Research Article

A Note on Hypertension Classification Scheme and Soft Computing Decision Making System

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Nowadays young professionals are a soft target of hypertension due to the increased work pressure and poor tolerance. Many people have high blood pressure for years without knowing it. Most of the time, there are no symptoms, but when this condition goes untreated it damages arteries and vital organs throughout the body and that is why it is also termed as the silent killer. Complications arising from hypertension could lead to stroke and heart failure. Soft computing approach provides a sharper conclusion from vague, ambiguous, and imprecise data (generally found in medical field) using linguistic variables. In this study, a soft computing diagnostic support system for the risk assessment of hypertension is proposed.

1. Introduction

A human body is a complex system and there are a number of variables that affect its functioning. The abnormality in its functioning causes a number of symptoms in the form of primary stages of different diseases although the recognition of these symptoms and their mapping with the diseases precisely is not an easy one. Sometimes complications in human body may be caused by improper diagnosis or improper management of the disease or due to the inaccessibility of medical personnel [1]. The quickening speed of change and adoption of western lifestyles by people in developing countries have led to a sharp rise in the incidence of hypertension [2]. Hypertension is a medical term for high blood pressure which is a condition that occurs when the pressure in the arteries is above the normal range. According to one of the studies “Recession has had an adverse impact on jobs in India and perhaps this is one of the reasons why cases of Hypertension have gone up in past two years among young IT professionals”. Recent analysis has predicted that more than 1.56 billion people will be living with hypertension worldwide by the year 2025. It has been declared by a survey report that one of four adults in India has high BP which kills 7.5 million people worldwide each year; moreover, AIDS, diabetes, road accidents, and tuberculosis are put together. In India 23.1% men and 22.6% women have high BP a notch lower than the global prevalence of one in three adults says the World Health statistics 2012 released, 16 May 2012. Jain [3] established a decision making process phenomenon in the presence of fuzzy variables. Poli et al. [4] developed a neural network expert system for diagnosing and treating hypertension. Degani [5] discussed computerized electrocardiogram diagnosis using fuzzy approach. Charbonnier et al. [6] proposed the statistical and fuzzy models of ambulatory systolic blood pressure for hypertension diagnosis. Jena et al. [7] discussed the application of soft computing in medical science. Pandey et al. [8] proposed a rule based system for cardiac analysis based on electrocardiography. Further, Allahverdi et al. [9] proposed a fuzzy expert system for the determination of coronary heart disease risk (CHD) of patient for the next ten years. Nalayini and Wahidabanu [10] were of the view that most of the cardiac diseases are characterized by varied degrees of intricacy and the conventional procedures are not capable of dealing with these intricacies very efficiently. Djam and Kimbi [1] developed a
fuzzy expert system for the management of hypertension. Recently, P. Srivastava and A. Srivastava [11] proposed a soft computing diagnostic system to evaluate the risk factor for coronary heart disease (CHD). Srivastava and Sharma [12] designed a soft computing diagnostic system that classifies ECG beats in different phases and enables us to identify the status of cardiac health as per available ECG graphs. The present paper introduces a new soft computing model that measures risk factor on the basis of newly designed algorithm; a number of cases have been discussed as per available database.

2. Methodology

For complex systems, fuzzy tools are quite suitable because of its tolerance to some imprecision. In the present study, the inputs consist of age, systolic blood pressure (SBP), diastolic blood pressure (DBP), body mass index (BMI), heart rate, low density lipoprotein (LDL), high density lipoprotein (HDL), triglyceride, smoking, and exercise, while the output is the risk grade of hypertension.

In order to design a user friendly informative system for evaluating risk percentage of hypertension, we propose fuzzy Algorithm 1.

2.1. Input Variables

2.1.1. Blood Pressure. In this field we use systolic BP (SBP) and diastolic BP (DBP). The input variables for SBP and DBP were classified into seven fuzzy sets (see Table 1).

Systolic Blood Pressure (SBP). Consider

$\mu_{\text{desirable}} = \begin{cases} 
1 & x \leq 90 \\
\frac{(x - 90)^2}{15} & 90 \leq x < 105 \\
1 - \frac{(x - 105)^2}{15} & 105 \leq x < 120 \\
0 & x \geq 120, 
\end{cases}$

$\mu_{\text{above desirable}} = \begin{cases} 
0 & x \leq 120 \\
\frac{x - 120}{3} & 120 < x \leq 123 \\
1 & 123 < x \leq 127 \\
\frac{130 - x}{3} & 127 < x \leq 130 \\
0 & x \geq 130, 
\end{cases}$

$\mu_{\text{above moderate}} = \begin{cases} 
0 & x \leq 140 \\
\frac{x - 140}{3} & 140 < x \leq 143 \\
1 & 143 < x \leq 147 \\
\frac{150 - x}{3} & 147 < x \leq 150 \\
0 & x \geq 150, 
\end{cases}$

$\mu_{\text{moderate}} = \begin{cases} 
0 & x \leq 130 \\
\frac{x - 130}{3} & 130 < x \leq 133 \\
1 & 133 < x \leq 137 \\
\frac{140 - x}{3} & 137 < x \leq 140 \\
0 & x \geq 140, 
\end{cases}$

