Design AI platform using fuzzy logic technique to diagnose kidney diseases

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Article Info

Article history:

Received Jan 11, 2022
Revised Jan 02, 2023
Accepted Jan 24, 2023

Keywords:

Artificial intelligence
Electronic-Doctor
Fuzzy logic system
Healthcare
Kidney diseases

ABSTRACT

Artificial intelligence (AI) is an advanced scientific technology that can provide strong ability to assist in analysis and diagnosis of almost every type of data, therefore; AI widely used in medical fields, which is applied in the diagnosis and early detection of diseases. Kidney disease is one of the common diseases that are diagnosed and the necessary treatments are suggested by artificial intelligence. In this research, a logic system was used. The fuzzy logic system (FLS) is one of the artificial intelligence systems for diagnosing kidney diseases, where the fuzzy logic system divided into five variable inputs, namely urea, creatinine, glucose, bun, and uric acid, and they represented laboratory tests of the patients, this variables and also three outputs were identified, which are chronic inflammation and kidney failure, stones and salts, acute inflammation of the kidneys and bladder, which is the result of the medical diagnosis of the disease. Five memberships for inputs and three memberships for outputs are used in FLS. Diseases are concluded based on the values of the inputs, and thus the system proved its effectiveness and accuracy in diagnosis and this system is considered an aid to the specialized doctors in the field of kidney diseases.

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1. INTRODUCTION

Artificial intelligence (AI) has a multiple impact in different fields. Accordingly, there are many projects that are being carried out to study the "future work" of the modern industrial revolutions. Therefore, artificial intelligence technologies, big data, block-chain and the Internet of Things are all now part of daily working life in many fields, such as smart phones, smart televisions, smart watches, or various electrical appliances and also the use of security and medical research techniques [1], Figure 1 shows the branches of AI.

Artificial intelligence is entering the field of medical healthcare by developing clinical decision support for patients. The large and rapid developments in improving computation in statistical techniques have resulted in the use of artificial intelligence techniques to identify hidden patterns and interactions in the large data set, which is usually complex and has multiple levels [2]. Kidney illness may be a major open wellbeing problem in portion since of its common etiology caused by diabetes, hypertension, corpulence, and maturing; the incidence of these conditions is expanding. According to the Global Burden of Diseases, Injuries, and Risk Factors Study 2015, 750 million individuals worldwide suffered from kidney infection [3].

Electronic medical records (EMR) that contains large-field clinical data, more realistic, and this data is the basis for the development of artificial intelligence technology in the field of multiple diseases. This big data is very difficult for a person to analyze it directly; the reasons are the large and consuming time for analysis and the accuracy required to avoid human errors, as well as the difficulty in generating ideas or information in a deep and accurate manner [4]. In recent studies on the development of artificial intelligence in the field of health and medical care, it has been shown that the clinical applications of artificial intelligence. Relatively common in many fields such as ophthalmology, oncology and others [5], but we see it rare to use artificial intelligence in kidney diseases, despite the availability of large data in this area [6] and one of the most common kidney diseases [7]. The hemodialysis center (HD) is performed three times a week for 3−5 hours, and thus there will be large amounts of clinical data that will be recorded in the EMR. This is the accumulated clinical data are ideal for AI applications [2].

AI application mechanisms (AITs) were used in many fields, including medical fields such as diagnosing diseases, treating diseases, following up on patients' cases, predicting disease risks, and others. The use of artificial intelligence technologies (AITs) enables the design of systems that allow building an intelligent system as a model for predicting the patient's diagnosis and response to specific treatment, as well as knowing the prediction of disease severity. It is smart forms that can be used for this purpose is fuzzy logic [8]. The natural developments that happen to various diseases, which is characterized by lack of clarity and ambiguity in that medical data may lead to the need for a more effective framework to deal with that ambiguity through the use of variables and multiple levels of memberships functions and approximate values Boolean. Therefore, fuzzy logic gives value to describing medical concepts by treating them as fuzzy sets [9], [10]. Use fuzzy logic in multiple medical systems [11]. The Figure 2 show the using fuzzy logic in healthcare.

