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A Novel Approach for Chronic Kidney Disease Identification Empowered with Fuzzy Logic

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Abstract: Chronic kidney disease (CKD) is a non-communicable condition that often leads to renal failure, which is when the kidneys are no longer able to filter waste and excess fluid from the body's circulation. Early detection of CKD can slow the progression of the illness and reduce the overall cost of treatment. In this work, a novel approach for identifying CKD using a fuzzy logic system is proposed. The fuzzy system includes eight input parameters such as weight, age, serum creatinine, diastolic blood pressure, systolic blood pressure, glomerular filtration rate, blood glucose, and smoking. The output variable describes a specific patient's stage of chronic renal disease based on these input factors. The output will indicate the current stage of a patient's kidney disease. This system can therefore assist specialists in determining the stage of chronic renal disease. The MATLAB software is used to create the fuzzy system. The proposed system is tested on a real data set of patients and the results obtained are promising.

Keywords: Chronic Kidney Disease; Clinical Decision Support System; Fuzzy Logic System.

1. Introduction

In the previous century, infectious diseases were the primary cause of death. However, in the 21st century, non-communicable diseases such as cancer, diabetes, and chronic diseases have emerged as the leading causes of disability and mortality. Chronic kidney disease (CKD) is a severe public health concern globally, with a prevalence exceeding 10% in the general population and a high economic cost for treatment [1-3]. The prevalence of CKD is increasing at an annual rate of 8% [4] and accounts for approximately 2% of medical spending worldwide. The prevalence of CKD is six to eight times higher in people aged 70 to 90 compared to those aged 30 to 50 [5]. CKD is characterized by a continuous decrease in glomerular filtration rate (GFR) or by morphological or anatomical changes in the kidneys. There are usually no significant symptoms of CKD in the early stages of the disease, but the patient may experience symptoms such as fatigue and loss of appetite as it progresses. The exact cause of CKD is not known and many patients are unaware of its origins. The financial burden of CKD is increasing and it is one of the main factors contributing to deaths worldwide. It was predicted that CKD would affect 500 million people globally in 2012 and it is more prevalent in developing countries than in industrialized countries [6].

Traditionally, the severity of CKD is estimated using various computational methods based on different biomarkers. The glomerular filtration rate, which is widely used in medical settings, is considered the most reliable measure of kidney function [7]. However, studies have shown that GFR alone is not sufficient to diagnose CKD [8]. While using markers such as insulin or iothalamate to evaluate GFR is reliable, these methods are not practical or cost-effective for everyday use [9]. Despite being the first line of defense in identifying and managing CKD, general practitioners are often unable to diagnose it in most cases. Some people with cardiovascular disease and diabetes have elevated GFR levels, which can make it difficult for healthcare practitioners to diagnose CKD in these individuals. The early stages of CKD are often asymptomatic, so it can go undetected for a long time. Therefore, timely identification and treatment of CKD are essential to reduce the financial burden [10].

Numerous factors, including insufficient knowledge and infrequently provided lab services, are contributing to the increased burden of renal disease globally [11]. Lack of awareness is caused by a lack of information, lack of accessibility, or inaccurate information. As a consequence of this knowledge gap, individuals often seek healthcare when their illness has progressed to a terminal stage, leading to a lower chance of successful treatment [12]. Early detection of diseases requires knowledge of their signs and symptoms and awareness among patients can decrease the progression of disease and help prevent future fatalities [7, 10, and 13]. Medical diagnosis can be made easier through the use of clinical decision-support technologies such as expert systems (ES) [11]. These systems utilize the ability of humans to solve problems that require human intelligence and provide specialized expertise in the form of decision rules. Many medical intelligence systems are available to assist with the diagnosis or treatment of disorders. However, fuzzy systems are often used to deal with uncertain real-world phenomena [12]. Fuzzy expert systems (FES) are intelligent systems that can convert expert knowledge into information that can be used to create patient treatment plans or make early diagnoses of diseases [13, 14]. The FES is particularly concerned with acquiring diagnostic expertise from medical professionals and obtaining ambiguous and imprecise information from patients. A FES can translate medical knowledge into mathematical models, which serve as a basis for making conclusions [15, 16]. There have been numerous studies that have used machine learning techniques or expert systems to diagnose or predict kidney-related diseases [7, 17-19]. However, there have been reports of a lack of valid and reliable tools. To date, very rarer studies have been published on CKD awareness and the use of fuzzy expert systems among hemodialysis patients in Pakistan [20-22].

The main objective of this manuscript is to develop an FES for early prediction of CKD in general physicians working in Pakistan. The study aims to address the crucial need for early detection of CKD and the cost of treatment by introducing an innovative method that uses a fuzzy logic system. The developed system has eight input parameters, which are specifically designed for the Pakistani context taking into account the unique cultural differences therein when it comes to patient input variables. It is desired that this study will provide an efficient tool for general practitioners in Pakistan that can identify CKD earlier thus enhancing patients' results and reducing healthcare expenses.

Section 2 contains a comprehensive review of related works; Section 3 provides a detailed description of the proposed methodology, while Section 4 presents experimental results and discussion. Finally, Section 5 gives conclusions and outlines future work.

2. Related Work

Fuzzy logic expert systems and various artificial intelligence techniques have been the subject of numerous studies for medical diagnosis. The introduction of fuzzy logic by Zadeh [23] has led to the development of numerous applications for fuzzy systems in industries such as manufacturing, decision-making, and medicine. The use of fuzzy expert systems in medical research can be traced back to 1985, and the significant increase in the number of articles published on the topic since then demonstrates the effectiveness of this type of system [24]. As many medical concepts in the medical sciences are poorly defined, research on fuzzy logic is essential for improving their modeling. In this section, we have conducted a review of the literature on the identification of chronic kidney disease in patients to assess the strengths and limitations of current research. A detailed review is presented below.