$\mu_{\text{little high}} = \begin{cases} 
0 & x \leq 150 \\
\frac{x - 150}{3} & 150 < x \leq 153 \\
1 & 153 < x \leq 157 \\
\frac{160 - x}{3} & 157 < x \leq 160 \\
0 & x \geq 160, 
\end{cases}$

$\mu_{\text{high}} = \begin{cases} 
0 & x \leq 160 \\
\frac{x - 160}{3} & 160 < x \leq 163 \\
1 & 163 < x \leq 167 \\
\frac{170 - x}{3} & 167 < x < 170 \\
0 & x \geq 170, 
\end{cases}$

$\mu_{\text{very high}} = \begin{cases} 
0 & x \leq 168 \\
\frac{(x - 168)^2}{6} & 168 \leq x < 174 \\
1 - \frac{(x - 174)^2}{6} & 174 \leq x < 180 \\
1 & x \geq 180. 
\end{cases}$

Diastolic Blood Pressure (DBP)

$\mu_{\text{normal}} = \begin{cases} 
1 & x \leq 60 \\
\frac{(x - 60)^2}{10} & 60 \leq x < 70 \\
1 - \frac{(x - 70)^2}{10} & 70 \leq x < 80 \\
0 & x \geq 80, 
\end{cases}$

Table 1

<table>
<thead>
<tr>
<th>Systolic BP in mm Hg</th>
<th>Diastolic BP in mm Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desirable 90–120</td>
<td>60–80</td>
</tr>
<tr>
<td>Above desirable 120–130</td>
<td>80–85</td>
</tr>
<tr>
<td>Moderate 130–140</td>
<td>85–90</td>
</tr>
<tr>
<td>Above moderate 140–150</td>
<td>90–95</td>
</tr>
<tr>
<td>Little high 150–160</td>
<td>95–100</td>
</tr>
<tr>
<td>High 160–170</td>
<td>100–110</td>
</tr>
<tr>
<td>Very high &gt;168</td>
<td>&gt;108</td>
</tr>
</tbody>
</table>
(I) Initial fuzzification mechanism
BEGIN
(1) Input-Fuzzy system with suitable "n" parameters $A_i$
(2) Initialize $i ← 1$
DO UNTIL $(i > n)$
Categorize $n_i$ fuzzy sets in $X_j$ linguistic variables
DO UNTIL $(j > n_i)$
(1) Construction of suitable membership function $\mu_{X_j}$
(2) Increment $j$
END DO UNTIL
Increment $i$
END

(II) Construction of Fuzzy Strings
BEGIN
(1) Input:"$n_i$" fuzzy sets in linguistic variables $X_j; i = 1, 2, \ldots, n$ and $j = 1, 2, \ldots, n_i$
(2) Input: $m$ output parameters $Y_o; o = 1, 2, \ldots, m$.
(3) Develop $t = k_1, k_2, \ldots, k_t$ linguistic strings $J_k; k = 1, 2, \ldots, t$
using AND operation on each linguistic term $X_j; j = 1, 2, \ldots, n_i$
(4) Initialize $k ← 1$
DO UNTIL $(k > t)$
Increment $j$
END DO UNTIL
Increment $k$
END

(III) Output Evaluation
BEGIN
(1) Construct Utility matrix $U$ of pxq order.
(2) Construct $r$ utility fuzzy sets $U_I; I = 1, 2, \ldots, r$
using $x \oplus y = x + y - xy$ for each $x, y \in U$
(3) Initialize $I ← 1$
DO UNTIL $(I > r)$
(4) Construct $r$ maximizing sets $U_{MI}, I = 1, 2, \ldots, r$
corresponding to each alternative.
(5) Develop $r$ optimal fuzzy utility sets $U_{OI}, I = 1, 2, \ldots, r$.
Each optimal fuzzy set $U_{OI}$ is obtained by fuzzy intersection $\bigwedge$ on fuzzy utility set and maximizing
set such that $\mu_{U_{OI}}(x) = \mu_{U_1}(x) \bigwedge \mu_{U_2}(x) = \min(\mu_{U_1}(x), \mu_{U_2}(x))$
for each utility value $x$.
(6) Take maximum membership value from each optimal utility fuzzy set.
(7) The optimal alternative $A_{OI}$ with corresponding maximum
membership grades obtained in step 10 such as
$A_{OI} = \{(\max) \mu_{U_{OI}}(x), B_i \} : \bigvee x \in U_{OI}\}$ for $I = 1, 2, \ldots, r$.
END DO UNTIL
Increment $I$
END

Algorithm 1

\[
\mu_{\text{above normal}} = \begin{cases} 
0 & x \leq 80 \\
\frac{x - 80}{2} & 80 < x \leq 82 \\
\frac{85 - x}{3} & 82 < x \leq 85 \\
0 & x \geq 85, 
\end{cases}
\]

\[
\mu_{\text{moderate}} = \begin{cases} 
0 & x \leq 85 \\
\frac{x - 85}{2} & 85 < x \leq 87 \\
\frac{90 - x}{3} & 87 < x \leq 90 \\
0 & x \geq 90, 
\end{cases}
\]
Table 2

