Spectrum of Soft Computing Risk Assessment Scheme for Hypertension

Pankaj Srivastava
Department of Mathematics
Motilal Nehru National Institute of Technology
Allahabad, U.P., India, 211004

Amit Srivastava
Department of Applied Mechanics
Motilal Nehru National Institute of Technology
Allahabad, U.P., India, 211004

ABSTRACT
The present paper deals with risk assessment scheme for Hypertension. It is believed that hypertension comes in to picture due to complex interaction of genetic, environmental and demographical features and nowadays it is a leading health problem in information technology world. In order to manage hypertension risk factor, we have made an attempt to design user friendly, intelligent and effective diagnostic system by making use of soft computing tools.

Keywords
Hypertension, CHD, FES, Risk assessment

1. INTRODUCTION

Hypertension is being considered as a leading silent killer disease throughout world now days. Medical experts are of the view that hypertension risk is root cause for raising the risk of chronic diseases such as kidney failure, heart disease, diabetes and cancer. The world health report published in 2002 recognized hypertension as the third ranked factor for disability adjusted life years. Recent analysis has predicted that more than 1.56 billon people will be living with hypertension worldwide by the year 2025. As per available data, it has been confirmed that hypertension is responsible for 13% of death worldwide. P. Degoulet et al [1] described that High blood pressure or hypertension is a condition that occurs when the pressure in our arteries is consistently above the normal range. Blood pressure is the force of blood pushing against the wall of the arteries. Szolvits et al [2] viewed that medical researchers cannot precisely characterize how diseases alter the normal functioning of the body .The unpredictability and complexity features of hypertension force physicians sometimes to make decision on their intuition. All of these complexities in medical practice make traditional mathematical approach of analysis insufficient. Hobbs and Boyles [3] pointed out that complications of hypertension could lead to stroke or heart failure. Such complications may be caused by improper diagnosis and or improper management of the disease, due to inaccessibility of experienced medical practioners at all times. Fuzzy theory plays important role in such situations. X.Y. Djam et al [4] suggested that Fuzzy systems are excellent in handling ambiguous and imprecise information prevalent in medical diagnosis.

The literature available makes clear that different types of Artificial intelligence systems have already been designed for the diagnosis of hypertension. Riccardo P. et al [5] had proposed a Neural Network Expert System for Diagnosing and Treating Hypertension. Further Sylevie Charbonnier et al [6] proposed the statistical and fuzzy models of Ambulatory systolic blood pressure for hypertension diagnosis. Novruz Allahverdi et al [7] proposed a fuzzy expert system to determination of coronary heart disease risk (CHD) of patient for next ten years. D.Pandey et al. [8] proposed a rule based system for cardiac analysis in which model developed on ECG based analysis. Pankaj Srivastava and Amit Srivastava [9] proposed a Fuzzy Expert System to determine coronary heart disease (CHD) risk of patients in India. In order to measure risk factor for hypertension, significant and user friendly fuzzy system has not been developed so far.

The present paper is focused on the design and development of fuzzy model to detect and diagnose hypertension risk factor using Age, BMI, blood pressure, heart rate, smoking, exercise, cholesterol level, triglyceride as input variables.

2. METHODOLOGY

2.1 Fuzzy Expert System

Chen and Chen [10] were of the view that Soft Computing is a computational method that is tolerant to sub-optimality, impreciseness, vagueness and thus giving quick, simple and sufficient good solutions. For complex systems, fuzzy tools is quite suitable because of its tolerance to some imprecision. Nalayini and Wahida [11] 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. In the present study, the inputs consist of age, SBP, DBP, BMI, heart rate, LDL, HDL, triglyceride, smoking and exercise, while the output is the risk of hypertension (%).

2.2 Input Variables:

a. Blood Pressure: In this field we use systolic BP (SBP) and diastolic BP (DBP). The input variables for SBP and DBP were classified in to seven fuzzy sets. Membership function of 'Normal' is ZMF and for 'Very high' sets SMF is used. Membership function of 'Above normal', 'moderate', 'above moderate', 'little high' 'High' sets are triangular.

	Systolic BP in mm Hg	Diastolic BP in mm Hg
Normal	< 120	< 80
Above Normal	120- 130	80- 85
Moderate	130- 140	85- 90
Above Moderate	140-150	90-95
Little High	150-160	95-100
High	160-170	100-110