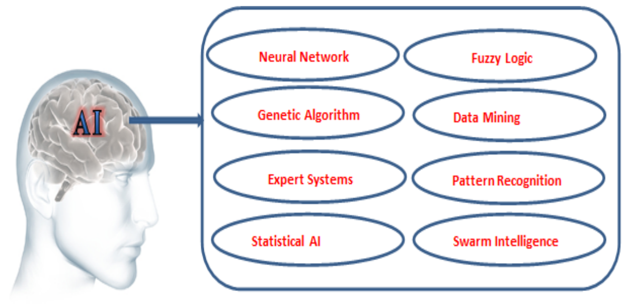

Figure 1. AI branches

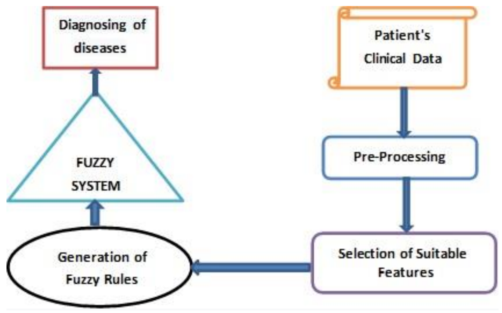

Figure 2. Fuzzy logic in healthcare

After fuzzy logic was introduced by Lotfi Zadeh in 1965 [12]; however, it has recently generated important applications in this area it was interesting [13], [14]. The diagnosis of an illness could be an issue in pharmaceutical since a few patients may have comparable indications, but the specialist may diagnose different maladies. So, this work will offer assistance specialist when he or she has fluffiness in that considering prepare [15], [16]. This study presents straightforward and productive strategy to create fuzzy expert systems for restorative determination.

2. RELATED WORKS

Ledbetter *et al.* [17] a small piece of kidney tissue is taken, which is called a kidney biopsy, through which diseases that affect the kidneys are diagnosed, and there are detailed studies to monitor and observe the pathological symptoms that result from damage to the glomeruli of the kidneys, which is called idiopathic nephrotic syndrome in patients who are at high risk. Biopsy samples were taken from more than 80 patients with kidney disease. The neural network inputs used were slices of kidney patients' images to do network learning.

Gallego *et al.* [18] the method of learning was used to know the diseases that affect the glomeruli in the kidneys after taking a biopsy of the kidneys, and deep artificial neural networks were used to segment the glomeruli and detect kidney diseases. Convolutional neural networks were used to develop two methods that have the ability to classify patches into glomerular and non-glomerular categories. This network consists of eight layers, five of which are convolutional and three of which are fully connected for reducing the number of iterations.

Ayyar *et al.* [19] used a set of medical images of the glomeruli of the kidneys and extracted a set of data from those images and created a glomeruli classification database (GCDB), the images were divided into two categories, the first is normal and the other is abnormal. This extracted data is trained by the method of deep neural network by these images. The final result is compared for the network with the categories that are under supervision.

Chimwayi *et al*. [20] the neural-fuzzy algorithm was applied hierarchical clustering algorithm to predict early kidney disease using specific network features. It gave an accuracy of about 70%. Then pooled the results of that prediction, to determine the percentage of patients with a high risk of developing kidney disease that are likely to have a high risk of diabetes.

Kunwar *et al.* [21] they presented research for the detection and analysis of chronic kidney disease through the use of fuzzy C-means (FCM) algorithm in which the clustering process is effective in the process of mining complex data that is ambiguous in nature among clinicians. This algorithm is concerned with the verification and collection of data of patients with chronic kidney disease (CKD) and not the disease itself. This algorithm was simulated in Matlab.

Jamal *et al.* [22] the z-number method was used together with the fuzzy clustering algorithm to increase reliability and human knowledge and to develop information that is uncertain. This algorithm collects the data of kidney patients and chooses the group to which the disease belongs (group 0, group 1, group 2, group 3, and group 4) based on the membership functions defined in the algorithm, which is the trapezoidal function. Using the z-number process with the fuzzy clustering algorithm gave high strength and reliability of the results of the proposed algorithm.