<table>
<thead>
<tr>
<th>Cholesterol (mg/dL)</th>
<th>LDL</th>
<th>HDL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>≥180</td>
<td>Normal</td>
</tr>
<tr>
<td>Above normal</td>
<td>160–190</td>
<td>Nearly normal</td>
</tr>
<tr>
<td>Borderline high</td>
<td>130–160</td>
<td>High</td>
</tr>
<tr>
<td>High</td>
<td>100–130</td>
<td>Very high</td>
</tr>
<tr>
<td>Very high</td>
<td>≤100</td>
<td>Normal</td>
</tr>
</tbody>
</table>

2.1.2. Cholesterol. In this study we have classified total cholesterol into low density lipoprotein (LDL) cholesterol and high density lipoprotein (HDL). LDL cholesterol level has been classified into four fuzzy sets. LDL cholesterol level has been classified into five fuzzy sets. High levels of LDL are associated with coronary artery disease, whereas high levels of HDL appear to protect against coronary artery disease. These fuzzy sets have been shown in Table 2.

\[ \mu_{\text{above moderate}} = \begin{cases} 
0 & x \leq 90 \\
\frac{x - 90}{95 - x} & 90 < x \leq 95 \\
\frac{2}{3} & x \geq 95,
\end{cases} \]

\[ \mu_{\text{little high}} = \begin{cases} 
0 & x \leq 95 \\
\frac{x - 95}{100 - x} & 95 < x \leq 97 \\
\frac{2}{3} & x \geq 100,
\end{cases} \]

\[ \mu_{\text{high}} = \begin{cases} 
0 & x \leq 100 \\
\frac{x - 100}{5} & 100 < x \leq 105 \\
\frac{110 - x}{5} & 105 < x \leq 110 \\
0 & x \geq 110,
\end{cases} \]

\[ \mu_{\text{very high}} = \begin{cases} 
0 & x \leq 108 \\
\frac{(x - 108)^2}{6} & 108 \leq x < 114 \\
1 - \left(\frac{x - 114}{6}\right)^2 & 114 \leq x < 120 \\
1 & x \geq 120.
\end{cases} \]

\[ \mu_{\text{normal}} = \begin{cases} 
1 & x \leq 50 \\
\frac{(x - 50)^2}{25} & 50 \leq x < 75 \\
1 - \frac{(x - 75)^2}{25} & 75 \leq x < 100 \\
0 & x \geq 100,
\end{cases} \]

\[ \mu_{\text{above normal}} = \begin{cases} 
0 & x \leq 100 \\
\frac{x - 100}{10} & 100 < x \leq 110 \\
\frac{130 - x}{10} & 120 < x \leq 130 \\
0 & x \geq 130,
\end{cases} \]

\[ \mu_{\text{borderline high}} = \begin{cases} 
0 & x \leq 130 \\
\frac{x - 130}{10} & 130 < x \leq 140 \\
\frac{160 - x}{10} & 150 < x \leq 160 \\
0 & x \geq 160,
\end{cases} \]

\[ \mu_{\text{high}} = \begin{cases} 
0 & x \leq 160 \\
\frac{x - 160}{10} & 160 < x \leq 170 \\
\frac{190 - x}{10} & 180 < x \leq 190 \\
0 & x \geq 190,
\end{cases} \]

\[ \mu_{\text{very high}} = \begin{cases} 
0 & x \leq 180 \\
\frac{(x - 190)^2}{20} & 180 \leq x < 200 \\
1 - \frac{(x - 200)^2}{20} & 200 \leq x < 220 \\
1 & x \geq 220.
\end{cases} \]
2.1.3. Age. This input field is classified into six fuzzy sets. The fuzzy sets with their range are shown in Table 3. Consider

\[
\mu_{\text{young}} = \begin{cases} 
1 & x \leq 0 \\
\frac{(x - 0)^2}{15} & 0 \leq x < 15 \\
1 - \frac{(x - 15)^2}{15} & 15 \leq x < 30 \\
0 & x \geq 30,
\end{cases}
\]

\[
\mu_{\text{adult}} = \begin{cases} 
0 & x < 25 \\
\frac{x - 25}{5} & 25 \leq x < 30 \\
1 & 30 \leq x < 40 \\
\frac{48 - x}{8} & 40 \leq x < 48 \\
0 & x \geq 48,
\end{cases}
\]

\[
\mu_{\text{mid aged}} = \begin{cases} 
0 & x < 45 \\
\frac{x - 45}{5} & 45 \leq x < 50 \\
1 & 50 \leq x < 56 \\
\frac{60 - x}{4} & 56 \leq x < 60 \\
0 & x \geq 60,
\end{cases}
\]

\[
\mu_{\text{aged}} = \begin{cases} 
0 & x < 58 \\
\frac{x - 58}{4} & 58 \leq x < 62 \\
1 & 62 \leq x < 66 \\
\frac{72 - x}{6} & 66 \leq x < 72 \\
0 & x \geq 72,
\end{cases}
\]

\[
\mu_{\text{high}} = \begin{cases} 
0 & x \leq 30 \\
\frac{x - 30}{5} & 30 < x \leq 45 \\
1 & 45 < x \leq 50 \\
0 & x \geq 50,
\end{cases}
\]

\[
\mu_{\text{nearly normal}} = \begin{cases} 
0 & x \leq 50 \\
\frac{x - 50}{3} & 50 < x \leq 53 \\
1 & 53 < x \leq 60 \\
\frac{60 - x}{3} & 60 < x \leq 70 \\
0 & x \geq 70,
\end{cases}
\]