Pujari and Hajare [23] conducted a study on chronic kidney disease using ultrasonography images of the kidney area. They employed image processing techniques to assess the fibrosis status of the patient's kidney tissue. Their proposed framework will record these findings and use them to categorize the stages of chronic kidney disease. In the same vein, Shakil Ahmed et al. [24] diagnosed kidney disease using a fuzzy expert system. Their paper describes a fuzzy logic-based diagnostic system for evaluating the health of a patient's kidneys. Their system uses data collected from kidney patients at Birdem Hospital in Dhaka. Seven input variables are considered: nephron function, blood sugar levels, blood pressure, age, weight, and alcohol consumption. The output of the system, a measure of kidney health on a scale of 0 to 10, is generated using the fuzzy logic toolbox in Matlab. Furthermore, Damodara, K., & Thakur [25] proposed adaptive neuro-fuzzy inference system-based prediction of chronic kidney disease. Chronic kidney disease is a condition in which the kidneys gradually lose function over some time. It is a common complication of diabetes mellitus and hypertension. Additionally, CKD can increase the risk of cardiovascular death due to the build-up of harmful levels of fluid and waste in the blood. Early detection of this disease is important to protect other organs that may be affected by kidney failure. Their work describes a model for predicting kidney disease using an Adaptive neurofuzzy logic system (ANFIS) and presents a Matlab-based ANFIS CKD stage prediction model with an accuracy of 94%.

The literature review underscores the criticality of early identification of chronic kidney disease to mitigate its advancement and curtail the financial burden of treatment. The proposed novel approach for identifying CKD employs a fuzzy logic system that incorporates eight input parameters, such as weight, age, serum creatinine, blood pressure, glomerular filtration rate, blood glucose, and smoking. The system is tailored to the Pakistani context and accommodates the unique cultural differences in patient input variables, which are relevant to developing countries. This is crucial since the environment and culture of patients can significantly impact their health outcomes.

3. Proposed Methodology

Fuzzy logic is a kind of artificial intelligence that deals with the concept of "varying levels of truth." The best result in a fuzzy logic system is determined by considering not only the absolute truth of the input but also its linguistic aspects. The output depends on the state of the input. A fuzzy logic system consists of four main parts: rule base, which stores rules and membership functions used for decision making; fuzzifier, which converts raw inputs into fuzzy sets; control system operates on these processed fuzzy sets; and finally an inference engine, which selects from applicable rules to produce suitable combinations. Fuzzy results are developed here by applying these rules to given sets. Defuzzification makes a clear output from these fuzzy sets. A fuzzified must be incorporated into any fuzzy logic system before it can be complete. Recently, a Fuzzy interface system (FIS) has been developed as a practical method to deal with situations characterized by uncertainty or vagueness. This is thanks to Zadeh's fuzzy set theory [23], which has been implemented successfully. As a result, FIS can model the knowledge of experienced medical professionals. The knowledge base of the system is crucial for its success, with the rule base being even more important than the database. Fine-tuning a fuzzy inference system involves finding the optimal distribution of the membership functions in the database. Gathering new information is the most time-consuming and labor-intensive part of building a FIS. It is vital to include the knowledge of experts from various fields to ensure that fuzzy inference systems can be effective in a wide range of contexts. This is because experts' knowledge can solve various problems involving uncertainty and imprecision in their specific areas of expertise. This work presents a fuzzy inference system that uses a large number of knowledge base rules from multiple experts to diagnose Chronic Kidney Disease. Figure 1 shows the architecture of the Fuzzy system used to predict CKD.

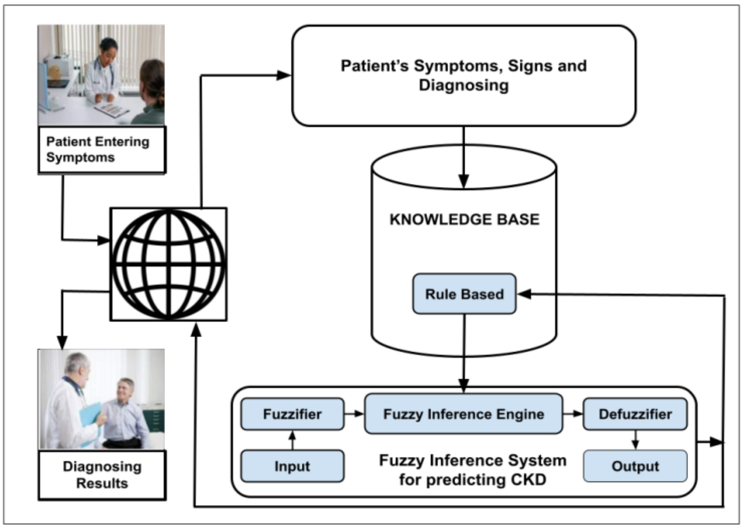

Figure 1. Fuzzy system architecture for predicting CKD.

3.1 Input and Output Parameters

The attributes should be selected carefully to ensure perfect classification of patients. The following is a description of the eight input variables that were considered during this study.

3.1.1 Weight

A person's kidneys can suffer as a direct result of their weight. When a person is overweight, their kidneys have to filter extra waste products. The risk of renal disease rises over time as a result of this additional work. It has three fuzzy sets of values. A low body weight is defined as being less than 45. A medium weight ranges from 46 to about 85. The weight is regarded as high when it exceeds 120.

