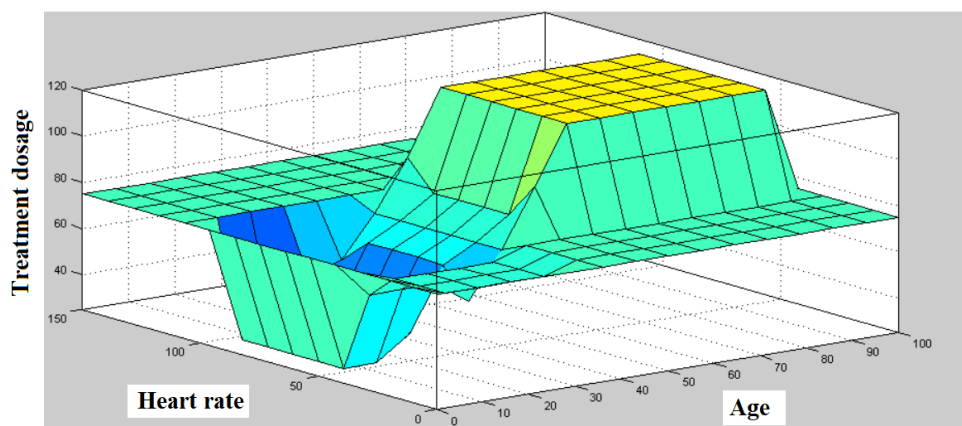


Figure 8. Variations in treatment dosage for different age and heart rate

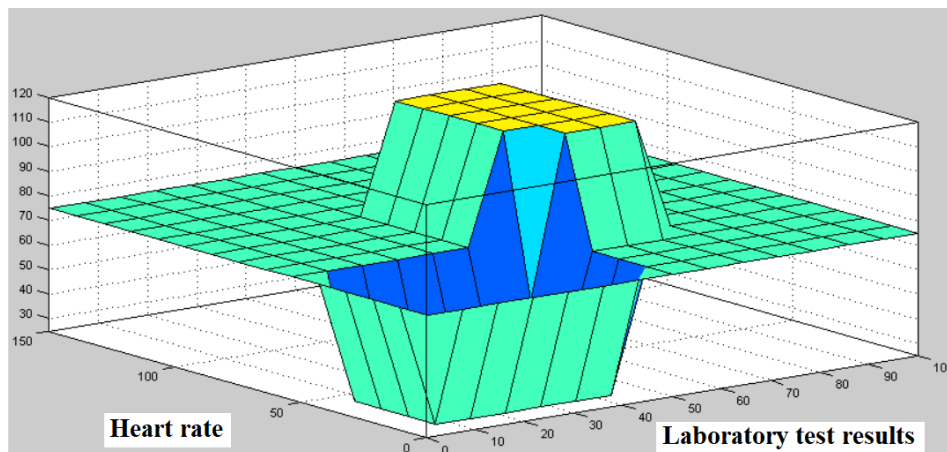


Figure 9. Variations in treatment dosage for different laboratory test results and heart rate

Conclusion

The value of the fuzzy logic method lies in its inherent versatility. In a healthcare setting characterized by dynamic patient situations that undergo changes over time, the system's capacity to consistently acquire knowledge from patient reactions and adapt dosage recommendations holds significant value. The adaptability mentioned here is in accordance with the concepts of personalized medicine, which acknowledges that a standardized approach to treatment dosages may not adequately cater to the varied requirements of patients.

The incorporation of ethical issues holds significant importance in the process of making healthcare decisions, and these considerations are effectively addressed by utilizing the transparency and interpretability that is inherent in the fuzzy logic method. The system aims to establish confidence among healthcare practitioners, patients, and the decision support process by offering well-founded arguments for dosage recommendations. The importance of transparency in the deployment of fuzzy logic systems in real-world clinical settings cannot be overstated, as it serves both ethical purposes and facilitates acceptance and collaboration. When considering the possibilities of the Fuzzy Logic Approach for Treatment Dosage Recommendations, it is crucial to acknowledge the collaborative character of its creation. The process of formulating fuzzy rules necessitates the involvement of healthcare professionals, thereby guaranteeing the incorporation of clinical guidelines and domain knowledge into the decision-making process. The collective endeavor highlights the practicality and significance of the suggested methodology in real-world contexts. In summary, the utilization of the Fuzzy Logic Approach for Treatment Dosage Recommendations signifies a significant departure from conventional healthcare decision support systems. This method demonstrates alignment with the expanding landscape of patient-centered care through the incorporation of ambiguity, adaptability to patient dynamics, and prioritization of ethical considerations. Future investigations and applications in clinical environments will surely provide additional insights into the transformative capacity of fuzzy logic in optimizing dosages for therapy, ultimately leading to enhanced patient outcomes and the progression of precision medicine in the healthcare field.

References

- [1] Saritas I, Ozkan IA, Allahverdi N, Argindogan M. (2009). Determination of the drug dose by fuzzy expert system in treatment of chronic intestine inflammation. *Journal of Intelligent Manufacturing*. 20: 169-176.
- [2] Zarei KH, Kamyad AV, Heydari AA. (2012). Fuzzy modeling and control of HIV infection. *Computational and Mathematical Methods in Medicine*. Article ID 893474, 12 pages.
- [3] Mauseth R, Hirsch IB, Bollyky J. (2013). Use of a fuzzy logic controller in a closed-loop artificial pancreas. *Diabetes Technology and Therapeutics*. 15(8): 628-633.
- [4] Choudhury MK, Baruah N. (2015). A fuzzy logic based expert system for determination of health risk level of patient. *IJRET: International Journal of Research in Engineering and Technology*. 4(5): 261-267.
- [5] Gorgulu O, Akilli A. (2016). Use of fuzzy logic based decision support systems in medicine. *Studies on Ethno-Medicine*. 10(4): 393-403.
- [6] Al-Dmour J, Sagahyroon A, Al-Ali AR, Abusnana S. (2019). A fuzzy logic-based warning system for patients classification. *Health Informatics Journal*. 25(3): 1004-1024.
- [7] Improta G, Mazzella V, Vecchione D, Santini S, Triassi M. (2019). Fuzzy logic-based clinical decision support system for the evaluation of renal function in post-transplant patients. *Journal of Evaluation in Clinical Practice*. 1224-1234.
- [8] Ekong B, Ifioke I, Udoeka I, Anamfiok J. (2020). Integrated fuzzy based decision support system for the management of human disease. *International Journal of Advanced Computer Science and Applications*. 11(2): 268-274.
- [9] Wantoro A, Syarif A, Muludi K, Berawi KN. (2021). Fuzzy-based application model and profile matching for recommendation suitability of type 2 diabetic. *International Journal of Advanced Science Engineering Information Technology*. 11(3): 1105-1116.
- [10] Xu Q, Xi W, Liao B, Hu C, Qin L, Yang Z, Xiong H, Lyu Y, Zhou Y, Luo A. (2023). Interpretability of clinical decision support systems based on artificial intelligence from technological and medical perspective: a systematic review. *Journal of Healthcare Engineering*. Article ID 9919269, 13 pages.