\[
\mu_{\text{normal}} = \begin{cases} 
0 & x \leq 58 \\
\frac{x - 58}{7} & 58 \leq x < 65 \\
1 - \frac{(x - 65)^2}{5} & 65 \leq x < 70 \\
1 & x \geq 70.
\end{cases}
\]

\[
\mu_{\text{old}} = \begin{cases} 
0 & x < 80 \\
\frac{x - 80}{7} & 80 \leq x < 87 \\
1 - \frac{(x - 87)^2}{8} & 87 \leq x < 95 \\
1 & x \geq 95.
\end{cases}
\]

\[
\mu_{\text{very old}} = \begin{cases} 
0 & x \leq 80 \\
\frac{x - 80}{7} & 80 \leq x < 87 \\
1 - \frac{(x - 87)^2}{8} & 87 \leq x < 95 \\
1 & x \geq 95.
\end{cases}
\]
Table 5

<table>
<thead>
<tr>
<th>Heart rate (beats/min)</th>
<th>50–65</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>60–80</td>
</tr>
<tr>
<td>High</td>
<td>78–110</td>
</tr>
<tr>
<td>Very high</td>
<td>105–125</td>
</tr>
</tbody>
</table>

\[
\mu_{\text{above medium}} = \begin{cases} 
0 & x \leq 25 \\
\frac{x - 25}{2} & 25 < x \leq 27 \\
1 & 27 < x \leq 30 \\
\frac{34 - x}{4} & 30 < x \leq 34 \\
0 & x \geq 34, 
\end{cases}
\]

\[
\mu_{\text{high}} = \begin{cases} 
0 & x \leq 32 \\
\frac{x - 32}{2} & 32 < x \leq 34 \\
1 & 34 < x \leq 38 \\
\frac{40 - x}{2} & 38 < x \leq 40 \\
0 & x \geq 40, 
\end{cases}
\]

\[
\mu_{\text{very high}} = \begin{cases} 
0 & x \leq 38 \\
\frac{x - 38}{2} & 38 < x \leq 40 \\
1 & 40 < x \leq 44 \\
\frac{46 - x}{2} & 44 < x \leq 46 \\
0 & x \geq 46, 
\end{cases}
\]

\[
\mu_{\text{very very high}} = \begin{cases} 
0 & x \leq 44 \\
\frac{(x - 44)^2}{3} & 44 < x < 47 \\
1 - \frac{(x - 47)^2}{3} & 47 \leq x < 50 \\
1 & x \geq 50. 
\end{cases}
\]

Table 6

<table>
<thead>
<tr>
<th>Triglyceride (mg/dL)</th>
<th>Normal</th>
<th>A little bit high</th>
<th>High</th>
<th>Very high</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;150</td>
<td>150–200</td>
<td>200–500</td>
<td>&gt;500</td>
</tr>
</tbody>
</table>

\[
\mu_{\text{normal}} = \begin{cases} 
0 & x \leq 60 \\
\frac{x - 60}{10} & 60 < x \leq 70 \\
1 & 70 < x \leq 75 \\
\frac{80 - x}{5} & 75 < x \leq 80 \\
0 & x \geq 80, 
\end{cases}
\]

\[
\mu_{\text{high}} = \begin{cases} 
0 & x \leq 78 \\
\frac{x - 78}{12} & 78 < x \leq 90 \\
1 & 90 < x \leq 100 \\
\frac{110 - x}{10} & 100 < x \leq 110 \\
0 & x \geq 110, 
\end{cases}
\]

\[
\mu_{\text{very high}} = \begin{cases} 
0 & x \leq 105 \\
\frac{(x - 105)^2}{10} & 105 < x \leq 115 \\
1 - \left(\frac{x - 115}{10}\right)^2 & 115 < x \leq 125 \\
1 & x \geq 125. 
\end{cases}
\]

(7)

2.1.6. Triglyceride. Triglycerides have been identified to play a major role in heart disease and hypertension. This input field is classified into four fuzzy sets. The fuzzy sets with their range are shown in Table 6. Consider

\[
\mu_{\text{normal}} = \begin{cases} 
1 & x \leq 0 \\
\frac{\left(\frac{x - 75}{75}\right)^2}{2} & 0 \leq x < 75 \\
1 - \left(\frac{x - 75}{75}\right)^2 & 75 \leq x < 150 \\
0 & x \geq 150, 
\end{cases}
\]

\[
\mu_{\text{little bit high}} = \begin{cases} 
0 & x \leq 150 \\
\frac{x - 150}{15} & 150 < x \leq 165 \\
1 & 165 < x \leq 185 \\
\frac{200 - x}{15} & 185 < x \leq 200 \\
0 & x \geq 200, 
\end{cases}
\]

2.1.5. Heart Rate. This input field is classified into four linguistic variables. The fuzzy sets with their range are shown in Table 5. Consider
2.1.7. Physical Exercise. This input field is classified into four fuzzy sets. The fuzzy sets with their range are shown in Table 7. If a person is not doing exercise, then input value is zero. Consider

$$\mu_{\text{high}} = \begin{cases} 
0 & x \leq 200 \\
\frac{x - 200}{100} & 200 < x \leq 300 \\
\frac{500 - x}{100} & 300 \leq x \leq 400 \\
0 & x \geq 500,
\end{cases}$$

$$\mu_{\text{very high}} = \begin{cases} 
0 & x \leq 500 \\
\frac{(x - 500)^2}{100} & 500 \leq x < 600 \\
1 - \frac{(x - 600)^2}{100} & 600 \leq x < 700 \\
1 & x \geq 700.
\end{cases}$$