Very High	> 170	> 110

$$\mu normal = \begin{cases} 1 & x \le 110 \\ 0 & x \ge 120 \end{cases}$$

$$\mu above\ normal = \begin{cases} 0 & x \le 120 \\ \frac{x-120}{5} & 120 < x \le 125 \\ \frac{130-x}{5} & 125 < x \le 130 \\ 0 & x \ge 130 \end{cases}$$

$$\mu moderate = \begin{cases} 0 & x \le 130 \\ \frac{x-130}{5} & 130 < x \le 135 \\ \frac{140-x}{5} & 135 < x \le 140 \\ 0 & x \ge 140 \end{cases}$$

$$\mu above\ moderate = \begin{cases} 0 & x \le 140 \\ \frac{x-140}{5} & 140 < x \le 145 \\ \frac{150-x}{5} & 145 < x \le 150 \\ 0 & x \ge 150 \end{cases}$$

$$\mu little\ high = \begin{cases} 0 & x \le 150 \\ \frac{x-150}{5} & 150 < x \le 155 \\ \frac{160-x}{5} & 155 < x \le 160 \\ 0 & x \ge 160 \end{cases}$$

$$\mu high = \begin{cases} 0 & x \le 160 \\ \frac{x-160}{5} & 160 < x \le 165 \\ \frac{170-x}{5} & 165 < x \le 170 \\ 0 & x \ge 170 \end{cases}$$

$$\mu very\ high = \begin{cases} 0 & x \le 170 \\ 1 & x \ge 180 \end{cases}$$

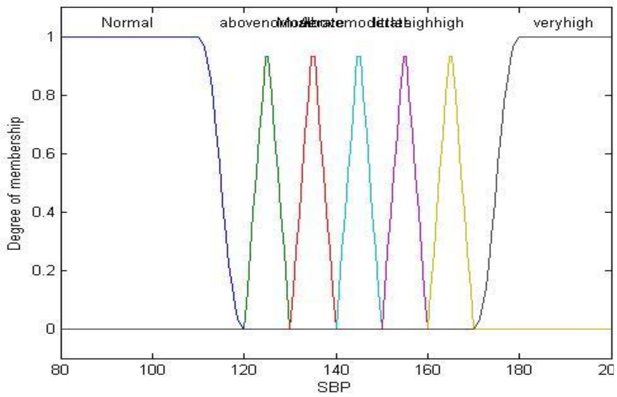

Figure1: Linguistic variables and membership function of Input variables 'SBP'

$$\mu normal = \begin{cases} 1 & x \le 70 \\ 0 & x \ge 80 \end{cases}$$

$$\mu above\ normal = \begin{cases} 0 & x \le 80 \\ \frac{x-80}{2} & 80 < x \le 82 \\ \frac{85-x}{3} & 82 < x \le 85 \\ 0 & x \ge 85 \end{cases}$$

$$\mu moderate = \begin{cases} 0 & x \le 85 \\ \frac{x-85}{2} & 85 < x \le 87 \\ \frac{90-x}{3} & 87 < x \le 90 \\ 0 & x \ge 90 \end{cases}$$

$$\mu above\ moderate = \begin{cases} 0 & x \le 90 \\ \frac{x-90}{2} & 90 < x \le 92 \\ \frac{95-x}{3} & 92 < x \le 95 \\ 0 & x \ge 95 \end{cases}$$

$$\mu little\ high = \begin{cases} 0 & x \le 95 \\ \frac{x-95}{2} & 95 < x \le 97 \\ \frac{100-x}{3} & 97 < x \le 100 \\ 0 & x \ge 100 \end{cases}$$

$$\mu high = \begin{cases} 0 & x \le 100 \\ \frac{x-100}{5} & 100 < x \le 105 \\ \frac{110-x}{5} & 105 < x \le 110 \\ 0 & x \ge 110 \end{cases}$$

$$\mu very\ high = \begin{cases} 0 & x \le 110 \\ 1 & x \ge 120 \end{cases}$$

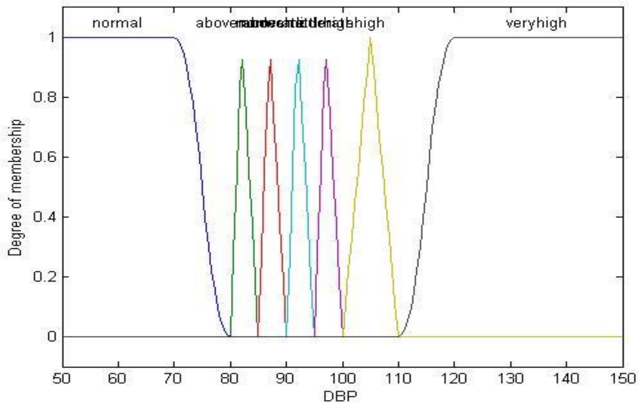

Figure2: Linguistic variables and membership function of Input variables 'DBP'.

b. Cholesterol: Cholesterol has been identified as one of the main risk factor for myocardial infarction. If Total Cholesterol level is too high or too low then further measurement of low density lipoprotein(LDL) cholesterol and High density lipoprotein (HDL) cholesterol are required. HDL Cholesterol level has been classified in four fuzzy sets (very high, high, nearly normal, normal). These fuzzy sets have been shown in table. Membership functions of very high, high, nearly normal sets are trapezoidal and for normal, SMF is used. LDL Cholesterol level has been classified in five fuzzy sets (optimal, above optimal, borderline high, high, very high). These fuzzy sets have been shown in table. Membership functions of normal, borderline, high sets were trapezoidal. For very high, SMF is used.

