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Design and Development of an Intelligent System to Assess Kidney Performances of Persons Suffering from Diabetes

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Abstract

Background: Diabetes is the leading cause of many covert diseases, and kidney disease is one of them. For diabetic patients, the prediction of the kidney performance in progressions over time is crucial because reducing the cause of End-Stage Renal Disease (ESRD) and increasing the mortality rates. **Objective:** This present study develops a qualitative-based linguistic decision-making algorithm for predicting the various stages of kidney performance and the chances of the corresponding stage. **Method:** Concerning various literature surveys, it takes mainly 11 input risk factors for a diabetic patient and converts these input factors into fuzzy variables using the fuzzy combination approach, to develop the proposed algorithm. **Result:** It has been observed that our model's prediction is near correct with doctors' predictions by applying the real-life data from nearby health centers. **Conclusion:** The proposed algorithm can be used to develop a digital system (i.e. remote medicine) for rural areas where medical experts are not available properly.

Disciplinary: Medicine and Health Research, Artificial Intelligence, Optimization, Bioinformatics.

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1 Introduction

1.1 Diabetic Nephropathy

Diabetes is a condition of raising the sugar levels in the blood. We all have sugar in our blood, which is very tightly controlled by insulin, and there are other ways in which the sugar levels are kept under tight control. Diabetes happens when the control mechanisms are defective, and the

high sugar is quite poisonous to their internal organs, particularly the blood vessels in our body. Diabetes mellitus is the main of ESRD (End-Stage Renal Disease), mainly in developing countries.

In the initial period, the complications start to build up, but the patient does not feel it for a long time; it may be anything up to 10 years before complications from damage to the small blood vessels, especially the capillaries start to show so it could call this a silent killer. For that reason, blood vessels are damaged, particularly in the back layer of the eyes and in the Kidneys and also those blood vessels supplying the nerves, so we have a problem with kidney damage and nerve damage which will show in the form of a leak of protein and gradual accumulation of toxic products.

If we are to live unhealthy life for an extended period, the high blood sugar causes harm to the inner lining of blood vessels; the smallest of the blood vessels are known as capillaries, and the capillary damage results in leakage of protein into the urinary system. One of the earliest signs of kidney damage with diabetes is a protein in your urine which can be detected long before the blood tests show an abnormality only when 60% or so of the kidneys are damaged. Blood tests show the evidence of kidney inadequacy of diabetes for an extended period the high sugars, its perfection on the tiny blood vessels damages the nerves.

1.2 Problems in Today's Society

Nowadays, Chronic Kidney Disease is increased worldwide at an alarming rate. 10%-15% adult population is affected by this disease, mainly in developed and developing countries [1,2]. In the last decade, World Health Organization (WHO) has invested about 1.1 trillion dollars for improving the diagnosis of Chronic Kidney Disease (CKD) [3].

In the age of Artificial Intelligence, renal failure is dependent on various parameters like Blood Sugar, Blood Pressure, age, lifestyle habits, hypertension. [4,5]. The early detection of this disease can manage and control by changing the various lifestyle factors [6,7]. Recently, using the fuzzy intelligent system in managing and diagnosing different diseases drastically changed in massive computational efforts. A mainly fuzzy expert system is more accurate than any other computational technique because its algorithmic processes are more likely than the human way of thinking. In today's society for imbalanced lifestyle, we need proper management and decision-making system that will help us manage our lifestyle factors and make a correct decision in every step of our life.

2 Literature Review

In few decades, many researchers, through various studies try to diagnose such diseases as soon as possible to prevent disease progression into an End-Stat Renal Disease (ESRD) like hyperphosphatemia, hypertension, and proteinuria. [8, 9, 10]. Different models have been developed to identify the possible risk factors to prevent it into ESRD [8, 10]. Although it has been seen that any model cannot quantitatively predict the accuracy of the various risk factors like "**Albumin in Urine**," "Glomerular Filtration Rate (**GFR**)." In various studied using different

population they have estimated GFR variations for CKD patients [8,9,11,12,13]. Aguilar et al. [14], using 103 CKD patients (mean age 70.8±13), find the associated factors like BMI>30, anemia, +ve cardiovascular disease, age>65, sex male, and they find that in their experiment, age and anemia are strongest factors. In 2004, Gaspari et al., using plasma iohexol clearance on 81 renal transplant patients, measured GFR by comparing 12 prediction equations of renal functions. Using Walser formulas, they have shown that only diet modification can give the lowest bias and highest precision [15].

In 2006, Pandey et al. [16] analyzed cardiac systems using a soft computing rule-based system. Further, in 2012, Srivastava and Srivastava [17, 18] proposed a soft computing risk assessment scheme for cardiac analysis and hypertension. In 2014, Srivastava P. and Sharma N. designed a soft computing model for medical diagnosis [19]. Srivastava et al. [20] developed Soft computing tools, and they applied classification criteria for hepatitis B. and also, in [21], they describe a Soft Computing Diagnostic System for Diabetes diagnosis.

From the literature, it has been observed that various machine learning techniques are used rapidly, and it is increased day by day in health and forecasting of disease-related context. This present study takes 11 input health risk factors [14, 15]. Our main objective is to build a qualitative type decision-making model that predicts the various CKD stages and gives the chances of these corresponding stages. For the qualitative decision-making model 1st transfer the input factors in fuzzy variables and then use the fuzzy combination approach to build this decision-making model.