(8)

2.1.8. Smoking. This input field is classified into four fuzzy sets. The fuzzy sets with their range are shown in Table 8. If person is not smoking, then input value is zero. Consider

$$\mu_{\text{low}} = \begin{cases} 
1 & x \leq 5 \\
\left(\frac{x - 5}{2}\right)^2 & 5 \leq x < 7 \\
1 - \left(\frac{x - 7}{3}\right)^2 & 7 \leq x < 10 \\
0 & x \geq 10,
\end{cases}$$

$$\mu_{\text{medium}} = \begin{cases} 
0 & x \leq 8 \\
\frac{x - 8}{6} & 8 \leq x < 14 \\
0 & x \geq 20,
\end{cases}$$

$$\mu_{\text{high}} = \begin{cases} 
0 & x \leq 18 \\
\frac{x - 18}{30} & 18 \leq x < 24 \\
0 & x \geq 30,
\end{cases}$$

$$\mu_{\text{very high}} = \begin{cases} 
0 & x \leq 28 \\
\left(\frac{x - 28}{4}\right)^2 & 28 \leq x < 32 \\
1 - \left(\frac{x - 32}{3}\right)^2 & 32 \leq x < 35 \\
1 & x \geq 35.
\end{cases}$$

(9)

2.2. Output Variable. The output contains risk grade of hypertension which is classified in five linguistic variables, very low, low, moderate, high, and very high. The output optimal alternatives indicate patient's present grade of hypertension. These optimal alternatives have been graphically shown in the form of Sugeno's spikes.
3. Result

Now we have developed various linguistic strings to represent the state of the patient using the input variables such as age, LDL, HDL, SBP, DBP, triglyceride, BMI, HR, exercise, and smoking. Some of the linguistic strings are given as follows.

\[ J_1 = \text{Young}_{\text{Age}} \text{Normal}_{\text{LDL}} \text{Normal}_{\text{HDL}} \text{Desirable}_{\text{SBP}} \text{Desirable}_{\text{DBP}} \text{Normal}_{\text{Triglyceride}} \text{M}_{\text{BMI}} \text{Normal}_{\text{HR}} \text{No}_{\text{Exercise}} \text{No}_{\text{Smoking}} \]

\[ J_2 = \text{Young}_{\text{Age}} \text{Normal}_{\text{LDL}} \text{Normal}_{\text{HDL}} \text{Desirable}_{\text{SBP}} \text{Desirable}_{\text{DBP}} \text{Normal}_{\text{Triglyceride}} \text{M}_{\text{BMI}} \text{Normal}_{\text{HR}} \text{Low}_{\text{Exercise}} \text{Low}_{\text{Smoking}} \]

\[ J_3 = \text{Young}_{\text{Age}} \text{Normal}_{\text{LDL}} \text{Normal}_{\text{HDL}} \text{Desirable}_{\text{SBP}} \text{Desirable}_{\text{DBP}} \text{Normal}_{\text{Triglyceride}} \text{M}_{\text{BMI}} \text{Normal}_{\text{HR}} \text{Medium}_{\text{Exercise}} \text{Low}_{\text{Smoking}} \]

\[ J_{100} = \text{Young}_{\text{Age}} \text{Normal}_{\text{LDL}} \text{Normal}_{\text{HDL}} \text{Normal}_{\text{SBP}} \text{Normal}_{\text{DBP}} \text{Normal}_{\text{Triglyceride}} \text{AM}_{\text{BMI}} \text{Normal}_{\text{HR}} \text{Medium}_{\text{Exercise}} \text{Low}_{\text{Smoking}} \]

\[ J_{101} = \text{Young}_{\text{Age}} \text{Normal}_{\text{LDL}} \text{Normal}_{\text{HDL}} \text{Desirable}_{\text{SBP}} \text{Desirable}_{\text{DBP}} \text{Normal}_{\text{Triglyceride}} \text{AM}_{\text{BMI}} \text{High}_{\text{HR}} \text{Medium}_{\text{Exercise}} \text{Med}_{\text{Smoking}} \]

\[ J_{250} = \text{Adult}_{\text{Age}} \text{Normal}_{\text{LDL}} \text{Normal}_{\text{HDL}} \text{Desirable}_{\text{SBP}} \text{ADesirable}_{\text{DBP}} \text{Normal}_{\text{Triglyceride}} \text{M}_{\text{BMI}} \text{Normal}_{\text{HR}} \text{No}_{\text{Exercise}} \text{No}_{\text{Smoking}} \]

\[ J_{500} = \text{Adult}_{\text{Age}} \text{High}_{\text{LDL}} \text{High}_{\text{HDL}} \text{Desirable}_{\text{SBP}} \text{Moderate}_{\text{DBP}} \text{Normal}_{\text{Triglyceride}} \text{AM}_{\text{BMI}} \text{High}_{\text{HR}} \text{Low}_{\text{Exercise}} \text{Smoking} \]