3.1.2 Age

Old age can severely harm the patient's kidneys. It contains three different variables. Elderly patients are those above 60, middle-aged patients are those between 33 and 55, and young patients are those under 28.

3.1.3 Serum Creatinine

Normal muscle breakdown produces creatinine as a waste product. Creatinine levels are a reasonably accurate marker of renal health. Creatinine levels above normal indicate renal dysfunction. It has three fuzzy sets of values. Blood creatinine values below 0.6 are low. Normal Creatinine levels in the blood of healthy persons typically range from 0.6 to 1.2 mg/dL. A value greater than 1.2 denotes an abnormal value.

3.1.4 Diastolic Blood Pressure

The diastolic blood pressure is at its lowest point before the left ventricle pushes blood into the aorta when the heart is at rest between beats. There are three fuzzy sets for it. The diastolic blood pressure is deemed low if the range is less than 80, high if the range exceeds 120, and medium if it is between 87 and 110.

3.1.5 Systolic Blood Pressure

Systolic blood pressure is the maximum force that the aorta may experience during a heartbeat as blood is discharged into the vessel from the left ventricle. Systolic blood pressure is measured in three ranges: low (below 118), medium (between 127 and 153), and high (beyond 180).

3.1.6 Glomerular Filtration Rate (GFR)

The glomerular filtration rate is a useful indicator of kidney health. The average amount of blood passing through the glomeruli in a minute is determined. Glomeruli, which are tiny filters in the kidneys, filter waste from the blood. If the result is less than 15, the functionality is extremely unsafe. Between 89 and 60, the risk is moderate, and between 90 and 120, it is considered normal.

3.1.7 Blood Glucose

Blood glucose levels are a quantitative indicator of the amount of glucose circulating in the blood. Three distinct fuzzy sets are provided for this. Generally, a blood glucose level below 65 is considered low, between 105 and 140 is considered borderline, and above 200 is considered high.

3.1.8 Smoking

According to the Multiple Risk Factor Intervention Trial (MRFIT), smoking can cause end-stage renal disease (ESRD). Nicotine increases proteinuria (excessive amount of protein in the urine) and increases the risk of CKD. Tobacco smoking also introduces other poisons. It has three fuzzy sets of values. The spread is low if it is significantly less than 2.64, medium if it is between 1.8 and 9.5, and high if it is more than 9.5.

3.1.9 Output Variable

The output variable evaluates the patient's kidney condition through various aspects of the input variables. The output has a 0 to 100 range. The numbers 0 and 100 represent how well or how badly the patient's kidneys are doing. The variable contains four fuzzy sets.

- Healthy: The patient is regarded as healthy if the output variable has a value between 1-30.
- Concerning CKD: The patient's renal health is concerning if the output variable's value falls within the range of 31 to 55, which is considered to indicate a concerning stage of renal disease; the kidney status is said to be complicated.
- Sick CKD: If the output number exceeds 55, which is considered the point at which the kidneys have reached the end of their useful life, and may lead to kidney failure.

3.2 Fuzzy Inference System for Identification of Chronic Kidney Disease

The first step in the FIS system for the identification of chronic kidney disease in Pakistan was collecting data regarding chronic kidney disease. The dataset used in our system includes 60 patient clinical test results from Mayo Hospital in Lahore collected over 2 years from 2021 to 2022. The purpose of this dataset is to improve the diagnosis of kidney diseases. It includes information on weight, age, serum creatinine, diastolic blood pressure, systolic blood pressure, glomerular filtration rate, blood glucose, and smoking. We selected eight input variables from these attributes based on their importance in determining kidney failure. We did not include the result of the ultrasound examination as it does not contain any uncertainty. The electrolyte levels generally have little effect on kidney health. The ages of the patients in the dataset range from 30 to 80 years, with the majority being around 52 years old. The dataset was originally larger, but outliers were removed and the data was balanced for gender. Each of the selected attributes was classified into ranges based on their values. For example, weight was divided into three levels: low, medium, and high. Age was divided into three categories: young (below 30), middle-aged (33-55), and old (above 51). Serum Creatinine was divided into three levels: low, normal, and critical. Diastolic Blood Pressure and Systolic Blood

Pressure were divided into three levels: low, medium, and high. The glomerular filtration rate was divided into three levels: very risky, moderately risky, and safe zone. Blood glucose was divided into three levels: low, borderline, and high. Smoking was divided into three levels: low, medium, and high. The inputs and outputs of the fuzzy system are depicted in Figure 2.

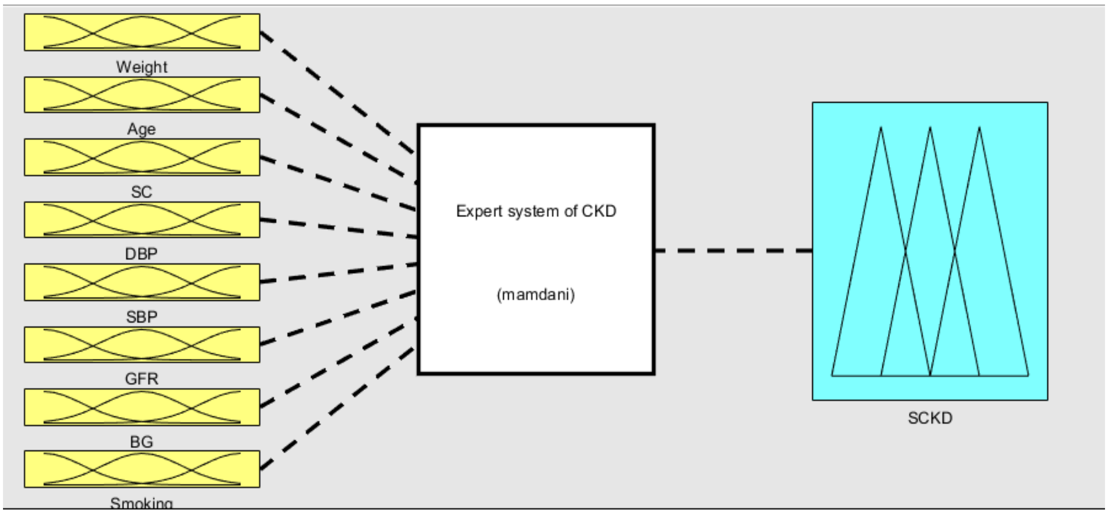

Figure 2. Inputs and output of the expert system for identification of Chronic Kidney Disease.