3 Preliminaries

3.1 Input Factors

In this section, it is discussed about some preliminaries of the intelligent information system. The inputs of this information system have been taken into three stages. In the **1st stage**, input factor is taken "**Blood Sugar (HBA1c)**" and "**Blood Pressure**" parameters because for a Diabetic patient, blood sugar is a primary symptom, and in this diabetic stage, if a patient has high blood pressure, then there may have a chance of kidney failure. So, after analyzing these parameters, we are going to the **2nd stage** input factors. In this stage, we have taken seven parameters, namely "**Smoking**," "**Diabetic Eating Plan**," "**Salty Food**," "**Exercises**," "**Obesity**," "**Heart Diseases**," "**Family History**." These parameters are depending on the lifestyles of a patient. So, analyzing these lifestyle factors, we are going to the final stage input factors. In this **3rd stage**, it is taken the laboratory values of "**Albumin in Urine**" and "**GFR**" values. These are the main two parameters for sure about the level of Kidney diseases.

3.1.1 The First Stage Input Factors

Two parameters, i.e., "Blood Sugar" and "Blood Pressure," have been taken in this stage. According to the input value of these two factors, it is converted into the fuzzy sets using Sigmoidal and Gaussian Membership functions(Shown in Equation 1), the details have been shown in Table 1, and the corresponding fuzzy sets are shown in Figure 1.

Sigmoidal Membership Function: $sigmf\,(x,[a,c]) = \frac{1}{1+e^{-a(x-c)}}$ (1).

Gaussian Membership Function: $gaussmf\,(x,[\sigma,c]) = e^{\frac{-(x-c)^2}{2\sigma^2}}$ (2).

Table 1: Stage 1 input of health risk factors.

Risk Factors	Level	Ranges (mmol/Lit)	Membership Functions
Blood Sugar	Low	<5.7	$\mu^1_{Low}(x) = sigmf\,(x,[-4.4,5.7])$
	Medium	5.7-6.4	$\mu^1_{Medium}(x) = gaussmf\,(x,[0.3,6])$
	High	>6.4	$\mu^1_{High}(x) = sigmf\,(x,[4.4,6.4])$
	Level	Ranges (mmHg)	Systolic/ Diastolic
Blood Pressure	Low	<120/80	$\mu^2_{Sys_L}(x) = sigmf\,(x,[-0.226,120])$ $\mu^2_{Dias_L}(x) = sigmf\,(x,[-0.226,80])$
	Medium	120/80-140/90	$\mu^2_{Sys_M}(x) = gaussmf\,(x,[7.5,130])$ $\mu^2_{Dias_M}(x) = gaussmf\,(x,[7.5,85])$
	High	>140/90	$\mu^2_{Sys_H}(x) = sigmf\,(x,[0.226,140])$ $\mu^2_{Dias_H}(x) = sigmf\,(x,[0.226,90])$

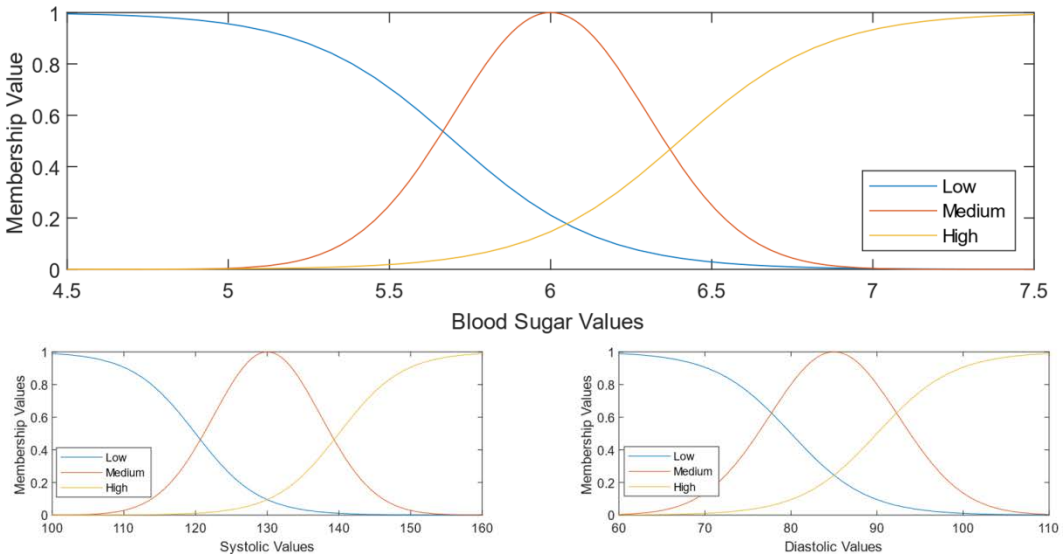

Figure 1: Fuzzy sets if stage 1 input factors

3.1.2 The Second Stage Input Factors

In this stage for seven input factors (i.e., "**Smoking**," "**Diabetic Eating Plan**," "**Salty Food**," "**Exercises**," "**Obesity**," "**Heart Diseases**," "**Family History**") is used as a rating system where 1: Awful, 2: Poor, 3: Fair, 4: Good, 5: Excellent. So, for seven input factors, there have 57 i.e. 78125 no. of combinations, and a patient gives only one input among 78125.

3.1.3 The Third Stage Input Factors

In this stage, it is used two main input factors, namely "**Albumin in Urine**" and "**Glomerular Filtration Rate (GFR)**." These input factors are converted into the fuzzy sets(using Equation 1) shown in Table 2, and the corresponding graphical picture is shown in Figure 2.