\[ J_{10001} = \text{Adult}_{\text{Age}} \text{High}_{\text{LDL}} \text{High}_{\text{HDL}} \text{Desirable}_{\text{SBP}} \text{Moderate}_{\text{DBP}} \text{Normal}_{\text{Triglyceride}} \text{AM}_{\text{BMI}} \text{High}_{\text{HR}} \text{Low}_{\text{Exercise}} \text{Medium}_{\text{Smoking}} \]

\[ J_{17009} = \text{Midaged}_{\text{Age}} \text{Normal}_{\text{LDL}} \text{Normal}_{\text{HDL}} \text{Desirable}_{\text{SBP}} \text{Desirable}_{\text{DBP}} \text{Normal}_{\text{Triglyceride}} \text{M}_{\text{BMI}} \text{Normal}_{\text{HR}} \text{No}_{\text{Exercise}} \text{No}_{\text{Smoking}} \]

\[ J_{17010} = \text{Midaged}_{\text{Age}} \text{Normal}_{\text{LDL}} \text{Normal}_{\text{HDL}} \text{Desirable}_{\text{SBP}} \text{Desirable}_{\text{DBP}} \text{Normal}_{\text{Triglyceride}} \text{M}_{\text{BMI}} \text{High}_{\text{HR}} \text{No}_{\text{Exercise}} \text{Low}_{\text{Smoking}} \]

\[ J_{20008} = \text{Aged}_{\text{Age}} \text{Normal}_{\text{LDL}} \text{Normal}_{\text{HDL}} \text{Desirable}_{\text{SBP}} \text{ADesirable}_{\text{DBP}} \text{Normal}_{\text{Triglyceride}} \text{M}_{\text{BMI}} \text{Normal}_{\text{HR}} \text{No}_{\text{Exercise}} \text{No}_{\text{Smoking}} \]

\[ J_{60501} = \text{Aged}_{\text{Age}} \text{High}_{\text{LDL}} \text{High}_{\text{HDL}} \text{Moderate}_{\text{SBP}} \text{Moderate}_{\text{DBP}} \text{Normal}_{\text{Triglyceride}} \text{VH}_{\text{BMI}} \text{VH}_{\text{HR}} \text{Low}_{\text{Exercise}} \text{Medium}_{\text{Smoking}} \]

\[ J_{96008} = \text{Aged}_{\text{Age}} \text{VeryHigh}_{\text{LDL}} \text{Normal}_{\text{HDL}} \text{Normal}_{\text{SBP}} \text{Normal}_{\text{DBP}} \text{Normal}_{\text{Triglyceride}} \text{VH}_{\text{BMI}} \text{VH}_{\text{HR}} \text{Low}_{\text{Exercise}} \text{High}_{\text{Smoking}} \]

\[ J_{120020} = \text{Old}_{\text{Age}} \text{High}_{\text{LDL}} \text{Normal}_{\text{HDL}} \text{AboveDesirable}_{\text{SBP}} \text{Moderate}_{\text{DBP}} \text{Normal}_{\text{Triglyceride}} \text{AM}_{\text{BMI}} \text{Normal}_{\text{HR}} \text{Low}_{\text{Exercise}} \text{No}_{\text{Smoking}} \]

\[ J_{3244569} = \text{Old}_{\text{Age}} \text{VeryHigh}_{\text{LDL}} \text{Normal}_{\text{HDL}} \text{VeryHigh}_{\text{SBP}} \text{AboveDesirable}_{\text{DBP}} \text{Normal}_{\text{Triglyceride}} \text{AM}_{\text{BMI}} \text{High}_{\text{HR}} \text{No}_{\text{Exercise}} \text{VeryHigh}_{\text{Smoking}} \]

\[ J_{5676889} = \text{VeryOld}_{\text{Age}} \text{VeryHigh}_{\text{LDL}} \text{Normal}_{\text{HDL}} \text{Desirable}_{\text{SBP}} \text{ADesirable}_{\text{DBP}} \text{Normal}_{\text{Triglyceride}} \text{AM}_{\text{BMI}} \text{Normal}_{\text{HR}} \text{Low}_{\text{Exercise}} \text{Low}_{\text{Smoking}} \]

\[ J_{7566780} = \text{VeryOld}_{\text{Age}} \text{High}_{\text{LDL}} \text{High}_{\text{HDL}} \text{VeryHigh}_{\text{SBP}} \text{VeryHigh}_{\text{DBP}} \text{VeryHigh}_{\text{Triglyceride}} \text{High}_{\text{BMI}} \text{VH}_{\text{HR}} \text{No}_{\text{Exercise}} \text{VeryHigh}_{\text{Smoking}} \]

\[ J_{855420} = \text{VeryOld}_{\text{Age}} \text{VeryHigh}_{\text{LDL}} \text{VeryHigh}_{\text{HDL}} \text{VeryHigh}_{\text{SBP}} \text{High}_{\text{DBP}} \text{VH}_{\text{Triglyceride}} \text{VH}_{\text{BMI}} \text{High}_{\text{HR}} \text{No}_{\text{Exercise}} \text{high}_{\text{Smoking}} \]

\[ J_{9034678} = \text{VeryOld}_{\text{Age}} \text{VeryHigh}_{\text{LDL}} \text{VeryHigh}_{\text{HDL}} \text{VeryHigh}_{\text{SBP}} \text{VeryHigh}_{\text{DBP}} \text{VeryHigh}_{\text{Triglyceride}} \text{VH}_{\text{BMI}} \text{VH}_{\text{HR}} \text{Low}_{\text{Exercise}} \text{VeryHigh}_{\text{Smoking}} \]

\[ J_{9034680} = \text{VeryOld}_{\text{Age}} \text{VeryHigh}_{\text{LDL}} \text{VeryHigh}_{\text{HDL}} \text{VeryHigh}_{\text{SBP}} \text{VeryHigh}_{\text{DBP}} \text{VeryHigh}_{\text{Triglyceride}} \text{MVVH}_{\text{BMI}} \text{VH}_{\text{HR}} \text{No}_{\text{Exercise}} \text{Very high}_{\text{Smoking}} \]