Agusta *et al.* [23] after collecting kidney patient data from University of California Irvine (UCI) groups, the system was developed using MySQL databases with larval framework, and the system used the waterfall method, which analyzes the system, design, coding and test it. Fuzzification was used in multiple stages. And configure the base rule for certain factor (CF), calculate CF expert, calculate CF values, set CF values, and also find CF maximum. After testing the fuzzy system, an accuracy rate of 92.25% was obtained for a data set of approximately 400, and also an accuracy rate of 97.25% for the certainty factor, and when combining the fuzzy logic and the certainty factor, an accuracy of 99% was obtained.

Hamedan *et al*. [24] they used an expert system that relies on fuzzy logic in identifying and predicting kidney disease, and then assessing the validity of the system with unclear or confusing data. The characteristics and criteria for kidney disease were defined by consulting 18 nephrologists to form rules for all these characteristics and cases and serve as a set of rules for fuzzy logic. An expert fuzzy logic system was designed to infer about disease and diagnose cases by taking random samples from the records and data of 216 patients registered in the medical records of previous auditors, some of whom had the disease and others who were not infected, in order to test the validity of the work of the expert system. Also, some noisy data were added to the system to compare the results with the clear and original data, and then compare the performance of the expert system with the original results proven in the doctor’s records, and the results indicated a significant correlation between them.

Pirmoradi *et al.* [25] the machine learning method was used to identify miRNAs and classify the types of cancerous diseases that affect the kidneys automatically. This algorithm works on two basic steps, the first is to apply the feature selection algorithm to select miRNAs for each subtype, and the inequality of arithmetic and geometric means (AMGM) measurement feature, which is characterized by high discrimination power, was used. The second step is implementing a self-organization deep neurofuzzy system to classify subgroups of renal cancer disease.

Iraji [26] used fuzzy neural networks. The network was based on 24 characteristics of chronic kidney disease and 450 samples. Proposed a network to predict and classify disease through two adaptive neuro fuzzy and this method called (TLA-ANFIS).

Sheikhtaheri *et al.* [27] designed a fuzzy expert system using the Mamdani method with Matlab language software. A group of samples were taken from the medical records of (216) patients with chronic kidney disease as well as without disease. The expert system for those samples was evaluated and the accuracy, quality and sensitivity of the system were very high, indicating the effectiveness of the system compared to the final medically recorded diagnosis of the patient. Jindal *et al*. [28] a smart system was designed to diagnose kidney cancer disease by using fuzzy logic and neurofuzzy. Two layers of the system were used, the first layer concludes whether the patient has kidney cancer or not, and the second layer determines the current stage of the patient who actually has kidney cancer. Gaussian function was used for the inputs in a neuro fuzzy system.

3. KIDNEY DISEASE

CKD is one of the diseases that are defined as the changes that occur to the shape or structure of the kidneys, as well as the changes that occur in its performance and function, and its impact on human health [29], [30]. Chronic kidney disease is known by the changes that you get in the urine continuously or the occurrence of some abnormalities in the kidneys’ structure. Most of the individuals who suffer from kidney disease are susceptible to other diseases such as (heart and blood vessels), which causes death. In many cases, the cause of kidney disease is high blood sugar and also high blood pressure [31]. People with chronic kidney disease have an increased heart rhythm and greater atrial fibrillation compared to patients who do not have such disease, which makes them more likely to have a stroke [32]. Figure 3 show the distinguish between normal kidney and disease kidney.