Table 2: Stage 3 input factors

Risk Factors	Level	Ranges (mg/dL)	Membership Functions
Albumin in Urine	Normal	<30	$\mu^4_{Nor}(x) = sigmf\ (x,[-0.22, 30])$
	Microalbuminuria	30-300	$\mu^4_{Mic}(x) = gaussmf\ (x,[-50, 165])$
	Macroalbuminuria	>300	$\mu^4_{Mac}(x) = sigmf\ (x,[0.22, 300])$
GFR	Normal	>90	$\mu^5_{Nor}(x) = sigmf\ (x,[1, 90])$
	Mild	60-90	$\mu^5_{Mild}(x) = gaussmf\ (x,[6.5, 74.5])$
	Moderate	30-59	$\mu^5_{Mod}(x) = gaussmf\ (x,[6.5, 44.5])$
	Severe	15-29	$\mu^5_{Sev}(x) = gaussmf\ (x,[3, 22])$
	Kidney Fail	<15	$\mu^5_{Kid.F}(x) = sigmf\ (x,[-0.3, 15])$

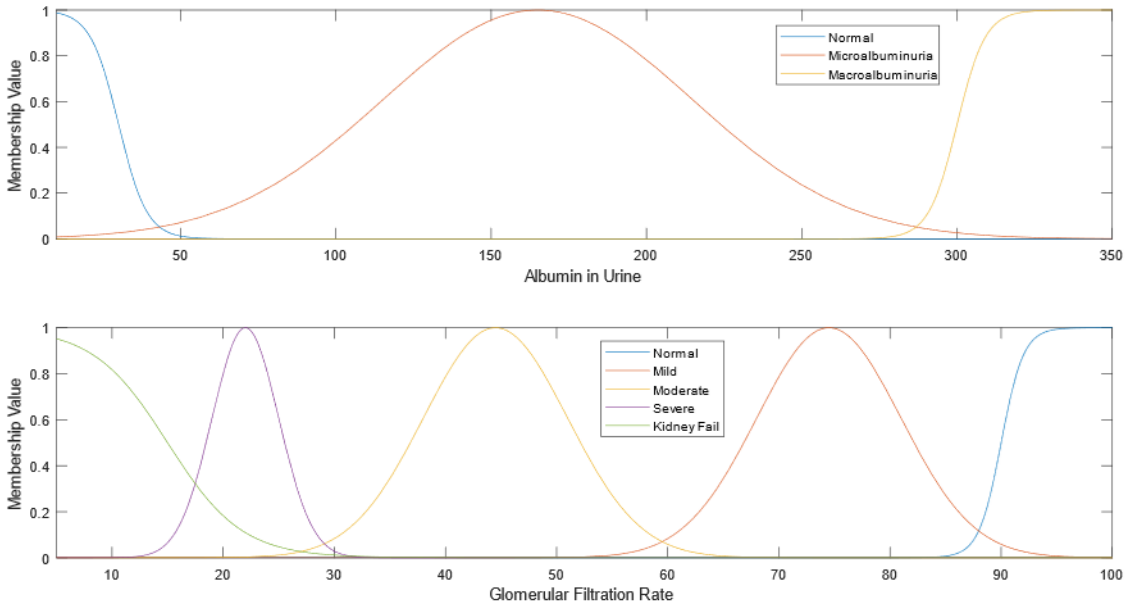

Figure 2: Fuzzy sets of stage 3 input factors

3.2 Output Factors

As an output factor, it is considered five stages, where stage 1 is the least severe stage, and stage 5 is the most severe stage. The symptoms of each stage are:

• **Stage 1:** There have no symptoms; the only exception is patients who spill a huge amount of protein in the urine. Because they can subsequently develop swelling in the legs or other parts of the body.

• **Stage 2:** Usually, there have no symptoms unless they do specific blood and urine testing.

• **Stage 3:** It is the most common kidney disease stage because it is in the middle road of GFR between 30-59. The most common symptoms in this stage are fatigue, swelling in the legs, frequent urination.

• **Stage 4:** The kidney function is considered severe GFR between 15 and 29. There may have more patients having symptoms in this stage can be similar to those with stage 3. However, there might have some additional symptoms like Loss of appetite, Shortness of breath.

• **Stage 5:** In this stage, there are more symptoms than any other stages like Skin Itching, Trouble in Sleeping, Worse Concentration, Nausea, Muscle Cramps.

4 Methodology

This study carried out the computation in 4 steps. In **1st step**, it is computed fuzzy sets for Stage 1 input factors. In the **2nd step**, take the patient's rating for Stage 2 input factors and convert it into a fuzzy set. **3rd step**, compute the fuzzy sets for Stage 3 input factors. Finally, in **step 4**, according to the values of the previous steps, compute the final output result. Its algorithm and graphical structure are shown in Table 3 and Figure 3, respectively.

4.1 Step 1

Let for stage 1 two input factors, "Blood Sugar" and "Blood Pressure," a patient gives the inputs x_1^1 and x_2^1 respectively. Where x_β^α, α: $\#Input\ Stage, \beta$: $\#no\ of\ input\ factors\ of\ stage\ \alpha$.

Then the fuzzy set of "Blood Sugar" is denoted by $\widetilde{F_1}$ and defined by

$$\widetilde{F_1} = \{(i, \mu_i) \big| \mu_i = max\{\mu_i^1(x_1^1)\}, i = Low, Medium, High\} \quad (3).$$

Similarly, for "Blood Pressure" 1st, we calculate the fuzzy sets of Systolic and Diastolic Blood Pressure then combine these two fuzzy sets to the final fuzzy set of Blood Pressure.

$$\text{Let } x_2^1 = {}^{x_{2_{Systolic}}^1}\Big/_{x_{2_{Diastolic}}^1} \quad (4).$$

Fuzzy sets of systolic and diastolic Blood Pressure are denoted by $\widetilde{F_{2_{Sys}}}$ and $\widetilde{F_{2_{Dias}}}$ respectively and defined by

$$\widetilde{F_{2_{Sys}}} = \left\{(\alpha, \mu_\alpha) \middle| \mu_\alpha = max\left\{\mu_{Sys_\alpha}^2\left(x_{2_{Systolic}}^1\right)\right\}, \alpha = L, M, H\right\} \quad (5),$$

$$\widetilde{F_{2_{Dias}}} = \left\{(\beta, \mu_\beta) \middle| \mu_\beta = max\left\{\mu_{Dias_\beta}^2\left(x_{2_{Diastolic}}^1\right)\right\}, \beta = L, M, H\right\} \quad (6).$$

Now combine $\widetilde{F_{2_{Sys}}}$ and $\widetilde{F_{2_{Dias}}}$ and get the final fuzzy set for Blood pressure is denoted by $\widetilde{F_1}$ and defined by

$$\widetilde{F_2} = \{(i, \mu_i) \big| \mu_i = mean\{\mu_\alpha, \mu_\beta\}, i: max\{\mu_\alpha, \mu_\beta\}, i = \alpha, \beta\} \quad (7),$$

4.2 Step 2

Let $x_i^2 (\in \{1,2 \cdots, 5\}); i = 1,2, \cdots, 7)$ be a choice rating of a patient for seven input factors in Stage 2. Because in this stage, a patient has five choices for each factor, and there have seven factors, total $5^7 i.e.$ 78125 no input can be made, and a patient can choose only one input among these 78125 inputs.