Cholesterol(mg/dL)			
LDL		HDL	
Optimal	0- 100	Very high	0-30
Above Optimal	100-130		
Borderline High	130-160	High	30-50
High	160-190	Nearly Normal	50-60
Very High	≥ 190	Normal	≥60

$$\mu optimal = \begin{cases} 1 & x \le 70 \\ 0 & x \ge 100 \end{cases}$$

$$\mu above\ optimal = \begin{cases} 0 & x \le 100 \\ \frac{x-100}{10} & 100 < x \le 110 \\ 1 & 110 \le x \le 120 \\ \frac{130-x}{10} & 120 < x \le 130 \\ 0 & x \ge 130 \end{cases}$$

$$\mu borderline\ high = \begin{cases} 0 & x \le 130 \\ \frac{x-130}{10} & 130 < x \le 140 \\ 1 & 140 \le x \le 150 \\ \frac{160-x}{10} & 150 < x \le 160 \\ 0 & x \ge 160 \end{cases}$$

$$\mu\ high = \begin{cases} 0 & x \le 160 \\ \frac{x-160}{10} & 160 < x \le 170 \\ 1 & 170 \le x \le 180 \\ \frac{190-x}{10} & 180 < x \le 190 \\ 0 & x \ge 190 \end{cases}$$

$$\mu very\ high = \begin{cases} 0 & x \le 190 \\ 1 & x \ge 220 \end{cases}$$

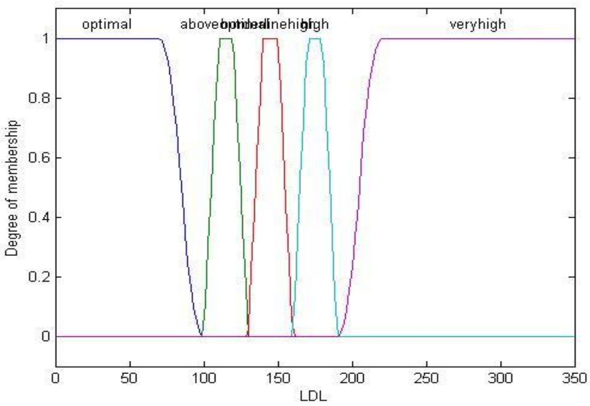

Figure3: Linguistic variables and membership function of Input variables 'LDL'

$$\mu very\ high = \begin{cases} 0 & x \le 0 \\ \frac{x-0}{10} & 0 < x \le 10 \\ 1 & 10 < x \le 20 \\ \frac{30-x}{10} & 20 < x \le 30 \\ 0 & x \ge 30 \end{cases}$$

$$\mu high = \begin{cases} 0 & x \le 30 \\ \frac{x-30}{5} & 30 < x \le 35 \\ 1 & 35 < x \le 45 \\ \frac{50-x}{5} & 45 < x \le 50 \\ 0 & x \ge 50 \end{cases}$$

$$\mu nearly\ normal = \begin{cases} 0 & x \le 50 \\ \frac{x-50}{3} & 50 < x \le 53 \\ 1 & 53 < x \le 57 \\ \frac{60-x}{3} & 57 < x \le 60 \\ 0 & x \ge 60 \end{cases}$$

$$\mu normal = \begin{cases} 0 & x \le 60 \\ 1 & x \ge 70 \end{cases}$$

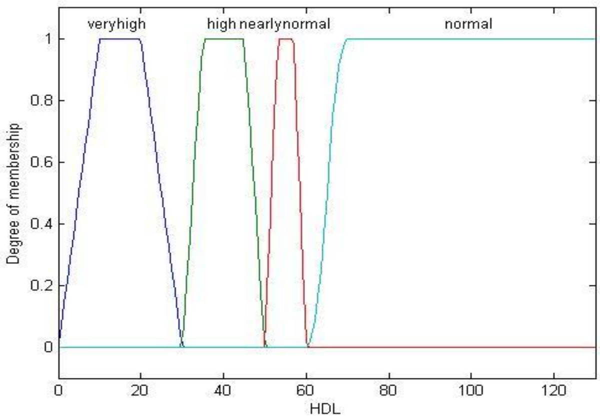

Figure 4: Linguistic variables and membership function of Input variables 'HDL'.

c. Age: This input field is classified in six fuzzy sets (young, Adult, Midaged, Aged, old, very old). The fuzzy sets with their range given in table. Membership function of young is ZMF and for very old, it is SMF. Membership functions of other's are trapezoidal.