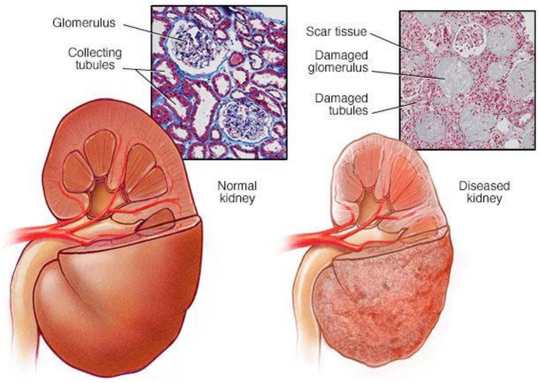

Figure 3. Kidney disease

4. FUZZY LOGIC CONCEPT

The fuzzy system is used for data containing ambiguity and vagueness. Verbal terminology is one of the ambiguities that fuzzy logic deals with. Fuzzy logic uses fuzzy sets that interact with each other with the universe of discourse. These fuzzy sets are represented by membership functions whose values range are between (0, 1) [33]. Basically, fuzzy logic is used in the development of expert systems for decision making and classification as a simulation of the human mind. The fuzzy logic of decision-making is based on knowledge bases stored from human experience. These rules are written programmatically as if-then [34], [35]. A fuzzy system contains four main components:
- Fuzzification: convert crisp inputs to fuzzy inputs.
- Rule base: present human knowledge or experience is stored in the form of if-then laws.
- Inference engine: stimulate rules and copy it's from knowledge's rules according to fuzzy input.
- Defuzzification: converting the fuzzy stimulate rules by inference engine to the crisp output values.

Figure 4 show the fuzzy logic system.

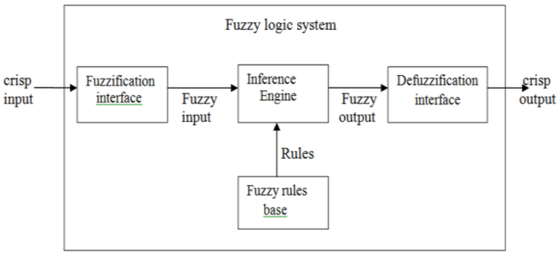

Figure 4. Fuzzy logic system

5. THE PROPOSED MECHANISM

The research mechanism uses medical tests for kidney diseases. There are many medical tests that can be used in diagnosis; the most commonly used are urea, creatinine, glucose, uric acid and bun. These tests are used as inputs to the fuzzy logic system (FLS) system, where the system analyzes those inputs and deduces the percentage of disease in which the patient's kidneys are affected. The proposed system helps doctors specializing in kidney diseases in the speed and accuracy of diagnosis. Focus will be on three main diseases related to the kidneys, namely:
- Acute inflammation of the kidneys and bladder (AIKB).
- The presence of chronic inflammation in the kidneys and kidney failure (PCIKF).
- The presence of stones in the kidneys, as well as the presence of salts (PSKS).

Figure 5 explain the Kidney disease diagnosis framework using fuzzy logic.

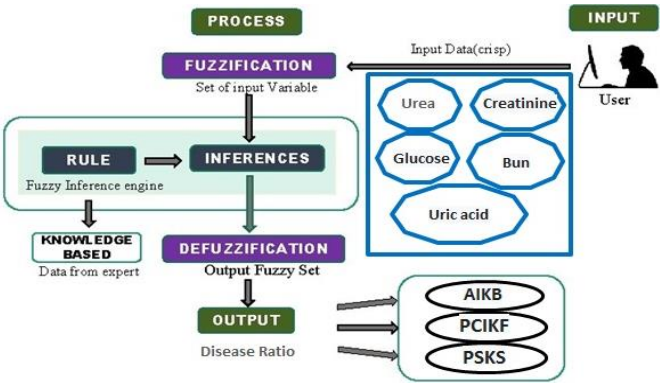

Figure 5. The proposed kidney disease diagnosis framework using fuzzy logic

The equation that can calculates the membership function is shown:

$$\mu A = \begin{cases} \frac{x-low}{center-low} & Low \leq x \leq center \\ \frac{x-high}{center-high} & Center \leq 0.5\ high \\ 0 & Otherwise \end{cases} \tag{1}$$

Figure 6 explain the proposed triangle membership function.

In the kidney disease diagnosis framework fuzzy logic system uses input values as shown in Table 1. The fuzzy rule-base is (35) = 243. One of case if the system takes urea = (low), glucose = (low), creatinine = (low), bun = (low) and uric acid = (low) then optimal value output is (high) that indicate there are a critical case. The rules are running in the inference engine in parallel mode. in the last stage, the optimal crisp value represents the output from the fuzzy space are found by defuzzification stage. This output value represents the kidney disease ratio.