So, in this step, the fuzzy set can be made through the following sub-steps:

i. Let $A = Combination\left(\begin{bmatrix}1\\2\\3\\4\\5\end{bmatrix}, \begin{bmatrix}1\\2\\3\\4\\5\end{bmatrix}, \begin{bmatrix}1\\2\\3\\4\\5\end{bmatrix}, \begin{bmatrix}1\\2\\3\\4\\5\end{bmatrix}, \begin{bmatrix}1\\2\\3\\4\\5\end{bmatrix}, \begin{bmatrix}1\\2\\3\\4\\5\end{bmatrix}, \begin{bmatrix}1\\2\\3\\4\\5\end{bmatrix}\right), \therefore length(A) = 5^7 = 78125$

And $(x_1^2, x_2^2, x_3^2, x_4^2, x_5^2, x_6^2, x_7^2) \in A$ and suppose $(x_1^2, x_2^2, x_3^2, x_4^2, x_5^2, x_6^2, x_7^2) = A(l); l = 1,2, \cdots, 5^7$

ii. Let $B = linspace(0,1,5^7) = [0, 1.2800 \times 10^{-5}, 2.5600 \times 10^{-5}, \cdots, 0.6140, 0.6141, \cdots, 1]$

iii. Now the fuzzy set can be defined as $\widetilde{F_3}$ and denoted by

$$\widetilde{F_3} = \{(i, \mu_i) | \mu_i = B(l), i = round(mean(A(l)))\} \quad (8).$$

4.3 Step 3

Let in this stage a patient gives an input $x_1^3$and x_2^3 for "Albumin in Urine" and "GFR" values, respectively.

So, the fuzzy sets of "Albumin in Urine" and "GFR" are defined by $\widetilde{F_4}$ and $\widetilde{F_5}$ and denoted by

$$\widetilde{F_4} = \{(i, \mu_i) | \mu_i = max\{\mu_i^4(x_1^3)\}, i = Nor, Mic, Mac\} \quad (9),$$

$$\widetilde{F_5} = \{(i, \mu_i) | \mu_i = max\{\mu_i^5(x_2^3)\}, i = Nor, Mild, Mod, Sev, Kid.F\} \quad (10).$$

4.4 Step 4

In this step, using the fuzzy sets from previous steps, calculate the final output result

$$\widetilde{F_1} = \{(i_1, \mu_{i_1}) | i_1 = Low(1), Medium(2), High(3)\}$$
$$\widetilde{F_2} = \{(i_2, \mu_{i_2}) | i_2 = L(1), M(2), H(3)\}$$
$$\widetilde{F_3} = \{(i_3, \mu_{i_3}) | i_3 = 1,2,3,4,5\}$$
$$\widetilde{F_4} = \{(i_4, \mu_{i_4}) | i_4 = Nor(1), Mic(2), Mac(3)\}$$
$$\widetilde{F_5} = \{(i_5, \mu_{i_5}) | i_5 = Nor(1), Mild(2), Mod(3), Sev(4), Kid.F(5)\}$$

Using these above five fuzzy sets, we have calculated the result through the following sub-steps

i. $C = Combination\left(\begin{bmatrix}1\\2\\3\end{bmatrix}, \begin{bmatrix}1\\2\\3\end{bmatrix}, \begin{bmatrix}1\\2\\3\\4\\5\end{bmatrix}, \begin{bmatrix}1\\2\\3\end{bmatrix}, \begin{bmatrix}1\\2\\3\\4\\5\end{bmatrix}\right) \therefore length(C) = 3 * 3 * 5 * 3 * 5 = 675$

ii. $\therefore (i_1, i_2, i_3, i_4, i_5) \in C$ and let $(i_1, i_2, i_3, i_4, i_5) = C(m), m = 1,2, \cdots, 675$

iii. $D = linspace(0,5,675) = [0,0.0074,0.0148, \cdots, 2.3071,2.3145, \cdots, 4.9926,5]$

iv. So, the corresponding stage of the output layer is $round(D(m))$.

v. Since the maximum value of $\mu_i's$ are one and $C(675) = (3,3,5,3,5)$

If everything has a maximum $i.e.\max(\mu_i's) * [C(675)]' = 3 + 3 + 5 + 3 + 5 = 19$

So, in our system, 100% denoted the values by 19; 1% is 0.19.

∴The chances value of the output stage $round(D(m))$ is $\frac{(\mu_{i_1}, \mu_{i_2}, \mu_{i_3}, \mu_{i_4}, \mu_{i_5}) * [C(m)]'}{0.19}$

Table 3: Algorithm of the decision-making system.