Age (in years)	
Young	< 28
Adult	25- 48
Midaged	45-60
Aged	58-72
Old	70-86
Very Old	> 82

$$\mu young = \begin{cases} 1 & x \le 0 \\ 0 & x \ge 28 \end{cases} \quad \mu very\ old = \begin{cases} 0 & x \le 82 \\ 1 & x \ge 90 \end{cases}$$

$$\mu adult = \begin{cases} 0 & x < 25 \\ \frac{x-25}{5} & 25 \le x \le 30 \\ 1 & 30 \le x \le 40 \\ \frac{48-x}{8} & 40 \le x \le 48 \\ 0 & x \ge 48 \end{cases}$$

$$\mu midaged = \begin{cases} 0 & x < 45 \\ \frac{x-45}{5} & 45 \le x \le 50 \\ 1 & 50 \le x \le 56 \\ \frac{60-x}{8} & 56 \le x \le 60 \\ 0 & x \ge 60 \end{cases}$$

$$\mu aged = \begin{cases} 0 & x < 58 \\ \frac{x-58}{4} & 58 \le x \le 62 \\ 1 & 62 \le x \le 66 \\ \frac{72-x}{6} & 66 \le x \le 72 \\ 0 & x \ge 72 \end{cases}$$

$$\mu old = \begin{cases} 0 & x < 70 \\ \frac{x-70}{4} & 70 \le x \le 74 \\ 1 & 74 \le x \le 78 \\ \frac{86-x}{8} & 78 \le x \le 86 \\ 0 & x \ge 86 \end{cases}$$

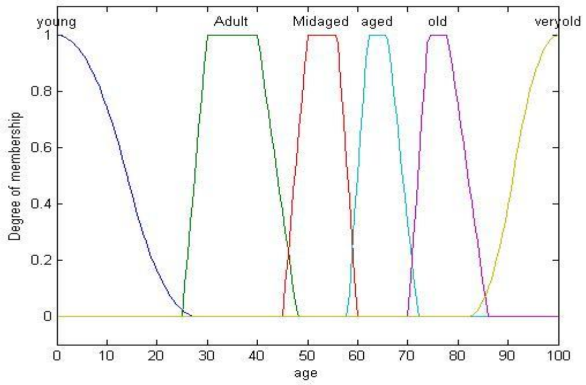

Figure5: Linguistic variables and membership function of Input variable 'Age'.

d. BMI- Body mass index is defined as the individual's body weight divided by square of his or her height. The formula used in medicine produce a unit of measure of kg/m^2. This input field is classified in four fuzzy sets. The fuzzy sets with their range are shown in table. Fuzzy sets are 'low (underweight)', 'medium (healthy weight)', 'high (slightly overweight)' and 'very high (overweight)' sets.

Body mass index(kg/m^2)	
Low	10-18
Medium	15-26
High	25-34
Very high	32-40

$$\mu low = \begin{cases} 1 & x \le 10 \\ 0 & x \ge 18 \end{cases} \quad \mu very\ high = \begin{cases} 0 & x \le 32 \\ 1 & x \ge 40 \end{cases}$$

$$\mu medium = \begin{cases} 0 & x \le 15 \\ \frac{x-15}{3} & 15 < x \le 18 \\ 1 & 18 < x \le 24 \\ \frac{26-x}{2} & 24 < x \le 26 \\ 0 & x \ge 26 \end{cases}$$

$$\mu high = \begin{cases} 0 & x \le 25 \\ \frac{x-25}{2} & 25 < x \le 27 \\ 1 & 27 < x \le 30 \\ \frac{34-x}{2} & 30 < x \le 34 \\ 0 & x \ge 34 \end{cases}$$

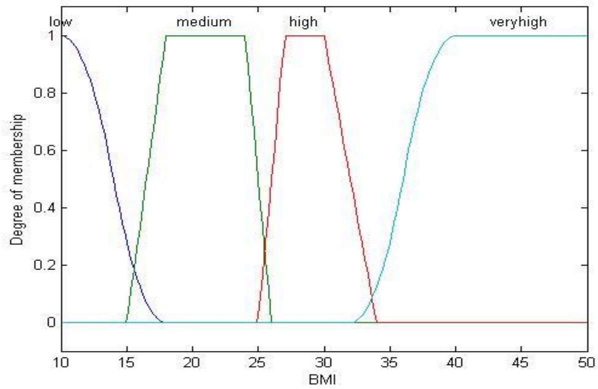

Figure6: Linguistic variables and membership function of Input variable 'BMI'.

e. Heart Rate- The value of this input field is heart rate of man during twenty four hours. By increasing of age in man, maximum of heart rate in twenty four hours decreases. In this field, we have four linguistic variables (low, normal, high, very high). The fuzzy sets with their range are shown in table.

Heart Rate(beats/min)	
Low	50-62
Normal	60-80
High	78-105
Very high	100-120

$$\mu low = \begin{cases} 1 & x \le 55 \\ 0 & x \ge 62 \end{cases} \quad \mu normal = \begin{cases} 0 & x \le 60 \\ \frac{x-60}{10} & 60 < x \le 70 \\ 1 & 70 < x \le 75 \\ \frac{80-x}{5} & 75 < x \le 80 \\ 0 & x \ge 80 \end{cases}$$

$$\mu high = \begin{cases} 0 & x \le 78 \\ \frac{x-78}{8} & 78 < x \le 86 \\ 1 & 86 < x \le 95 \\ \frac{105-x}{10} & 95 < x \le 105 \\ 0 & x \ge 105 \end{cases}$$