3.3 Knowledge Base System

The information base system for the recommended unfamiliar method of CKD identification, whose mainstay is fuzzy logic, comprises a combination of several input variables including weight, age, serum creatinine level, blood pressures (diastolic and systolic), GFR, blood glucose, and smoking. This involves putting together these parameters utilizing fuzzy logic which ensures an adaptable and extensible decision-making framework. The adoption of this kind of reasoning allows the system to handle inaccurate data as well as information that may not be so clear hence it ensures more accurate diagnostics and a less costly treatment process for chronic kidney disease. The proposed approach is Pakistani based customizing it to fit in with the cultural variations as well as patient input variables specifically relevant to developing nations. Therefore, this system will assist medical doctors in identifying which stage a person is in chronic renal disease thus allowing early intervention hence saving money on treatment. A novelty for this knowledge base system comes from its use of Mamdani's rule-based fuzzy inference system implemented using MATLAB which provides a wide variety of rules based on different contexts and areas of expertise enabling it to be an effective tool for identification and management of CKD. The suggested model has eight inputs plus one output variable while the description contains comprehensive explanations about them. Table 1 presents the ranges for the Fuzzy Inference System used in the identification of Chronic Kidney Disease. Table 2 provides the linguistic representation of the output variable for diagnosis and Figure 3 illustrates the flowchart of the proposed system.

Table 1. Ranges for Fuzzy Inference System for Identification of Chronic Kidney Disease

Sr. No	INPUT Parameters	RANGE	Semantic sign
1.	Weight	“<45”, “46-85” “120>”	“Low”, “Medium” “High”
2.	Age	“<28” “33-55” “60>”	“Young” “Mid age” “Old”
3.	Serum Creatinine	” <0.6” “0.6-1.2” “1.2>”	“Low” “Normal” “Critical”
4.	Diastolic Blood Pressure	“<80”, “87-110”, “120>”	“Low”, “Medium” “High”
5.	Systolic Blood Pressure	“<118”, “127-153”, “180>”	“Low”, “Medium” “High”
6.	Glomerular filtration rate(GFR)	“<0.35”, “0.3-0.5”, “0.47>”	“Very-Risky” “Moderately Risky” “Safe-zone”
7.	Blood glucose	“<65”, “105-140”, “200>”	“Low” “Borderline” “High”
8.	Smoking	“<2.64” “1.8-9.5”, “9.5>”	“Low”, “Medium” “High”

Table 2. Linguistic representation of output variable diagnosis.

Sr. No	Fuzzy Output Variable	Range	Parameters of Fuzzy set
1.	Stages of Cronic kidney disease (SCKD)	“1-30”, “31-55”, “61-100”	“Healthy”, “Concerning”, “Sick”,

3.4 Rule Based

Fuzzy rule-based systems have become increasingly popular in a wide range of applications due to their adaptability and extensibility. They can handle a wide variety of input and output shapes and different types of fuzzy logic, making them versatile in making decisions. In the context of predicting CKD, fuzzy inference systems utilize fuzzy rules to represent a wide range of knowledge in different contexts. In this study, the Mamdani fuzzy inference rule-making system was utilized to generate all the rules required. Figure 4 provides a graphical representation of the rules diagram.

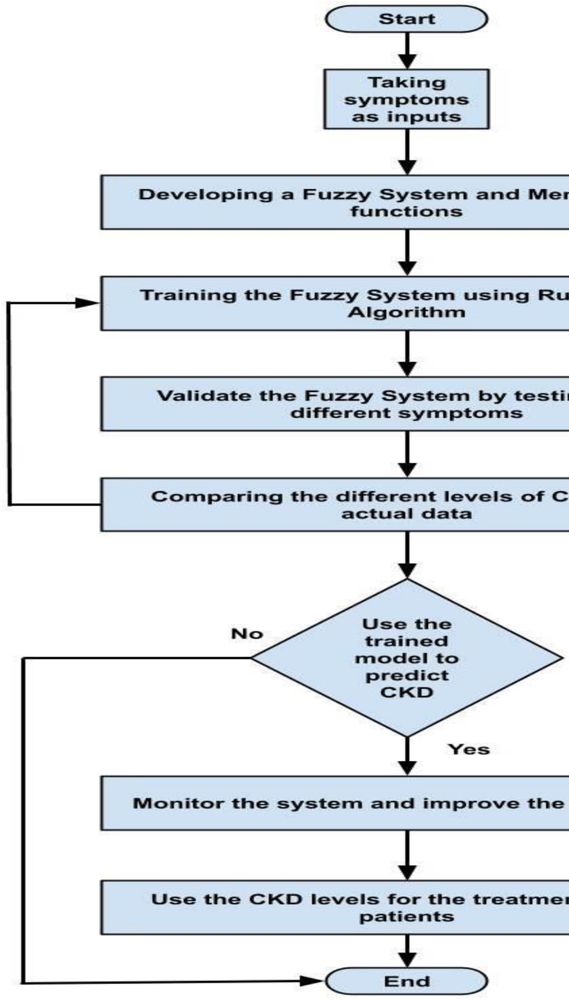

Figure 3. Flowchart of the proposed system.