Table1. Fuzzy rule of the proposed technique

	L	M	H
L	L	H	M
M	H	M	L
H	M	M	L

The procedure that shows the FLS are presented:

Procedure proposed FLS:

Begin

Number of membership function:

Input1: urea = 3

Input2: glucose = 3

Input3: creatinine = 3

Input4: bun = 3

Input5: uric acid = 3

Output: membership output = 3

Input the values of urea, glucose, creatinine, bun, and uric acid to the FLS;

Begin

Calculate the membership function for the urea, glucose, creatinine, bun, uric acid;

Put the result in $Y1...Y3$;

$$U^k = \sum_{I=1}^{M=1} \sum_{V=1}^{M=2} Yi * Yv \tag{2}$$

Find the degree of all fuzzy sets by U^k the equation:

Using center of gravity method (COG) to find the result as a crisp value depending on the following equation:

$$\text{COG}= \sum_{1}^{i} \frac{U\ i*C\ i}{U\ i} \tag{3}$$

End; end;

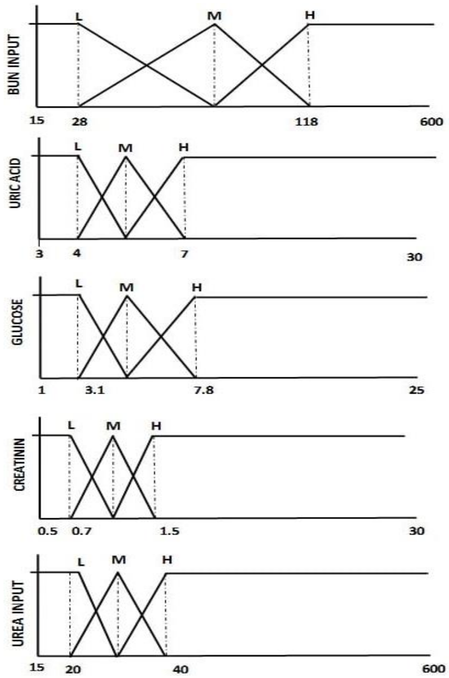

Figure 6. Representation of inputs membership function

6. EXPERIMENTAL RESULTS AND DISCUSSIONS

In this algorithm, fuzzy logic was used in diagnosing common kidney diseases through the use of five inputs, which represent the percentage of medical tests taken from medical laboratories after conducting a medical examination. These medical tests that were calculated are urea, creatinine, glucose, bun, and uric acid, which was considered as crisp inputs to the system, and after converting those crisp inputs into fuzzy inputs through the fuzzification process and calculating the membership functions, a rule-base for all the possibilities that can be obtained based on those inputs was established. After that, the system was tested by entering the approved data and numbers, and the required results were obtained and compared with the real medically approved results, and it was found that they matched with the results in the system, and accordingly, the proposed system can be adopted to help physicians specialized in kidney diseases quickly diagnose diseased cases.

Figure 7 shows a disease case in which a group of medical tests are urea, creatinine, glucose, bun, and uric acid. When these values are entered into the proposed fuzzy logic system, we find that the result was giving a special percentage for each disease case, for example, chronic inflammation and kidney failure = 0.6, kidney stones and salts = 0.8 and acute inflammation of the kidneys and bladder = 0.6. Therefore, we conclude from this value that the patient suffers from a large percentage of kidney stones and salts, and the remaining values were obtained as a result of the high value of kidney stones and salts. There are infections with a ratio of 0.6.

Figure 8 shows another disease case in which the medical tests of urea, creatinine, glucose, bun and uric acid are very high than normal rates. Then we find that the results of the diagnosis of chronic inflammation and kidney failure = 0.8 and kidney stones and salts = 0.8, acute inflammation of the kidneys and bladder = 0.4. Therefore, we conclude from this value that the patient suffers from a very large percentage of kidney stones and salts, and there is likely to be kidney failure.

Figure 7. Shows the results obtained using the proposed system

Figure 8. Another results of proposed system

Figure 9 is also another disease case in which the medical tests of urea, creatinine, glucose, bun and uric acid showed that there were moderate increases in the percentages of the tests than normal rates. Then we find that the results of the diagnosis of chronic inflammation and kidney failure = 0.4 and kidney stones and salts = 0.7 and acute inflammation of the kidneys and bladder = 0.9. Therefore, we conclude from these values that the patient suffers from the presence of few kidney stones and salts, and also there are high infections in the bladder with a very low probability of kidney failure.