$$\mu very\ high = \begin{cases} 0 & x \le 100 \\ 1 & x \ge 120 \end{cases}$$

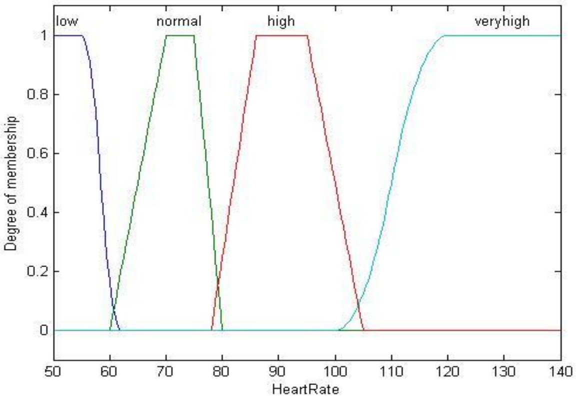

Figure7: Linguistic variables and membership function of Input variable 'Heart Rate'.

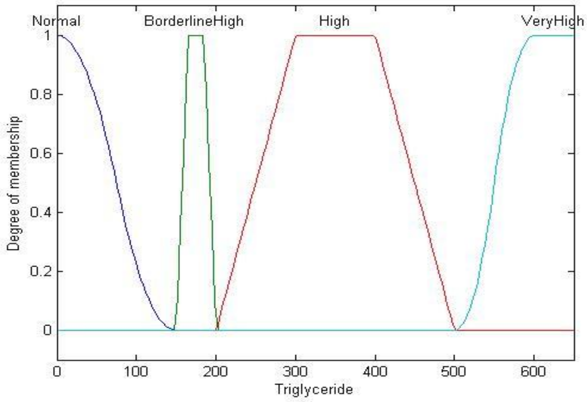

Figure8: Linguistic variables and membership function of Input variable 'Triglyceride'.

f. Triglyceride- Triglycerides are lipids, or fats, found in our bloodstream. Triglycerides play a major role in heart disease, heart attacks and strokes. The higher value of triglycerides just might be one cause of high blood pressure or hypertension. It is believed that a high level of triglycerides may contribute to atherosclerosis, which is the thickening or hardening of the arteries. Atherosclerosis will lead to high blood pressure. This input field is classified in four fuzzy sets. The fuzzy sets with their range are shown in table.

Triglyceride(mg/dL)	
Normal	< 150
Borderline high	150-200
High	200-500
Very high	≥ 500

$$\mu normal = \begin{cases} 1 & x \leq 0 \\ 0 & x \geq 150 \end{cases}$$

$$\mu borderline = \begin{cases} 0 & x \leq 150 \\ \frac{x-150}{15} & 150 < x \leq 165 \\ 1 & 165 \leq x \leq 185 \\ \frac{200-x}{15} & 185 < x \leq 200 \\ 0 & x \geq 200 \end{cases}$$

$$\mu high = \begin{cases} 0 & x \leq 200 \\ \frac{x-200}{100} & 200 < x \leq 300 \\ 1 & 300 \leq x \leq 400 \\ \frac{500-x}{100} & 400 < x \leq 500 \\ 0 & x \geq 500 \end{cases}$$

$$\mu very\ high = \begin{cases} 0 & x \leq 500 \\ 1 & x \geq 600 \end{cases}$$

g. Exercise: This input field is classified in four fuzzy sets. We have considered moderate exercise as most of the people doing moderate exercising during daily life. The fuzzy sets with their range are shown in table. If person is not doing exercise then input value is zero.

Moderate Exercise effectiveness(in Min)	
low	5-30
medium	30-60
high	60-100
Very high	90-120

$$\mu low = \begin{cases} 1 & x \leq 5 \\ 0 & x \geq 30 \end{cases} \qquad \mu very\ high = \begin{cases} 0 & x \leq 90 \\ 1 & x \geq 120 \end{cases}$$

$$\mu medium = \begin{cases} 0 & x \leq 30 \\ \frac{x-30}{10} & 30 < x \leq 40 \\ 1 & 40 \leq x \leq 50 \\ \frac{60-x}{10} & 50 < x \leq 60 \\ 0 & x \geq 60 \end{cases}$$

$$\mu high = \begin{cases} 0 & x \leq 60 \\ \frac{x-60}{10} & 60 < x \leq 70 \\ 1 & 70 \leq x \leq 90 \\ \frac{100-x}{10} & 90 < x \leq 100 \\ 0 & x \geq 100 \end{cases}$$

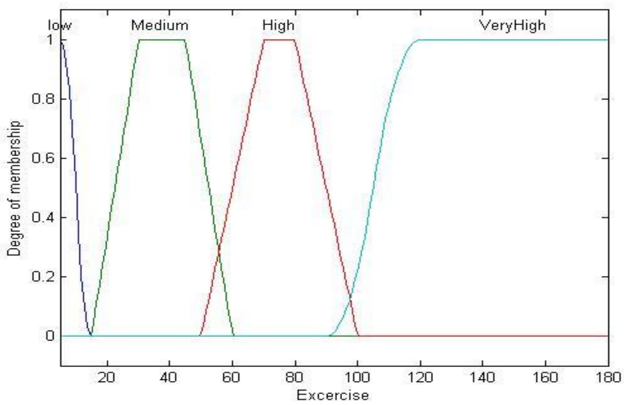

Figure9: Linguistic variables and membership function of 'Moderate Exercise'.

h. Smoking: This input field is classified in four fuzzy sets. The fuzzy sets with their range are shown in table. If person is not doing smoking then input value is zero.