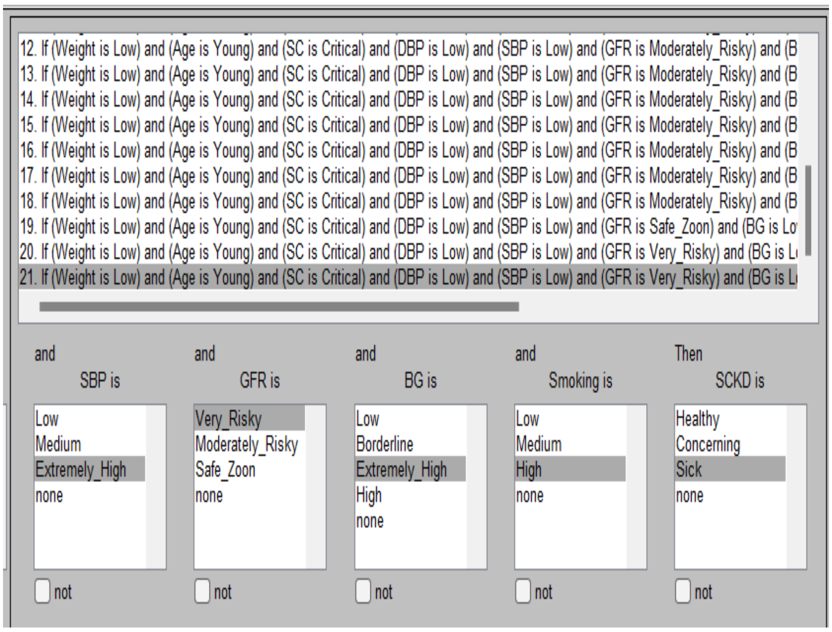

Figure 4. Input and output rules for Chronic Kidney disease identification system.

4. Experimental Results and Discussions

Figure 5 describes the values of weight (51.8), age (27.5), serum creatinine (0.68), diastolic blood pressure (89.8), systolic blood pressure (132), glomerular filtration rate (0.425), blood glucose (110), and smoking (1.08). The SCKD outcome value is 15, indicating that the individual is in a healthy state.

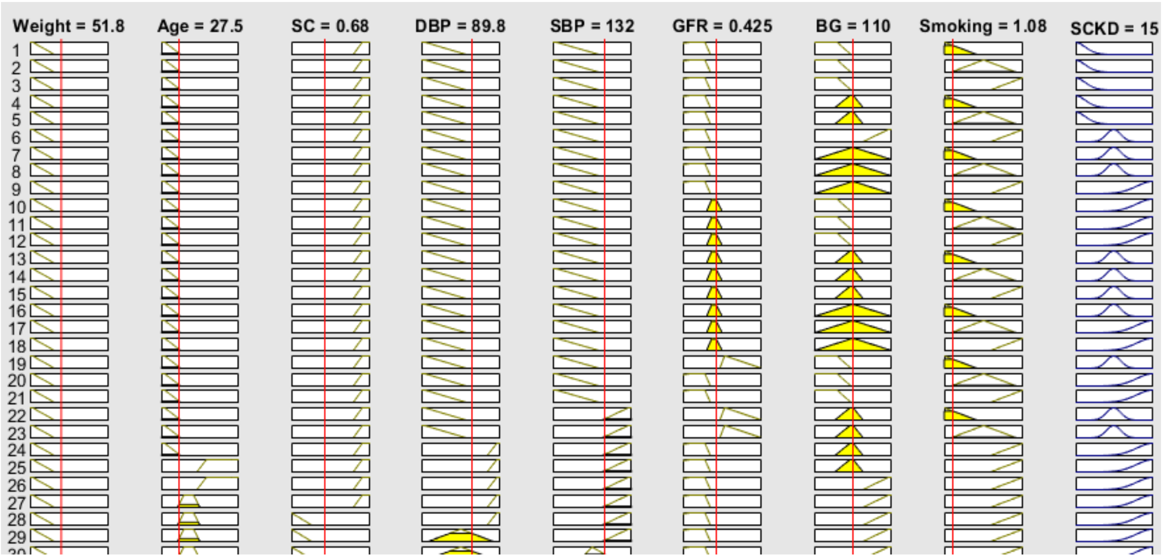

Figure 5. Lookup diagram for healthy individuals.

Figure 6 describes the values of weight (76.9), age (58), serum creatinine (1.24), diastolic blood pressure (113), systolic blood pressure (158), glomerular filtration rate (0.442), blood glucose (144), and smoking (6.58). The SCKD outcome value is 50, indicating that the patient is concerning.