INPUT

i. **Stage 1:** *Blood Sugar (x_1^1), Blood Pressure (x_2^1)*
ii. **Stage 2:** Rating between 1 to 5 (*Smoking (x_1^2); Maintain Diabetic Eating Plan (x_2^2); Taken Salty foods (x_3^2); Daily Exercise (x_4^2); Obesity (x_5^2); Heart Diseases (x_6^2); Family History of Kidney disease (x_7^2)*)
iii. **Stage 3:** *Albumin in Urine (x_1^3), GFR (x_2^3)*

OUTPUT: a) Level of Kidney Disease, b) Corresponding Chances

METHODOLOGY

STEP 1:

i. From input x_1^1, compute the fuzzy sets $\widetilde{F_1} = \langle i_1, \mu_{i_1} \rangle$ for Blood Sugar

ii. From input x_2^1 , compute $\widetilde{F_{2_{Sys}}}$ and $\widetilde{F_{2_{Dias}}}$ for Systolic and Diastolic Blood Pressure, respectively. Combine $\widetilde{F_{2_{Sys}}}$ and $\widetilde{F_{2_{Dias}}}$ compute $\widetilde{F_2} = \langle i_2, \mu_{i_2} \rangle$.

STEP 2:

i. Calculate A and find the indexing of $(x_1^2, x_2^2, x_3^2, x_4^2, x_5^2, x_6^2, x_7^2)$ in A.

ii. Divide the interval between 0 and 1 into $length(A)$ no. of equal subintervals.

iii. Calculate the fuzzy set $\widetilde{F_3} = \langle i_3, \mu_{i_3} \rangle$ for Stage 2 input data.

STEP 3:

i. From inputs x_1^3 compute $\widetilde{F_4} = \langle i_4, \mu_{i_4} \rangle$ for *Albumin in Urine*

ii. From input x_2^3compute $\widetilde{F_5} = \langle i_5, \mu_{i_5} \rangle$ for *GFR*

STEP 4:

i. Calculate C and find the indexing of $(i_1, i_2, i_3, i_4, i_5)$ in C.

ii. Divide the interval between 1 and 5 into $length(C)$ no. of equal subintervals.

iii. Compute the level of the Kidney Disease and the corresponding chances of that level.

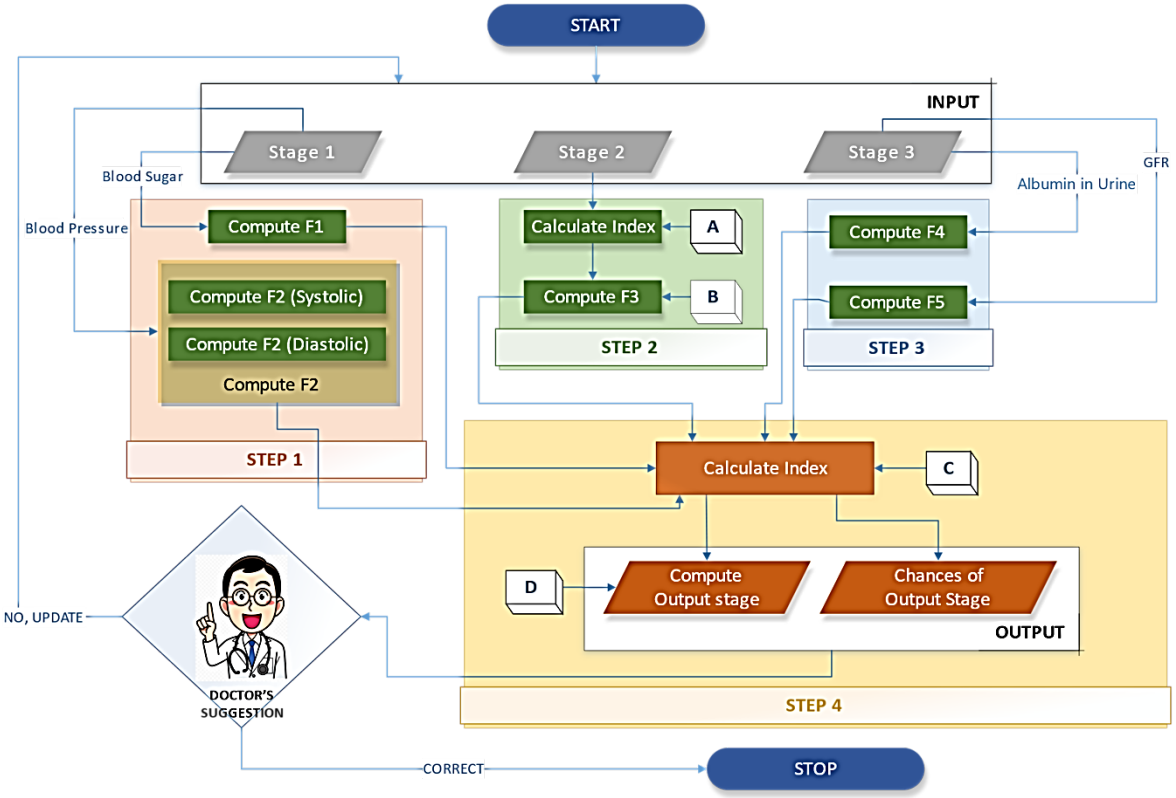

Figure 3: Graphical Structure of the Proposed Algorithm

5 Case Studies

We have taken a patient's medical report from our nearby health centers (details are given in Acknowledgement Section) to justify the proposed algorithm.

1st Stage Input: Blood Sugar=6.2mmol/L; Blood Pressure=143/94mmHg;

2nd Stage Rating: Smoking: 2; Maintain Diabetic Eating Plan: 4; Taken Salty foods: 3; Daily Exercise: 1; Obesity: 4; Heart Diseases: 2; Family History of Kidney disease: 2.

3rd Stage Input: Albumin in Urine=160mg/dL; GFR=65

From stage 1 input, calculate the fuzzy sets $\widetilde{F_1}$ and $\widetilde{F_2}$.