Smoking	
Low	5-10 cigarettes
Medium	8-20 cigarettes
High	18-30cigarettes
Very high	28-35 cigarettes

$$\mu low = \begin{cases} 1 & x \leq 5 \\ 0 & x \geq 10 \end{cases} \quad \mu medium = \begin{cases} 0 & x \leq 8 \\ \frac{x-8}{6} & 8 < x \leq 14 \\ \frac{20-x}{6} & 14 < x \leq 20 \\ 0 & x \geq 20 \end{cases}$$

$$\mu high = \begin{cases} 0 & x \leq 18 \\ \frac{x-18}{6} & 18 < x \leq 24 \\ \frac{30-x}{6} & 24 < x \leq 30 \\ 0 & x \geq 30 \end{cases} \quad \mu very\ high = \begin{cases} 0 & x \leq 28 \\ 1 & x \geq 35 \end{cases}$$

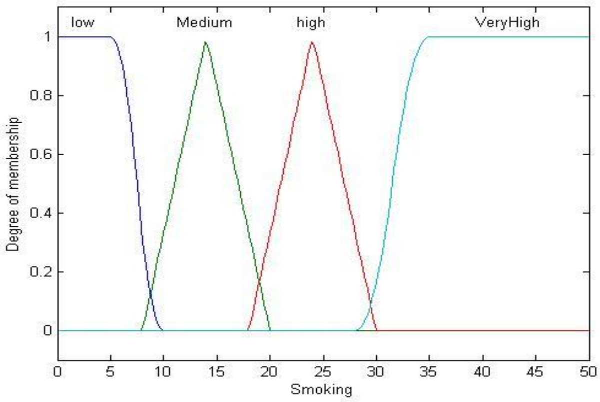

Figure10: Linguistic variables and membership function of 'Smoking'.

2.3 Output variable

The output field refers to the percentage of Hypertension Risk in the patient. It is classified in four classes; low, Mild, Moderate and Severe. As this percentage increases, Hypertension risk factor increases. We have considered trapezoidal membership functions for analysis and these are mentioned in following figure.

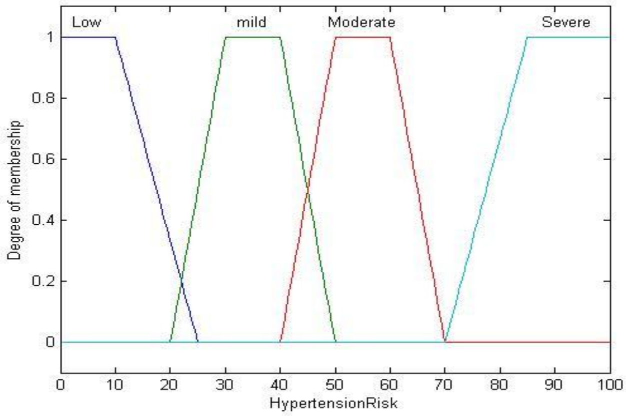

Figure11: Linguistic variables and membership function of output 'Risk'.

2.4 Fuzzy rule

The Rule Base consists of a set of Fuzzy compositions and is derived from the Knowledge Base of the Medical Experts. A fuzzy statement establishes a relationship between different input fuzzy sets and output sets. Some of the rules are given below in table.

				Input Variables						Output variable
Age	**BMI**	**Heart Rate**	**Triglyceride**	**SBP**	**DBP**	**LDL**	**HDL**	**Smoking**	**Exercise**	
Young	low	normal	normal	normal	normal	normal	normal	no	no	low
Young	low	normal	normal	normal	normal	borderline	normal	2	no	low
-----	------	-------	------	------	------	------	-------	------	------	------
young	medium	normal	borderline	Ab. nor	Ab. nor	normal	N. Nor	4	20 min	low
-----	------	-------	------	------	------	------	-------	------	------	------
young	high	high	normal	Ab. nor	Lt. high	borderline	normal	2	no	mild
young	medium	normal	high	Mod.	Ab. nor	borderline	normal	6	no	mild
-----	------	-------	------	------	------	------	-------	------	------	------
Mid aged	High	normal	borderline	Ab. Mod.	normal	borderline	normal	5	25 min	mild
-----	------	-------	------	------	------	------	-------	------	------	------
Mid aged	medium	high	high	high	Mod.	borderline	high	6	no	moderate
-----	------	-------	------	------	------	------	-------	------	------	------
Mid aged	High	Very high	high	Very high	high	high	v. high	18	no	severe
Mid aged	Very high	high	Very high	high	Very high	Very high	v. high	15	10 min	severe
-----	------	-------	------	------	------	------	-------	------	------	------
Aged	low	normal	normal	normal	normal	normal	normal	4	25 min	low