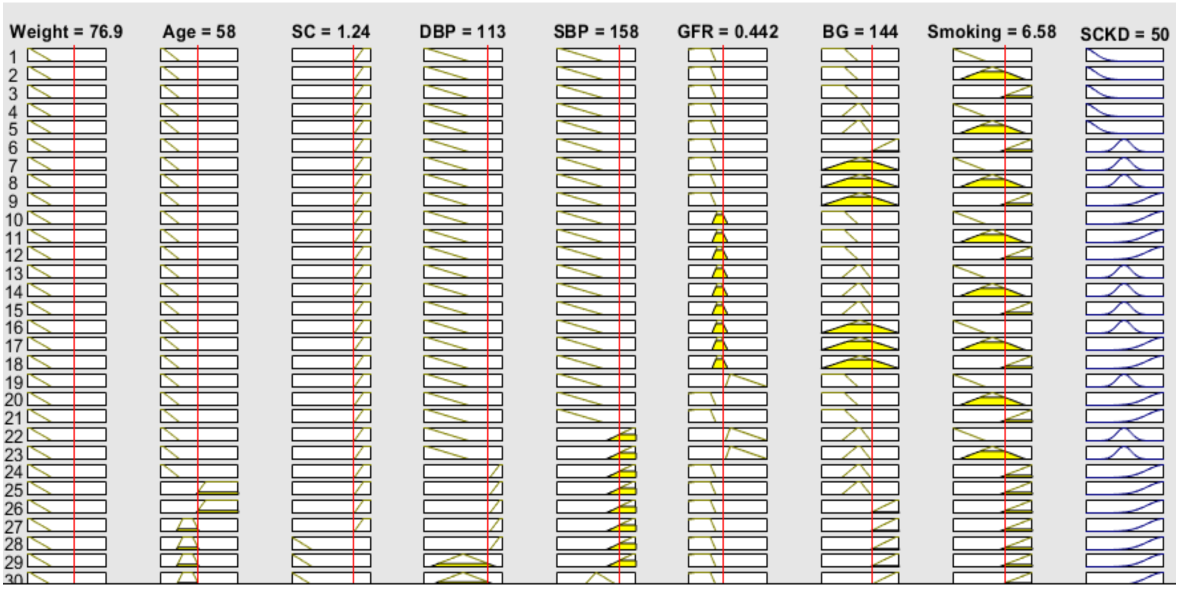

Figure 6. Lookup diagram for the concerning state of the patient.

Figure 7 describes the values of weight (92.1), age (58), serum creatinine (1.24), diastolic blood pressure (113), systolic blood pressure (175), glomerular filtration rate (0.308), blood glucose (57.8), and smoking (5.25). The SCKD outcome value is 70, indicating that the patient is in a very sick state.

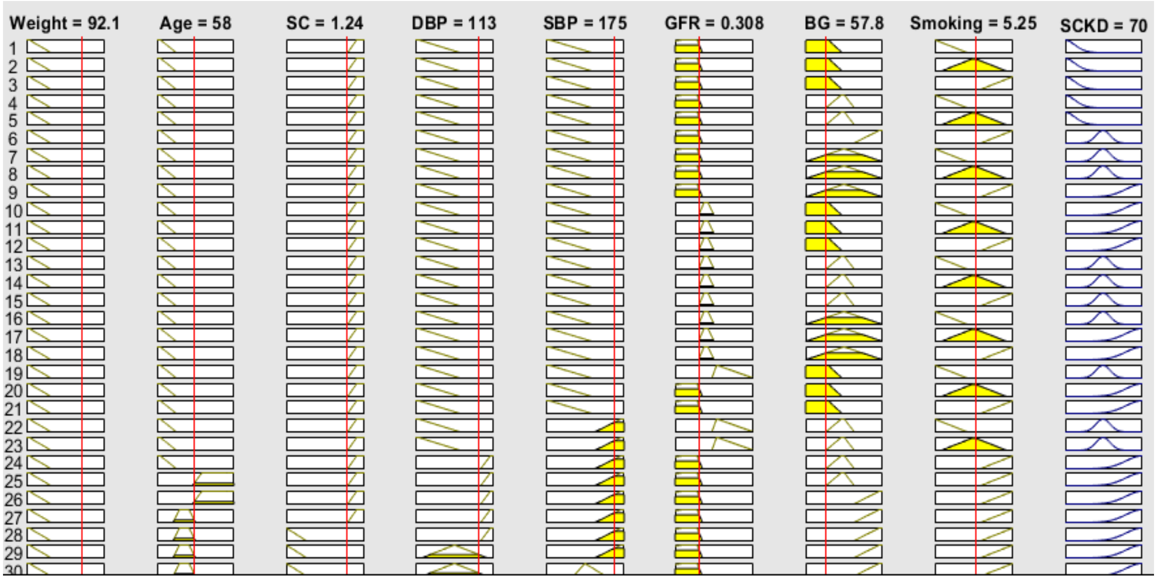

Figure 7. Lookup diagram for the sick patient.

4.1 Proposed System for Identification of Chronic Kidney Diseases

The input symptoms and indicators for the CKD predictor include CKD-related symptoms and indicators. The presence of these symptoms and indicators like Age, Weight, Serum Creatinine, Diastolic Blood Pressure, Systolic Blood Pressure, GFR, Blood sugar level, and Smoking aids in predicting CKD at three levels: "Healthy", "Concerning" or "Sick". In Figure 8-10, the system's design shows how the inputs from the user are transformed to determine their risk level. This system aims to give a rapid and precise evaluation of CKD risk among patients which can be used for medical consultations or even as a tool for following up on a patient's disease progression over time. This CKD prediction system is intended to offer an invaluable tool for early detection and management of chronic kidney diseases thus enhancing timely response to health care needs.