Figure 10 is also a new disease case in which the medical tests of urea, creatinine, glucose, bun and uric acid showed that there are very high increases in the percentages of the tests above normal rates. Then we find that the results of the diagnosis of chronic inflammation and kidney failure = 0.8 kidney stones and salts = 0.8 and acute inflammation of the kidneys and bladder = 0.4. Therefore, we conclude from these values that the patient suffers from the presence of large kidney stones and salts, and also there are high infections and acute kidney failure with the possibility of few infections in the bladder.

Figure 9. Another tests of proposed system

Figure 10. A new tests of proposed system

Figure 11 the medical examinations are good because most of the percentages of the tests were within the normal limits except for a slight rise in the percentage of urea. Therefore, we find that the results of the diagnosis of chronic inflammation and kidney failure = 0.1, kidney stones and salts = 0.3, and acute inflammation of the kidneys and kidneys bladder = 0. Therefore we conclude from these values that the patient does not suffer from the presence of kidney stones and perhaps there are few salts, also there are no infections or kidney failure as well as no infections in the bladder.

Figure 11. Normal ratio tests of proposed system

7. CONCLUSION

This paper explains the process of identifying kidney disease early and helps specialized doctors in the process of rapid diagnosis and reducing the effort in knowing the type of disease in a more accurate and reliable way compared to the traditional method. The goal of this study is to develop a new method in the fuzzy logic of diagnosing kidney diseases based on skill and experience specialized doctors and recorded in approved tables for diagnosis. The results that were approved for diagnosis in kidney diseases are chronic inflammation and kidney failure, kidney stones and salts, acute inflammation of the kidneys and bladder. In this system, various samples of pathological symptoms were taken according to the tables established in the medical diagnosis and it was found that they matched the results known to the doctors who specialize in the disease and their accuracy in identifying and diagnosing disease cases. The system can be developed in the future to include all different kidney diseases through the use of hybrid soft computing technology.

REFERENCES

[1] A. Kashyap, "Artificial Intelligence & Medical Diagnosis, "*Scholars Journal of Applied Medical Sciences*, vol. 6, no. 12, pp. 4982-4985, 2018. [Online]. Available: https://www.researchgate.net/publication/330205451_Artificial_Intelligence_Medical_Diagnosis

[2] S. Chaudhuri *et al.*, "Artificial intelligence enabled applications in kidney disease," *Seminars in Dialysis*, vol. 34, no. 1, pp. 5-16, 2021, doi: 10.1111/sdi.12915.

[3] GBD 2015 DALYs and HALE Collaborators, "Global, regional, and national disability-adjusted life-years (DALYs) for 315 diseases and injuries and healthy life expectancy (HALE), 1990-2015: a systematic analysis for the Global Burden of Disease Study 2015," *The Lancet*, vol. 388, pp. 1603-1658, 2016, doi: 10.1016/S0140-6736(16)31460-X.

[4] Amisha, P. Malik, M. Pathania, and V. K. Rathaur, "Overview of artificial intelligence in medicine," *Journal of Family Medicine and Primary Care*, vol. 8, no.7, pp. 2328-2331, 2019, doi: 10.4103/jfmpc.jfmpc_440_19.

[5] B. X. Tran *et al.*, "Global evolution of research in artificial intelligence in health and medicine: a bibliometric study," *Clinical Medicine*, vol. 8, no. 3, 2019, doi: 10.3390/jcm8030360.

[6] J. S. -Rodriguez, M. M. Rinschen, J. Floege, and R. Kramann, "Big science and big data in nephrology," *Kidney International*, vol. 95, no. 6, pp. 1326-1337, 2019, doi: 10.1016/j.kint.2018.11.048.

[7] Y. Xie *et al.*, "Analysis of the Global Burden of Disease study highlights the global, regional, and national trends of chronic kidney disease epidemiology from 1990 to 2016," *Kidney International*, vol. 94, no. 3, pp. 567-581, 2018, doi: 10.1016/j.kint.2018.04.011.

[8] N. Allahverdi, "Design of Fuzzy Expert Systems and Its Applications in Some Medical Areas," *International Journal of Applied Mathematics, Electronics and computers (IJAMEC)*, vol. 2, no.1, pp. 1–8, 2014, [Online]. Available: https://dergipark.org.tr/en/download/article-file/89419

[9] F. Steimann, "On the use and usefulness of fuzzy sets in medical AI," *Artificial Intelligence in Medicine*, vol. 21, no. 1-3, pp. 131-137, 2001, doi: 10.1016/s0933-3657(00)00077-4.