Aged	low	normal	borderline	normal	Ab. nor	borderline	normal	6	45 min	low
-----	------	-------	------	------	------	------	-------	------	------	------
Aged	medium	normal	high	Mod.	Mod.	normal	high	15	no	mild
-----	------	-------	------	------	------	------	-------	------	------	------
Aged	medium	high	high	Mod.	Mod.	high	high	2	60 min	moderate
Aged	high	high	high	high	high	borderline	high	12	no	severe
-----	------	-------	------	------	------	------	-------	------	------	------
old	medium	normal	normal	Ab. nor	normal	borderline	normal	2	20 min	low
-----	------	-------	------	------	------	------	-------	------	------	------
old	medium	high	borderline	LH	LH	borderline	high	8	30 min	mild
-----	------	-------	------	------	------	------	-------	------	------	------
old	medium	high	borderline	high	LH	high	normal	7	60 min	moderate
-----	------	-------	------	------	------	------	-------	------	------	------
Very old	high	high	high	high	high	high	normal	4	90 min	severe
Very old	Very high	Very high	Very high	Very high	Very high	Very high	Very high	12	60 min	severe

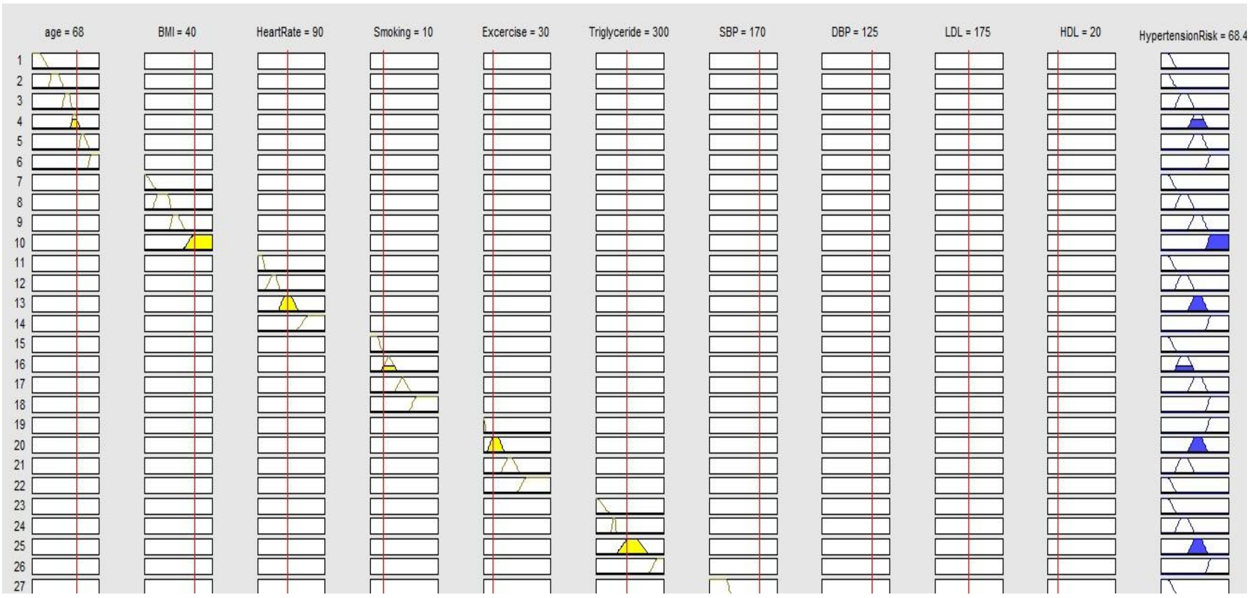

Figure12: Result of FES

3. DEFUZZIFICATION

The main objective of this study is to determine hypertension risk based on the linguistics description of the input parameters Age, SBP, DBP, BMI, LDL, HDL, Triglyceride, Heart rate, smoking and exercise. Hypertension risk will be assessed by different antecedent parts but with the same consequence.

4. RESULT

The rules have been developed using if- then method. Figure 13 shows result for person of age 68, BMI of 40kg/m2, heart rate 90 beats/min, Triglyceride 300mg/dL, SBP 170mm, DBP 125mm, LDL 175mg/dL and HDL 20mg/dL having hypertension risk of about 69%. The figure 13 (b) shows 3D surface diagram in between HDL and LDL. It is very much clear that, at low LDL and Low HDL hypertension risk is moderate and for increasing value of HDL, Hypertension risk will decrease. As a consequence, we may say that higher HDL and Lower LDL level decreases risk for Hypertension and Heart disease.