- $\widetilde{F_1} = \langle Medium(2), 0.8007 \rangle$
- $\widetilde{F_{2_{Sys}}} = \langle H, 0.6457 \rangle, \widetilde{F_{2_{Dias}}} = \langle H, 0.6900 \rangle; \therefore \widetilde{F_2} = \langle H(3), 0.6678 \rangle$
- Since,$(2,4,3,1,4,2,2) = A(20692) \therefore B(20692) = 0.264; round\big(mean([2,4,3,1,4,2,2])\big) = round(2.5714) = 3. \therefore \widetilde{F_3} = \langle 3, 0.2648 \rangle$
- $\widetilde{F_4} = \langle Mic(2), 0.9991 \rangle$
- $\widetilde{F_5} = \langle Mild(2), 0.7310 \rangle$

$(i_1, i_2, i_3, i_4, i_5) = (2, 3,3,2,2) = C(206)$ and $D(206) = 2.2166$

Therefore, the output layer stage is $round(2.2166) = 2$, and the value of the corresponding chance is $\frac{(0.8007,0.6678,0.2648,0.9991,0.7310)*(2,3,3,2,2)'}{0.19} = 41.3653\%$

According to our algorithm, this patient is in stage 2 level kidney disease with chances of 41.3653%.

6 Sensitivity Analysis

This section is discussed about the sensitivity of the proposed algorithm. If small changes happened in the input variables, then how it affects the output variables.

Let us consider the above patient; for the stage 1 input factor, if the small changes in Blood Sugar and Blood Pressure and other input variables remain constant, what kind of changes happen in output variables? Details have been shown in Figure 4 and Figure 5

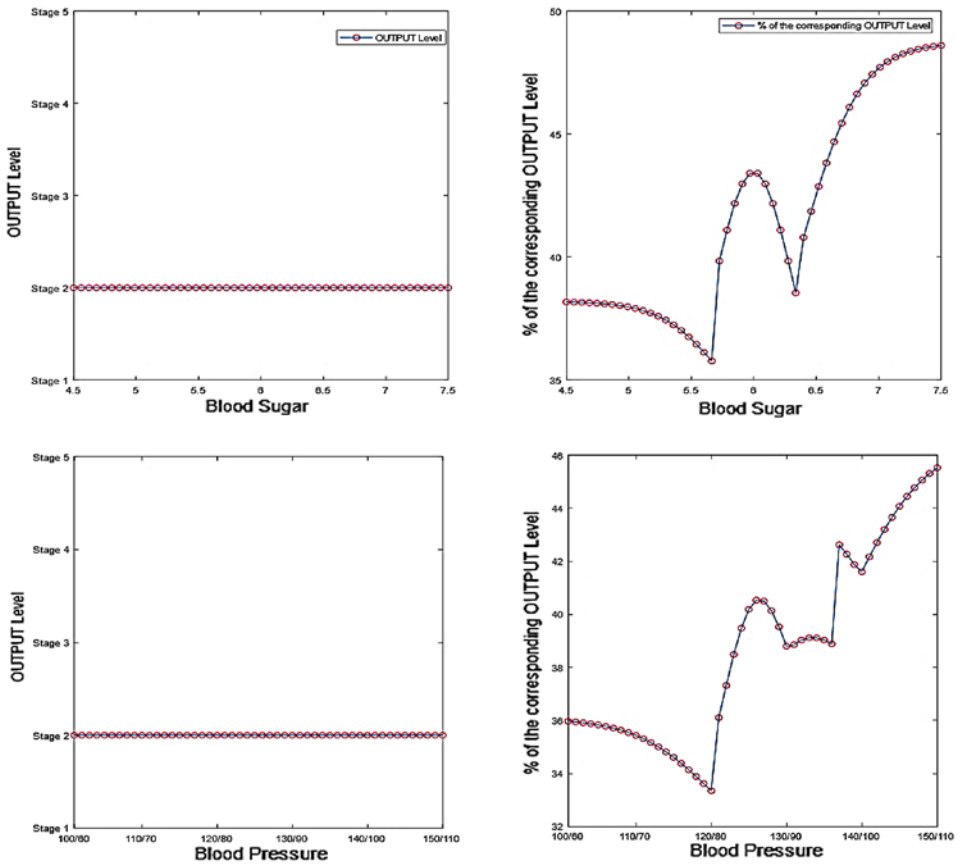

Figure 4: Small changes of Stage 1 input health factors.

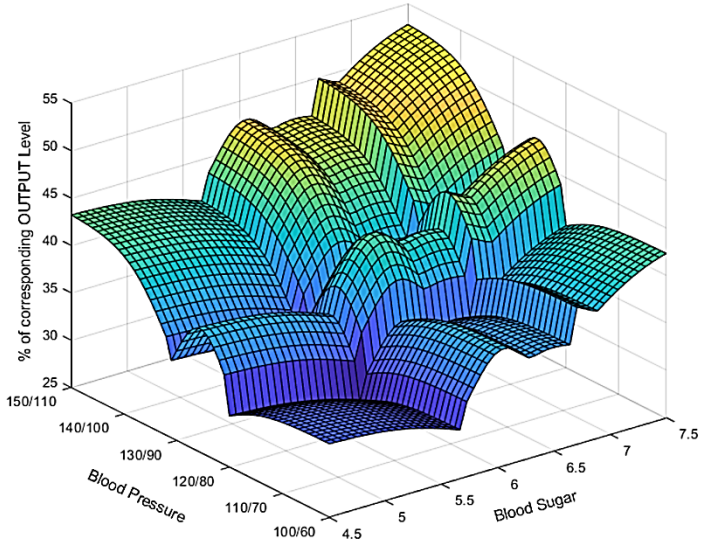

Figure 5: Simultaneously changes of Stage 1 both input factors

From the results, it is shown that if small changes happen in the 1st stage input factor and others are remaining constant, then the output level is still unchanged, but the percentage of the corresponding output level is increased, shown in the above three pictures.

Now consider the 3rd Stage input factors, i.e., Albumin in Urine and GFR values, similar to if small changes happen in these input factors and remaining are constant, then how it affects the output variables has been shown in Figure 6.