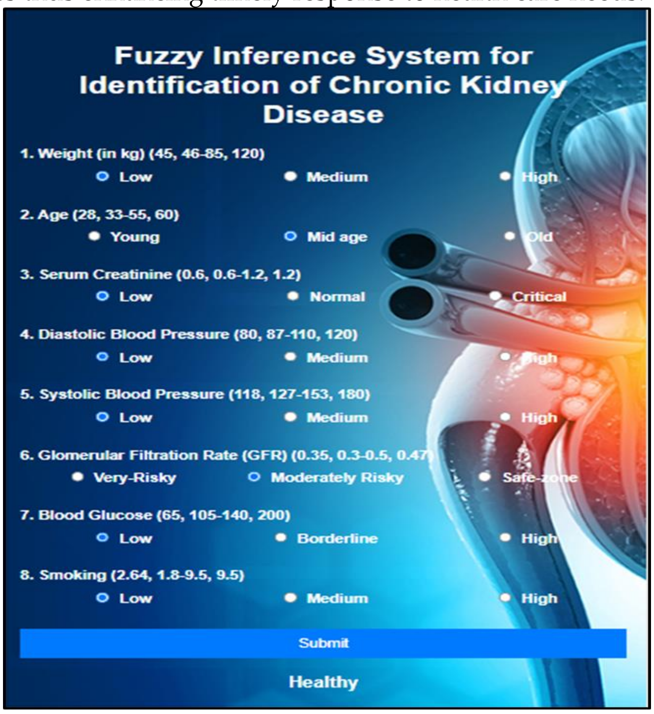

Figure 8. CKD fuzzy symptom prediction system (healthy).

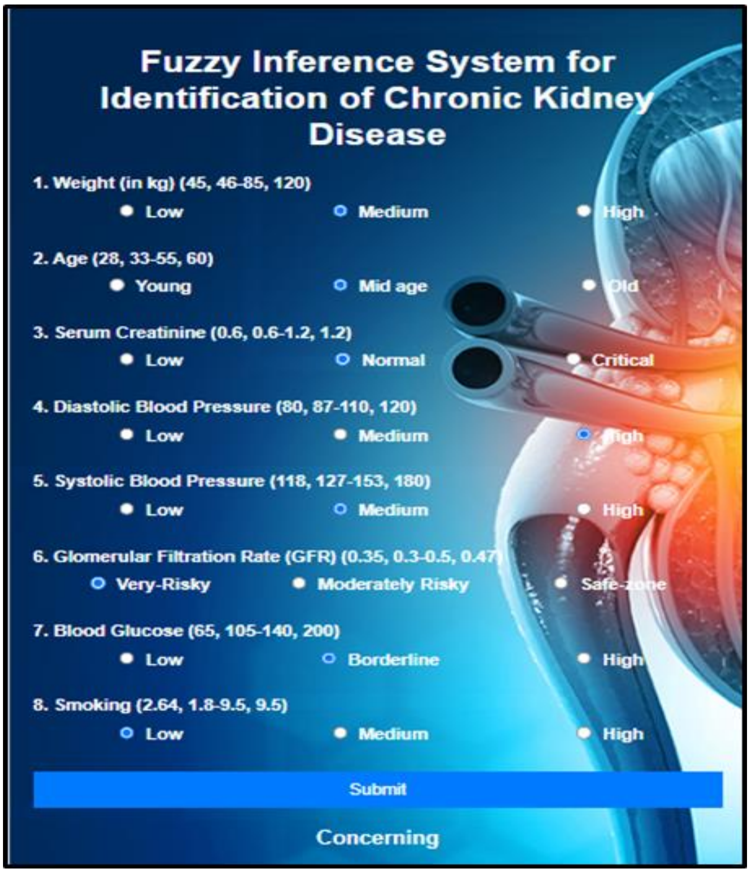

Figure 9. CKD fuzzy symptom prediction system (concerning).

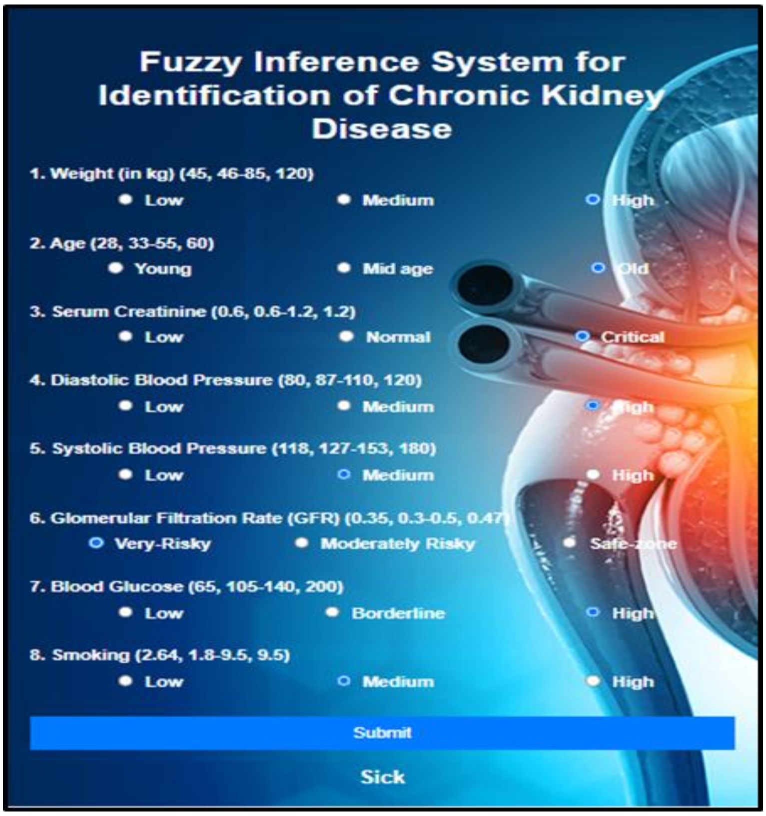

Figure 10. CKD fuzzy symptom prediction system (sick).