[10] I. Gadaras and L. Mikhailov, "An interpretable fuzzy rule-based classification methodology for medical diagnosis," *Artificial Intelligence in Medicine*, vol. 47, no. 1, pp. 25- 41, 2009, doi: 10.1016/j.artmed.2009.05.003.

[11] N. H. Phuong and V. Kreinovich, "Fuzzy logic and its application in medicine," *International Journal of Medical Informatics*, vol. 62, no. 2-3, pp.165-173, 2001. [Online]. Available: https://asset-pdf.scinapse.io/prod/2003160342/2003160342.pdf

[12] L. A. Zadeh, "Fuzzy sets," *Information and Control*, vol. 8, no. 3, pp. 338-353, 1965, doi: 10.1016/S0019-9958(65)90241-X.

[13] N. Belacel, M. R. Boulassel, "Multicriteria fuzzy assignment method: A useful tool to assist medical diagnosis," *Artificial Intelligence in Medicine*, vol. 21, no. 1-3, pp. 201-207, 2001, doi: 10.1016/s0933-3657(00)00086-5.

[14] S. -M. Chen, "A weighted fuzzy reasoning algorithm for medical diagnosis," *Decision Support Systems*, vol. 11, no. 1, pp. 37-43, 1994, doi: 10.1016/0167-9236(94)90063-9.

[15] A. Roychowdhury, D. K. Pratihar, N. Bose, K. P. Sankaranarayanan, and N. Sudhahar, "Diagnosis of the diseases– using a GA-fuzzy approach," *Information Sciences*, vol. 162, no. 2, pp. 105-120, 2004, doi: 10.1016/j.ins.2004.03.004.

[16] I. Saritas, N. Allahverdi, I. U. Sert, "A fuzzy expert system design for diagnosis of prostate cancer," in *Proc. of the 4th International Conference on Computer Systems and Technologies - CompSysTech*, 2003, pp. 345-351, doi: 10.1145/973620.973677.

[17] D. Ledbetter, L. V. Ho, and K. V. Lemley, "Prediction of kidney function from biopsy images using convolutional neural networks," *arXiv: Machine Learning*, 2017. [Online]. Available: https://www.semanticscholar.org/reader/ad0427befa82c7a031b05f6a6c767f6d66a7de21.

[18] J. Gallego *et al.*, "Glomerulus classification and detection based on convolutional neural networks," *Journal of Imaging*, vol. 4, no. 1, 2018, doi: 10.3390/jimaging4010020.

[19] M. Ayyar, P. Mathur, R. R. Shah, and S. G. Sharma, "Harnessing AI for Kidney Glomeruli Classification," in *2018 IEEE International Symposium on Multimedia (ISM)*, 2018, pp. 17-20, doi: 10.1109/ISM.2018.00011.

[20] K. B. Chimwayi, N. Haris, R. D. Caytiles, and N. Ch. S. N. Iyengar, "Risk Level Prediction of Chronic Kidney Disease Using NeuroFuzzy and Hierarchical Clustering Algorithm (s*)," International Journal of Multimedia and Ubiquitous Engineering*, vol. 12, no. 8, pp. 23-36, 2017, doi: 10.14257/ijmue.2017.12.8.03.

[21] V. Kunwar, A. S. Sabitha, T. Choudhury and A. Aggarwal, "Chronic Kidney Disease Using Fuzzy C-Means Clustering Analysis," *International Journal of Business Analytics*, vol. 6, no. 3, 2019, doi: 10.4018/IJBAN.2019070104.

[22] N. J. M. Jamal, K. M. N. Ku Khalif and M. S. Mohamad, "The implementation of z-numbers in fuzzy clustering algorithm for wellness of chronic kidney disease patients," *2nd International Conference on Applied & Industrial Mathematics and Statistics*, 2019, vol. 1366, doi: 10.1088/1742-6596/1366/1/012058.