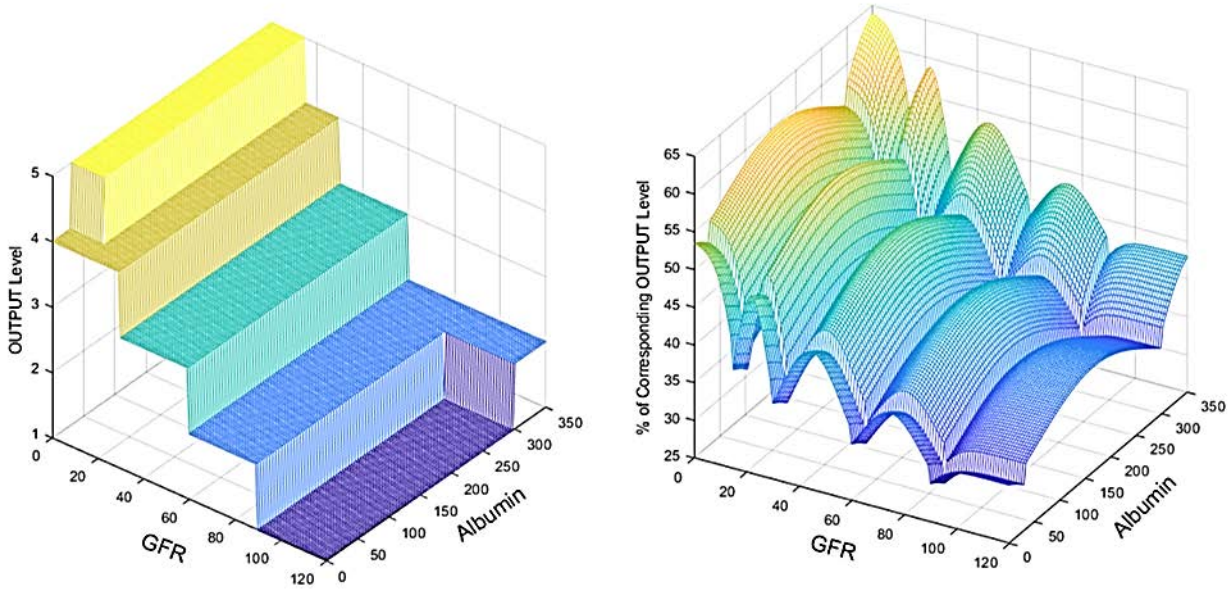

Figure 6: Simultaneously changes of Stage 3 both input factors.

From the analysis, it is concluded that the **Stage 3 input factor is more sensitive** than stage 1 input factors because small changes of Stage 1 input factors do not affect the level of the output variables but the small changes of stage 3 input factors effects too much in the output variable.

Now consider the stage 2 input choices; for seven input factors, a patient choice anyone among 5^7 *i.e.* 78125 no of combinations. If all kinds of combinations have been chosen, how it affects the output factors has been shown in Figure 7.

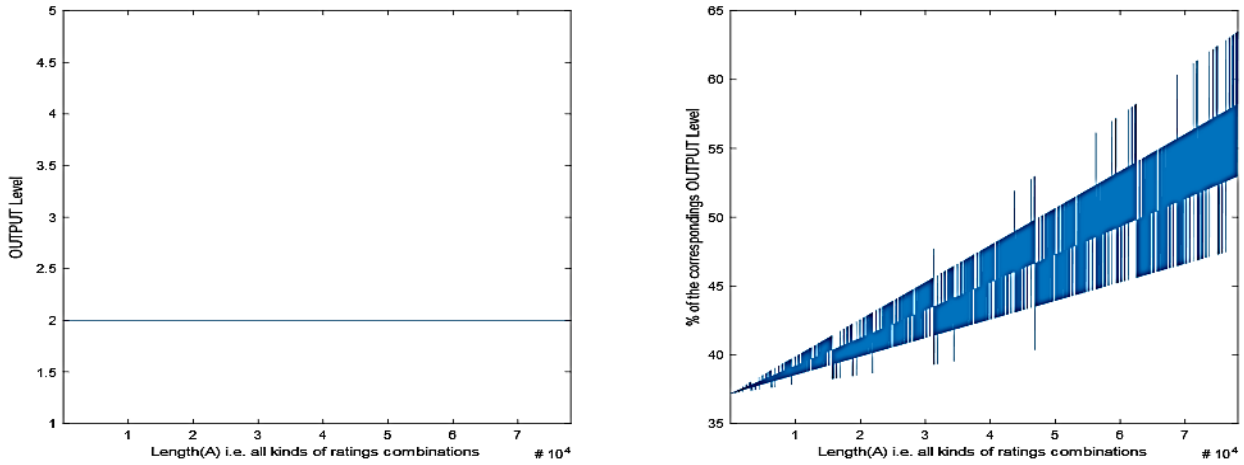

Figure 7: Considering all kinds of combinations of Stage 2 input factors vs. Output

From the above pictures, the changes of stage 2 input variables do not affect so much in the output level much, but the percentage of the corresponding output level, it is much more useful than stage 1 input factors.

From the above three analyses, we can conclude that in our algorithm, Stage 3 input variables are most sensitive than Stage 2, and Stage 2 input variables are more sensitive than Stage 1 input variables.

Stage 3 > Stage 2 > Stage 1

Screenshots of MATLAB App designer for various patients input data (Figures 8-10), an application has been built, and using various patient clinical data to this application; the doctors verify the output result.