4.2 Performance Analysis of the Proposed System

Data was obtained from Mayo Hospital's research center in Lahore, Pakistan. These data were organized when patients were being examined by the outpatient department. Symptoms collected by the doctors to diagnose chronic kidney disease were then used to evaluate the accuracy and results of our system. As shown in Table 3, our CKD prediction system worked well when compared with opinions given by professionals, medical reports, and our system. To check its validity we tested it using patient data from Mayo Hospital, Lahore, Pakistan. We matched the results derived from our system with those that were reported by doctors of various cases and recorded symptoms on patient files respectively. By comparing expert opinions' results and those obtained from medical reports with ones emanating from our system, we detected any disparities that could have occurred and evaluated the general precision of our tool as a whole. This also helped us identify areas where the system may require further improvements. Our proposed system had a 95% accuracy rate. The figure was arrived at by comparing this result. Using the (57÷60x100=95) formula we estimated its accuracy. Detailed performance measurement is available in Table 3.

Table 3 compares the diagnoses for 60 patients across three categories: Expert Opinions, Medical Reports, and a Proposed System. In most cases, both the expert opinions and the proposed system match the medical reports, indicating a general agreement in diagnosing patients as "Sick," "Concerning," or "Healthy." However, there are a few instances where the expert opinions or the proposed system deviate from the medical reports, such as Patient 4 (where the expert identified the patient as healthy, but the medical report indicated a concerning condition) and Patient 13 (where the proposed system labeled a patient as concerning, while both the expert and medical report marked them as sick). Overall, the proposed system seems to have high accuracy, closely aligning with the medical reports in the majority of cases.

Table 3. Evaluation comparison.

Patients	Expert Opinions	Medical Reports	Proposed System
Patient 1	Sick	Sick	Sick
Patient 2	Sick	Sick	Sick
Patient 3	Concerning	Concerning	Concerning
Patient 4	Healthy	Concerning	Healthy
Patient 5	Concerning	Concerning	Concerning
Patient 6	Healthy	Healthy	Healthy
Patient 7	Healthy	Healthy	Healthy
Patient 8	Healthy	Healthy	Healthy
Patient 9	Concerning	Concerning	Concerning
Patient 10	Concerning	Concerning	Concerning
Patient 11	Concerning	Concerning	Concerning
Patient 12	Sick	Sick	Sick
Patient 13	Sick	Sick	Concerning
Patient 14	Healthy	Healthy	Healthy
Patient 15	Healthy	Healthy	Healthy
Patient 16	Sick	Sick	Sick
Patient 17	Concerning	Sick	Sick
Patient 18	Concerning	Concerning	Concerning
Patient 19	Healthy	Healthy	Healthy
Patient 20	Sick	Sick	Sick

Patient 21	Concerning	Concerning	Concerning
Patient 22	Healthy	Healthy	Healthy
Patient 23	Sick	Sick	Sick
Patient 24	Concerning	Concerning	Concerning
Patient 25	Healthy	Healthy	Healthy
Patient 26	Sick	Sick	Sick
Patient 27	Concerning	Concerning	Concerning
Patient 28	Healthy	Healthy	Healthy
Patient 29	Sick	Sick	Sick
Patient 30	Healthy	Healthy	Healthy
Patient 31	Concerning	Concerning	Concerning
Patient 32	Healthy	Healthy	Healthy
Patient 33	Sick	Sick	Sick
Patient 34	Concerning	Concerning	Concerning
Patient 35	Healthy	Healthy	Healthy
Patient 36	Sick	Sick	Sick
Patient 37	Concerning	Concerning	Concerning
Patient 38	Healthy	Healthy	Healthy
Patient 39	Sick	Sick	Concerning
Patient 40	Concerning	Concerning	Concerning
Patient 41	Healthy	Healthy	Healthy
Patient 42	Sick	Sick	Sick
Patient 43	Concerning	Concerning	Concerning
Patient 44	Healthy	Healthy	Healthy
Patient 45	Sick	Sick	Sick
Patient 46	Concerning	Concerning	Concerning
Patient 47	Healthy	Healthy	Healthy
Patient 48	Sick	Sick	Sick
Patient 49	Concerning	Concerning	Concerning
Patient 50	Healthy	Healthy	Healthy
Patient 51	Sick	Sick	Sick
Patient 52	Healthy	Concerning	Concerning
Patient 53	Healthy	Healthy	Healthy
Patient 54	Sick	Sick	Sick
Patient 55	Concerning	Concerning	Concerning
Patient 56	Healthy	Healthy	Healthy
Patient 57	Sick	Sick	Sick
Patient 58	Concerning	Concerning	Concerning
Patient 59	Healthy	Healthy	Concerning
Patient 60	Sick	Sick	Sick

5. Conclusion

A new approach for CKD identification has been proposed using a fuzzy logic system with eight input parameters consisting of weight, age, serum creatinine, blood pressure, glomerular filtration rate, blood glucose, and smoking. The proposed model is specifically designed for Pakistan where such variables differ in cultural meaning among the patients which is important for developing countries. Specialists can use this system to determine the stage of chronic renal ailments thereby enabling early detection that will help slow down its progression and reduce the total cost of treatment. Promising results were obtained based on testing the actual patient data. Future work could be extended to include other input models like genetic factors, dietary habits, and environmental factors that will enhance accuracy in diagnosis. Besides, it can also be applied to other developing nations to improve CKD diagnosis and management.

Declarations

Ethics Approval and Consent to Participate

The results/data/figures in this manuscript have not been published elsewhere, nor are they under consideration by another publisher. All the material is owned by the authors, and/or no permissions are required.

Consent for Publication

This article does not contain any studies with human participants or animals performed by any of the authors.

Availability of Data and Materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Competing Interests

The authors declare no competing interests in the research.

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Author Contribution

All authors contributed equally to this research.

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