On the basis of our proposed technique to investigate the health status of a person whose medical data is available, three different cases have been discussed as follows.

**Case 1.** The input variables of first patient are

1. Age = \{(0, young), (0.8, adult), (0, midaged), (0, aged), (0, old), (0, very old)\}.

2. LDL = \{(0.71, normal), (0, above normal), (0, borderline high), (0, high), (0, very high)\}.
(3) HDL = \{(0, very high), (0, high), (0, nearly normal), (1, normal)\}.

(4) SBP = \{(0, desirable), (0.8, above desirable), (0, moderate), (0, above moderate), (0, little high), (0, high), (0, very high)\}.

(5) DBP = \{(0, desirable), (1, above desirable), (0, moderate), (0, above moderate), (0, little high), (0, high), (0, very high)\}.

(6) Triglyceride = \{(0.72, normal), (0, a little bit high), (0, high), (0, very high)\}.

(7) BMI = \{(0, low), (0.99, medium), (0, above medium), (0, very high), (0, very very high)\}.

(8) HR = \{(0, low), (0.86, normal), (0, high), (0, very high)\}.

(9) Exercise = \{(1, low), (0, medium), (0, high), (0, very high)\}.

(10) Smoking = \{(1, low), (0, medium), (0, high), (0, very high)\}.

This is the fuzzy set which represents the state of concerned patient:

\[ X = \{(0.71, J_{A,N,A,D,N,A,D,N,M,L})\} \]. \hspace{1cm} (11)

The utility matrix \( U \) of order 5x903680 by using the fuzzy rule base designed is as follows:

\[
U = \begin{pmatrix}
98 & 95 & \cdots & 10 & \cdots & 10 & \cdots & 05 \\
86 & 80 & \cdots & 20 & \cdots & 30 & \cdots & 10 \\
30 & 25 & \cdots & 45 & \cdots & 62 & \cdots & 40 \\
20 & 20 & \cdots & 92 & \cdots & 90 & \cdots & 86 \\
10 & 10 & \cdots & 55 & \cdots & 20 & \cdots & 95
\end{pmatrix}
\]. \hspace{1cm} (12)

The five fuzzy utilities are

(1) \( U_1 = \{(0.71, 98)\} \),

(2) \( U_2 = \{(0.71, 68)\} \),

(3) \( U_3 = \{(0.71, 30)\} \),

(4) \( U_4 = \{(0.71, 20)\} \),

(5) \( U_5 = \{(0.71, 10)\} \).

The maximum sets corresponding to each alternative are

(1) \( U_{1m} = \{(1, 98)\} \),

(2) \( U_{2m} = \{(0.69, 68)\} \),

(3) \( U_{3m} = \{(0.30, 30)\} \),

(4) \( U_{4m} = \{(0.20, 20)\} \),

(5) \( U_{5m} = \{(0.10, 10)\} \).

Now, the optimal fuzzy utilities using fuzzy utilities and maximizing sets are

(1) \( U_{1o} = \{(0.71, 98)\} \),

(2) \( U_{2o} = \{(0.69, 68)\} \),

(3) \( U_{3o} = \{(0.30, 30)\} \),

(4) \( U_{4o} = \{(0.20, 20)\} \),

(5) \( U_{5o} = \{(0.10, 10)\} \).

Using these utilities, the optimal alternatives are given by

\[ A_o = \{(0.71, very low), (0.69, low), (0.30, moderate), (0.20, high), (0.10, very high)\} \]. \hspace{1cm} (13)

This optimal alternative indicates that the patient presently is in very low grade of hypertension. The optimal alternatives have been graphically shown in Figure 1 in the form of Sugeno’s spikes.

Case 2. The input variables of the second patient are as follows.

(1) Age = \{(0, young), (0, adult), (1, midaged), (0, aged), (0, old), (0, very old)\}.

(2) LDL = \{(1, normal), (0, above normal), (0, borderline high), (0, high), (0, very high)\}.

(3) HDL = \{(0, very high), (0.6, high), (0, nearly normal), (0, normal)\}.

(4) SBP = \{(0, desirable), (0.8, above desirable), (0, moderate), (0, above moderate), (0, little high), (0, high), (0, very high)\}.

(5) DBP = \{(0, desirable), (0.66, above desirable), (0, moderate), (0, above moderate), (0, little high), (0, high), (0, very high)\}.

(6) Triglyceride = \{(0.66, normal), (0, a little bit high), (0, high), (0, very high)\}.

(7) BMI = \{(0, low), (0, medium), (0.86, above medium), (0, high), (0, very high)\}.

