Decision making in diagnosis of diabetes mellitus using RDFP method

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Abstract
In recent years, most of the people are suffering by diabetes mellitus usually known as diabetes. Diabetes is a disease that unable to produce insulin or not functioning properly. We must be aware of diabetes otherwise it may leads to several complications to the retina, kidneys, nerves, feet wounds and heart attack. So in this paper we introduced Range Dominate Fuzzy Prediction Method (RDFP Method) to identify the risk level of diabetes mellitus at an early stage among the patients with different symptoms and risk factors. Ordering the rank of output in this proposed RDFP Method, concludes which patient has high risks or low risks of the diabetes to the medical practitioners in diabetes diagnosis. Subsequent to preparing the system with adequate number of preparing pair got from standard informational index, testing is done on the different cases that demonstrate the viability of proposed approach. Detection of diabetes and risks using RDFP Method gives better accuracy than TOPSIS method in the fast manner.

Keywords
Diabetes Mellitus, Decision Matrix, Range Dominate Fuzzy number, Weighted RDF decision matrix, Ideal Control Value (I\textsuperscript{c}), Positive Prediction Closeness (PC\textsuperscript{+}), Negative Prediction Closeness (PC\textsuperscript{-}), RDFP Method).

AMS Subject Classification:
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1. Introduction
Insulin changes glucose to energy in every human body. It is a life-long disease which is treatable but not fully curable. But sometimes the pancreas are not able to produce sufficient insulin or not in good usage of insulin leads to the diabetes disease. Increasing the level of blood sugar damages the functioning of many organs like eyes, kidneys, nerves, and feet in our body. Lack of prediction in the beginning stage of diabetes ends with dangerous and complicated diseases like Heart disease, Stroke and coma also. So physicians need a best quality system which considers all the parameters and predicts the level of diabetes with more accuracy. In this paper, we introduced Range Dominate Fuzzy Prediction Method to identify the level of risk factors. This proposed RDFP Method helps to the medical practitioners to give more attention to the patients who has high risks of Diabetes. In this work, we minimize the quantity of attributes and criterion used in Diabetes diagnosis that will consequently lessen the number of tests which are required to be tested for a patient.

2. Diabetes Mellitus
Diabetes Mellitus is a disease that reflects how a human body utilize glucose. Glucose is the important source of energy in body’s cell. Level of glucose is maintained by insulin which is secreted by the pancreas.
There are three main Types of Diabetes Mellitus:
1. Type-I Diabetes Mellitus: when the pancreas produce less quantity of insulin or no insulin develops Type-I Diabetes Mellitus (insulin dependent)
2. Type-II Diabetes Mellitus: when the body does not utilize to insulin develops Type-II Diabetes Mellitus (insulin independent)
3. Gestational Diabetes: pregnant woman suffer this type of diabetes during their pregnancy time.

A. Risk factors of Diabetes Mellitus
Common risk factors or symptoms of general Diabetes Mellitus are listed below

1. Excessive urine secretion (polyuria)
2. Excessive feeling of hungry (polyphagia)
3. Sudden weight loss
4. High blood pressure (systolic/diastolic)
5. Haemoglobin A1c
6. Excessive thirst (polydipsia)
7. Fatigue
8. High blood sugar
9. Obesity (BMI)
10. Physical inactivity, etc.

1. High blood sugar
High blood sugar is one of the main risk factors of diabetes mellitus. We get glucose by taking food like rice, milk, bread, vegetables and fruits, etc. This glucose helps to proper function in our body. Insulin is a hormone produced by the pancreas, that transport glucose into the cells through bloodstream. Concentration of glucose contains in human blood known as blood glucose level. Due to improper usage of insulin and physical inactivity may increase (Hyperglycemia) or decrease (Hypoglycemia) the level of blood sugar. Molar concentration mmol/L or mass concentration mg/dl is the measurement unit of blood glucose level. Its range from 40 to 230.

2. Diastolic blood pressure
A person’s pressure is measured by two different values. The upper value indicates systolic pressure and bottom value is diastolic pressure. Generally Blood flow through the blood vessels requires the heart to work harder than usual due to this elevated condition. Depending on whether the heart muscle is contracting (systole) or relaxing (diastole) between the heart beats. That is, Blood pressure is the pressure of circulating blood on the walls of blood vessels. Most of this pressure is due to work done by the heart by pumping blood through the circulatory system. Simply, Systolic pressure - maximum pressure during one heart beat. Diastolic pressure - minimum pressure in between two heart beats. The measurement unit is millimeters of mercury – mmHg and varies from 60-100.