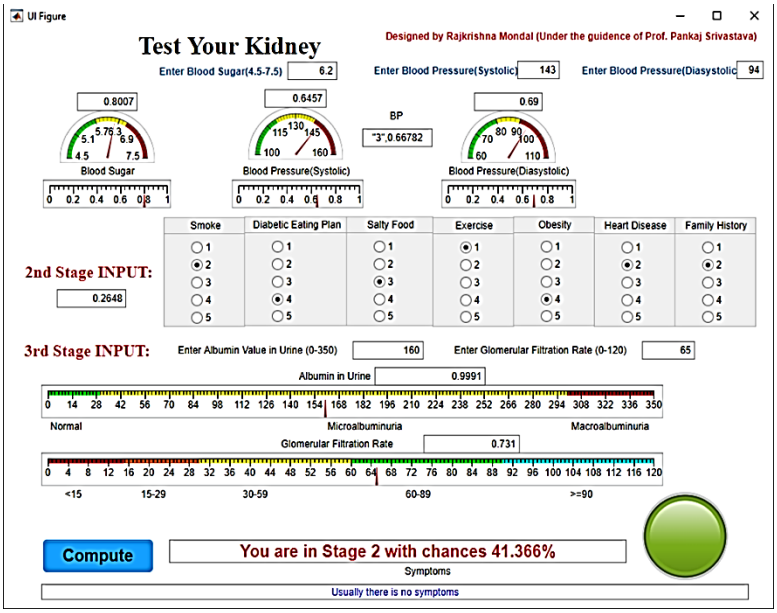

Figure 8: Input Data and the corresponding output of Patient#1 using MATLAB App Designer.

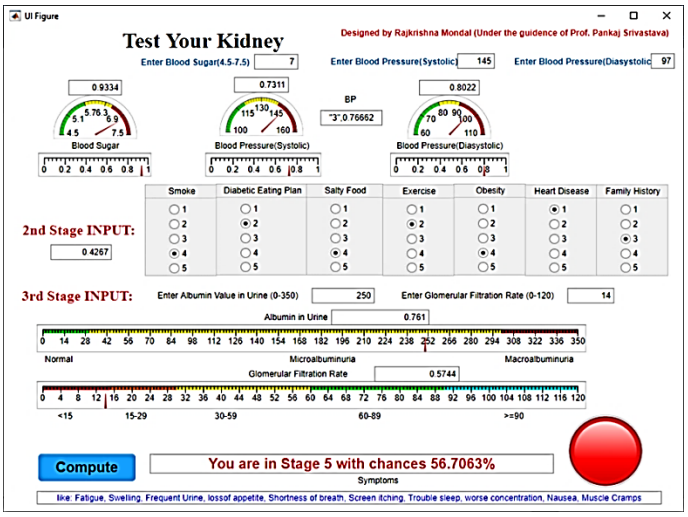

Figure 9: Input Data and the corresponding output of Patient#2 using MATLAB App Designer.

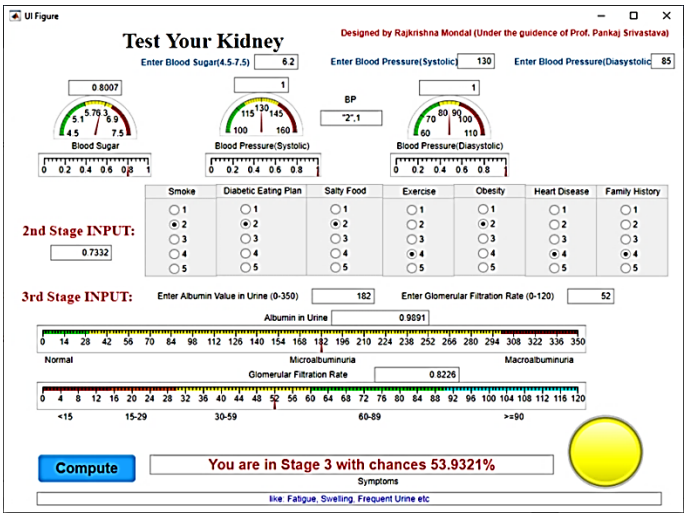

Figure 10: Input Data and the corresponding output of Patient#3 using MATLAB App Designer.

7 Validation of Output Results

The results have shown that which input factor how much sensitive. This section discusses the validation of the output result according to the sensitivity of the input factors.

Since Stage 3 input factors are more sensitive than the other two-stage input factors, the input data for "Albumin in urine" and "GFR" is essential to get a final decision output. According to the Doctor's suggestion, for diagnosing a Kidney performance, first, they try to assess the Blood pressure, Blood Sugar (which is used in the Stage 1 input factor) level then ask some common questions about their age, weight, obesity, lifestyles, family history (in Stage 2 input factor, most of the terms has been taken). Finally, they have taken a final decision concerning laboratory values of Urine and Blood test ("Albumin in Urine" and "GFR" lab test data has been taken in stage 3 input factor), which are the essential factors in the total input variables. Therefore Stage 3 input variable sensitive than the other two Stage input variables.

In the case study, it has been shown that the considered patient's Kidney disease is in level 2 with chances of 41.37%. This output result is also verified by the doctor, which is near about correct with the doctors' suggestion.

8 Conclusion

In this present study, a novel algorithm has been developed to access the Kidney disease's performance using the fuzzy combination frameworks. Current research is partitioned into two parts: in the first part, it developed the algorithm and validated the output results with expert doctors' help. In the second part, using MATLAB App Designer, build up an application using the proposed algorithm. The main advantages of this algorithm are as follows

1. The proposed approach helps develop a medical expert system with the current stage of chronic Kidney disease and the % of chances for this corresponding stage.
2. Fuzzy combinations approach gives a higher accurate result by considering all kinds of possible inputs.

3. Using the Nonlinear membership functions for the input variables makes a better effective result to the Output.

4. Fuzzy approach makes this algorithm the human way of decision making.

5. The proposed approach can develop a mobile application for rural areas where medical experts are not available properly.

Fuzzy nonlinear membership function and fuzzy combination approach make this work possible. It is important to remark that because we could not find a large amount of benchmark data that will fit our model, the short amount of collected data (with reference to the Doctors) is fitted here and validation processes of some case studies are made the group of experts.

9 Data Availability Statement

The data for this study can be available upon a request made to the corresponding author.

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