(8) HR = \{(0, low), (0.76, normal), (0, high), (0, very high)\}.

(9) Exercise = \{(0, low), (0.79, medium), (0, high), (0, very high)\}.

(10) Smoking = \{(1, low), (0, medium), (0, high), (0, very high)\}.

This is the fuzzy set which represents the state of concerned patient:

\[ X = \{(0.6, J_{M,N,H,A,D,N,A,M,N,L})\} \]. \hspace{1cm} (14)
The utility matrix is the same as in Case 1. The five fuzzy utilities are

1. \( U_1 = \{(0.6, 55)\} \),
2. \( U_2 = \{(0.6, 92)\} \),
3. \( U_3 = \{(0.6, 40)\} \),
4. \( U_4 = \{(0.6, 24)\} \),
5. \( U_5 = \{(0.6, 10)\} \).

The maximum sets corresponding to each alternative are

1. \( U_{1m} = \{(0.59, 55)\} \),
2. \( U_{2m} = \{(0.6, 92)\} \),
3. \( U_{3m} = \{(0.43, 35)\} \),
4. \( U_{4m} = \{(0.26, 24)\} \),
5. \( U_{5m} = \{(0.10, 10)\} \).

Now, the optimal fuzzy utilities using fuzzy utilities and maximizing sets are

1. \( U_{1o} = \{(0.59, \text{very low})\} \),
2. \( U_{2o} = \{(0.6, \text{low})\} \),
3. \( U_{3o} = \{(0.43, \text{moderate})\} \),
4. \( U_{4o} = \{(0.26, \text{high})\} \),
5. \( U_{5o} = \{(0.10, \text{very high})\} \).

Using these utilities, the optimal alternatives are given by

\[
A_o = \{(0.59, \text{very low}), (0.60, \text{low}), (0.43, \text{moderate}), (0.26, \text{high}), (0.10, \text{very high})\}.
\] (15)

This optimal alternative indicates that the patient presently is in low grade of hypertension. The optimal alternatives have been graphically shown in Figure 2 in the form of Sugenov's spikes.

**Case 3.** The input variables of the third patient are as follows.

1. Age = \{0 (young), 0 (adult), 0 (midaged), 0 (aged), 0 (75, old), 0 (very old)\}.
2. LDL = \{0 (normal), 0 (above normal), 0 (borderline high), 0.8 (high), 0 (very high)\}.

(3) HDL = \{(0, very high), (1, high), (0, nearly normal), (0, normal)\}.

(4) SBP = \{(0, desirable), (0, above desirable), 0.8 (moderate), 0 (above moderate), (0, little high), (0, high), (0, very high)\}.

(5) DBP = \{(0, desirable), (1, above desirable), 0 (moderate), 0 (above moderate), (0, little high), (0, high), (0, very high)\}.

(6) Triglyceride = \{(1, normal), 0.66 (a little bit high), 0 (high), (0, very high)\}.

(7) BMI = \{(0, low), (0, medium), (0, above medium), 0.78 (high), 0 (very high), (0, very very high)\}.

(8) HR = \{(0, low), (0, normal), 0.96 (high), (0, very high)\}.

(9) Exercise = \{(0, low), (1, medium), (0, high), (0, very high)\}.

(10) Smoking = \{(1, low), (0, medium), (0, high), (0, very high)\}.

This is the fuzzy set which represents the state of concerned patient:

\[
X = \{(0.66, J_{O,H,H,M,A,D,L,H,H,H,L})\}.
\] (16)

The utility matrix \( U \) is the same as in Case 1. The five fuzzy utilities are

1. \( U_1 = \{(0.66, 15)\} \),
2. \( U_2 = \{(0.66, 30)\} \),
3. \( U_3 = \{(0.66, 45)\} \),
4. \( U_4 = \{(0.66, 80)\} \),
5. \( U_5 = \{(0.66, 50)\} \).

The maximum sets corresponding to each alternative are

1. \( U_{1m} = \{(0.187, 15)\} \),
2. \( U_{2m} = \{(0.375, 30)\} \),
3. \( U_{3m} = \{(0.562, 45)\} \),
4. \( U_{4m} = \{(1, 80)\} \),
5. \( U_{5m} = \{(0.62, 50)\} \).

Now, the optimal fuzzy utilities using fuzzy utilities and maximizing sets are

1. \( U_{1o} = \{(0.187, \text{very low})\} \),
2. \( U_{2o} = \{(0.375, \text{low})\} \),
3. \( U_{3o} = \{(0.562, \text{moderate})\} \),
4. \( U_{4o} = \{(0.66, \text{high})\} \),
5. \( U_{5o} = \{(0.62, \text{very high})\} \).

Using these utilities, the optimal alternatives are given by

\[
A_o = \{(0.187, \text{very low}), (0.375, \text{low}), (0.562, \text{moderate}), (0.66, \text{high}), (0.62, \text{very high})\}.
\] (17)
This optimal alternative indicates that the patient is presently in high grade of hypertension.

The optimal alternatives have been graphically shown in the form of Sugeno’s spikes in Figure 3.

4. Conclusion

The present research paper confirms that the soft computing diagnostic system can represent the expert’s thinking in an efficient manner to handle complex cases. The design and development of soft computing risk assessment system on the basis of the proposed technique will assist medical experts to measure grade classification of hypertension efficiently.

References