3. Obesity
A disorder involving excessive body fat that increases the diabetes risk. It causes due to excessive food, lack of exercise and genetics. Body Mass Index (BMI) is used to calculate obesity. The weight in kilograms divided by the square of height in meters gives the BMI value in kg/m², which also categorize whether a person is under weight, normal, over weight and obese. It has a range between 10 and 30.

4. Hemoglobin A1c (HbA1c)
Usually glycated hemoglobin is known as HbA1c. Hemoglobin is a protein which lies in red blood cells, helps to pass oxygen into body cells. Hemoglobin combines with glucose to make glycated that develops HbA1c. Many people are not aware of the important HbA1c test in methods of diagnosing and monitoring diabetes. The HbA1c test is more accurate than the usual method of measuring sugar in the blood. This is because the results of the method of detecting the amount of sugar in the blood depend on what the experimenter ate that day and the day before but the HbA1c test we can find out how much blood glucose has increase in the past three months and how much is restricted. It’s range is [3-7] in mmol/mol unit.

3. Data Set
Dataset for this system is collected from various Hospitals on consultation with the expert in the field of diabetes, interviewing various patients, and from various laboratory also. The aim of this dataset is to make a decision of risk levels according their rank priority. In this work, we select four risk factors High blood sugar, Diastolic blood pressure, Obesity (Body Mass Index), HaemoglobinA1c of five different diabetes patients from the collection. The membership function of input variables are named as very low, low, normal, high and very high in [0,1]. The output reflects patient’s risk factor level of diabetes as low risk, moderate risk, normal (healthy), high risk and very high in [0,1]. Increasing the values between 0 to 1 increases the risk factors of Diabetes Mellitus.

4. Proposed Work
In this paper, we introduced the Range Dominate Fuzzy Prediction method for preventing diabetes patient who has different symptoms at an early stage. Also, this method gives a better accuracy compared with TOPSIS method in short calculation period.

Description
In spite of the fact that different variables assume a significant values in making the dangers for diabetes, this work has focused on four criterion. They are High blood sugar, Diastolic blood pressure, Obesity (Body Mass Index), Haemoglobin
A. Calculation

**The Procedure of RDPF Method**

**Step 1:** First we construct decision matrix DM as,

\[
\begin{bmatrix}
A_1 & \vdots & A_q \\
\begin{bmatrix}
C_1 \\
C_2 \\
\vdots \\
C_q
\end{bmatrix}
\end{bmatrix}
\begin{bmatrix}
X_{11} & X_{12} & \cdots & X_{1q} \\
X_{21} & X_{22} & \cdots & X_{2q} \\
\vdots & \vdots & \ddots & \vdots \\
X_{p1} & X_{p2} & \cdots & X_{pq}
\end{bmatrix}
\]

Here \(x_{ij}\) is the value of \(i^{th}\) alternative (patient) with respect to \(j^{th}\) criterion (risk factors) where \(i = 1,2,\ldots,p\) and \(j = 1,2,\ldots,q\).

**Step 2:** Fuzzification: Finding Normalized DM which is the conversion of crisp input values to fuzzy values by introducing new Range Dominate Fuzzy (RDF) number. For this, we have to find maximum and minimum values each criteria \(C_j\) from the corresponding overall range \([a,b]\).

\[
RDF(x) = \begin{cases} 
0, & \text{if } x \leq a \\
\left(\frac{\max(C_j) - x}{\max(C_j) - \min(C_j)}\right), & \text{if } a < x \leq b \\
1, & \text{if } x > b.
\end{cases}
\]

and denoted as \(N_{ij}\), where \(i = 1,2,\ldots,p\) and \(j = 1,2,\ldots,q\).

**Step 3:** Evaluating weighted RDF by,

\[
WRDF = W_{ij} = N_{ij} \cdot w_j,
\]

where \(w_j\) (weight) is the relative importance of each criterion it’s sum is one and \(j = 1,2,\ldots,q\).