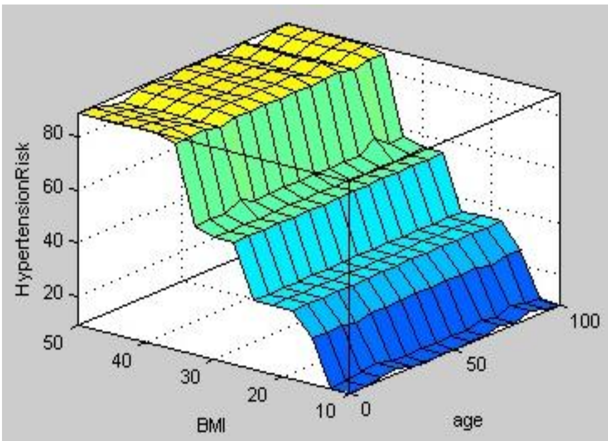

Fig 13: (a)

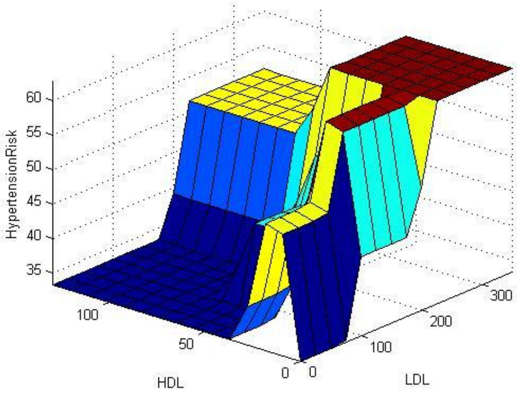

Fig 13(b)

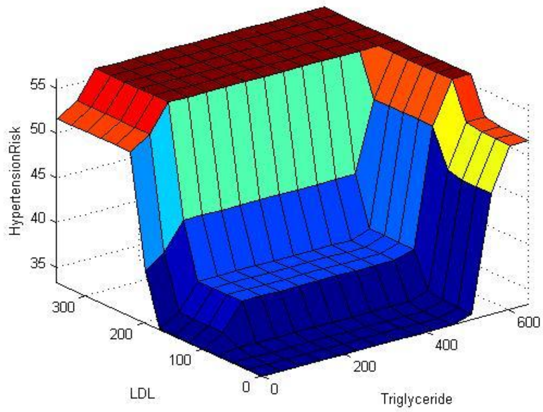

Fig 13 (c)

Figure13: (a), (b), (c) Surface view of FES.

5. CONCLUSION

The diagnosis of hypertension involves several layers of uncertainty and imprecision. The task of hypertension diagnosis and management is complex because of the numerous variables involved. Patients cannot describe exactly how they feel; doctors and nurses cannot tell exactly what they observe. The present research article confirms that the fuzzy expert system can represent the expert's thinking in a satisfactory manner in handling complex cases. The proposed FES is user friendly and effective for hypertension management and it has been verified by medical experts.

6. REFERENCES

[1] Degoulet P., Devries C., and Sauquet D., 1989 "Data and knowledge management integration in hospital information system," in Towards News Information Systems, Amsterdem,North-Holland, pp. 149-156.

[2] Szolovits, P., Patil, R.S., and Schwartz, W.B. 1988. "Artificial Intelligent in Medical Diagnosis".Journal of Internal Medicine. 108(1):80-87.

[3] Hobbs, R. and Boyle, A. 2004. Disease Management Project. ACC/AHA Guidelines for the Evaluation and Management of Chronic Heart Failure in the Audit: Executive Summary. American College of Cardiology/American Heart Association: Washington, D.C.

[4] Djam X.Y. and Kimbi Y.H., 2011. "Fuzzy Expert System for the Management of Hypertension" The Pacific Journal of Science and Technology Volume 12. Number 1.May 2011 (Spring)

[5] Riccardo P. and Stefano C. 1991 "A Neural Network Expert Systemfor Diagnosing and Treating Hypertension" University of Florence Riccardo Livi, pp.64-71.

[6] Sylvie C., Sylvie G., Gilles M., and Jean P. S.,2000 "Statistical and Fuzzy Models of Ambulatory Systolic Blood Pressure for Hypertension Diagnosis" IEEE Transactions on Instrumentation And Measurement, Vol. 49, No. 5, pp.998-1003

[7] Novruz ALLAHVERDI, Serhat and TORUN Ismail SARITAS, 2007 "Fuzzy Expert System Design for Determination of Coronary Heart Disease Risk" International Conference on Computer Systems and Technologies .

[8] Pandey D., Mahajan Vaishali & Srivastava Pankaj 2006 "Rule Based System for Cardiac Analysis", NATL ACAD SCI LETT, Vol. 29, No. 7&8, pp 299-309

[9] Srivastava Pankaj, Srivastava Amit 2012 "A Soft Computing Approach for Cardiac Analysis" Journal of Basic and Applied Scientific Research, 2(1)376-385

[10] Chen, C.L. and Chen, W.C. 1994. "Fuzzy Controller Design by Using Neural Network Techniques". IEEE Transactions on Fuzzy Systems. 2(3):235-244.

[11] Nalayini, N. and Wahidabanu, R.S.D. 2008. "Design Methodology of a Controller to Forecast the Uncertain Cardiac Arrest Using Fuzzy Logic Approach". International Conference Intelligent Systems and Controls: Karpagam College of Engineering, Coimbatore. 46-52.