[23] A. Agusta, F. Y. Arini, and R. Arifudin, "Implementation of Fuzzy Logic Method and Certainty Factor for Diagnosis Expert System of Chronic Kidney Disease," *Journal of Advances in Information Systems and Technology*, vol. 2, no.1, pp. 61-68, 2020. [Online]. Available: https://journal.unnes.ac.id/sju/index.php/jaist/article/view/44369

[24] F. Hamedan, A. Orooji, H. Sanadgol, and A. Sheikhtaheri, "Clinical Decision Support System to Predict Chronic Kidney Disease: A Fuzzy Expert System Approach," *International Journal of Medical Informatics*, vol. 138, 2020, doi: 10.1016/j.ijmedinf.2020.104134.

[25] S. Pirmoradi, M. Teshnehlab, N. Zarghami, and A. Sharifi, "A Self-Organizing Deep Neuro-Fuzzy System Approach for Classification of Kidney Cancer Subtypes Using miRNA Genomics Data," *Computer Methods and Programs in Biomedicine*, vol. 206, 2021, doi: 10.1016/j.cmpb.2021.106132.

[26] M. S. Iraji, "Chronic Kidney Disease Prediction Using Two Layer Adaptive Neuro-Fuzzy Inference System Topology," *International Journal of Computer Science and Information Security (IJCSIS)*, vol. 14, no. 8, 2016. [Online]. Available: https://www.academia.edu/29039488/Chronic_Kidney_Disease_Prediction_Using_Two_Layer_Adaptive_Neuro_Fuzzy_Inference_ System Topology

[27] A. Sheikhtaheri, F. Hamedan, H. Sanadgol, and A. Orooji, "Development of a fuzzy Expert System to diagnose chronic kidney disease," *Razi Journal Medical Science (RJMS)*, vol. 25, no. 10, pp. 46-60, 2019. [Online]. Available: https://rjms.iums.ac.ir/browse.php?a_id=5200&sid=1&slc_lang=en&ftxt=0

[28] N. Jindal *et al.*, "Fuzzy Logic Systems for Diagnosis of Renal Cancer," *Applied Sciences*, vol. 10, no. 10, 2020, doi: 10.3390/app10103464.

[29] G. Eknoyan *et al.*, *KDIGO 2012 Clinical Practice Guideline for the Evaluation and Management of Chronic Kidney Disease*, Kidney International Supplements, 2013, vol. 3, no. 1. [Online]. Available: https://kdigo.org/wp-content/uploads/2017/02/KDIGO_2012_CKD_GL.pdf

[30] C. Zoccali *et al.*, "The systemic nature of CKD," *Natural Reviews Nephrology*, vol. 13, pp. 344-358, 2017, doi: 10.1038/nrneph.2017.52.

[31] P. Romagnani *et al.*, "Chronic kidney disease," *Nature reviews disease primers*, vol. 3, no. 17088, 2017. [Online]. Available: https://www.nature.com/articles/nrdp201788.

[32] M. P. Turakhia *et al.*, "Chronic kidney disease and arrhythmias: conclusions from a Kidney Disease: Improving Global Outcomes (KDIGO) Controversies Conference," *European Heart Journal*, vol.39, no. 24, pp. 2314-2325, 2018, doi: 10.1093/eurheartj/ehy060.

[33] T. Faisal, M. N. Taib, and F. Ibrahim, "Adaptive Neuro-Fuzzy Inference System for diagnosis risk in dengue patients," *Expert Systems with Applications*, vol. 39, no. 4, pp. 4483-4495, 2012, doi: 10.1016/j.eswa.2011.09.140.
[34] M. Marashi, A M. Torkashvand, A. Ahmadi, and M. Esfandyari, "Adaptive neuro-fuzzy inference system: Estimation of soil aggregates stability," *Acta Ecologica Sinica*, vol. 39, no.1, pp. 95-101**,** 2019**,** doi: 10.1016/j.chnaes.2018.05.002.
[35] M. K. Hussein, K. R. Hassan, and H. M. Al-Mashhadi, "The quality of image encryption techniques by reasoned logic," *TELKOMNIKA (Telecommunication, Computing, Electronics and Control)*, vol. 18, no. 6, pp. 2992-2998, 2020, doi: 10.12928/TELKOMNIKA.v18i6.14340.

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