**Step 4:** Next, we calculate Ideal control value as,

\[
l_1 = \text{max}(W_{ij} / \sum_{j} W_{ij}),\text{ For each } j = 1,2,\ldots,q
\]

**Step 5:** Obtaining prediction closeness value by

Negative Prediction Closeness \(PC^- = S_i = \sqrt{\sum_i (W_{ij} - V_j)^2} ; j = 1,2,\ldots,q; i = 1,2,\ldots,p; 0 \leq PC^- \leq 1
\)

Positive Prediction Closeness \(PC^+ = 1 - S_i, i = 1,2,\ldots,p; 0 \leq PC^+ \leq 1
\)

Finally, we have to defuzzify the output which lies between in the fuzzy set [0-1] by ordering the rank priority method using max-membership principle where 0 indicates low risk and 1 is very high risk of diabetes. So, output will indicate that the person has diabetes risk factors level at low risk, moderate risk, normal (healthy), high risk and very high, according their rank ordering. RDFP method gives accurate solutions in short period of calculation time compared to TOPSIS method.

## 5. Calculation

**Table 1.** Range of risk factors

| Risk factor | Very low | Low | Medium | High | Very High |
|-------------|----------|-----|--------|------|-----------|
| Blood sugar (R1) | (40-90) | (91-120) | (121-160) | (161-200) | (200-230) |
| Diastolic blood pressure (R2) | (80-89) | (90-99) | (100-109) | (110-119) | (120-129) |
| Body mass index value (R3) | (18.5-24) | (25-29) | (30-34) | (35-39) | (40-44) |
| Haemoglobin (Hb) (R4) | (13.5-15.5) | (15.5-17.5) | (17.5-19.5) | (19.5-21.5) | (21.5-23.5) |

**Table 2.** Crisp values of input variables

| Patients | Risk factor | R1 | R2 | R3 | R4 |
|----------|-------------|----|----|----|----|
| P1       | 80          | 60 | 11 | 3.5|    |
| P2       | 100         | 70 | 13 | 4.5|    |
| P3       | 225         | 100| 30 | 6.5|    |
| P4       | 160         | 80 | 19 | 5.1|    |
| P5       | 200         | 95 | 26 | 5.8|    |

**Table 3.** Normalized DM using Range Dominate Fuzzy number

| Patients | normalized value | N1 | N2 | N3 | N4 |
|----------|------------------|----|----|----|----|
| P1       | 0.2105           | 0.1111 | 0.05 | 0.125|    |
| P2       | 0.3158           | 0.3333 | 0.15 | 0.375|    |
| P3       | 0.9737           | 1    | 1   | 0.875|    |
| P4       | 0.6316           | 0.5556 | 0.45 | 0.525|    |
| P5       | 0.8421           | 0.8889 | 0.8  | 0.7 |    |

**Table 4.** Weighted RDF Decision values

| Patients | weights | W1 | W2 | W3 | W4 |
|----------|---------|----|----|----|----|
| P1       | 0.08    | 0.0311 | 0.01 | 0.0175 |    |
| P2       | 0.12    | 0.0933 | 0.03 | 0.0525 |    |
| P3       | 0.37    | 0.28  | 0.2 | 0.1225 |    |
| P4       | 0.24    | 0.1556 | 0.09 | 0.0735 |    |
| P5       | 0.32    | 0.2489 | 0.16 | 0.098 |    |

**Table 5.** Ideal control values and Prediction closeness

| Patients | PC^- | S1  | S2  | S3  | S4  | Total | PC^+ | PC^- |
|----------|------|-----|-----|-----|-----|-------|------|------|
| P1       | 0.612 | 0.1586 | 0.1018 | 0.4208 | 0.6487 | 0.3513 |      |      |
| P2       | 0.043 | 0.143 | 0.0807 | 0.3306 | 0.575 | 0.425 |      |      |
| P3       | 0.0018 | 0.0433 | 0.0458 | 0.0953 | 0.3087 | 0.6913 |      |      |
| P4       | 0.0076 | 0.0363 | 0.1013 | 0.0692 | 0.2144 | 0.463 | 0.537 |      |
| P5       | 0.0001 | 0.0094 | 0.0616 | 0.0569 | 0.128 | 0.3578 | 0.6422 |      |

**Table 6.** prediction closeness using TOPSIS method
6. Conclusion

The proposed new RDFP method gives the decision that patient-3 has very high risk of diabetes mellitus disease, and patient -1 in terrible stage according their prediction closeness values. While comparing RDFP method with TOPSIS Method, we get better accuracy of results in less calculations with short period of time and acceptable significant difference also. RDFP strategy gives a decision that which patient affected by diabetes factor at high level or in low depending upon their increasing order. This system also predict the diabetes patients at an early stage to avoid critical situation and unnecessary excitement. So the patients who has very high risk factors need more concentration about their health condition. By maintaining proper food, habit of exercise, taking medications may helpful to reduce the chance of diabetes.

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