J. Basic. Appl. Sci. Res., 2(1)376-385, 2012
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ISSN 2090-4304
Journal of Basic and Applied Scientific Research
www.textroad.com

A note on Soft Computing Approach for Cardiac Analysis

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ABSTRACT

Coronary Heart Disease affects millions of people every year. CHD is leading cause of mortality. In heart disease diagnosis, we encounter vagueness in information and uncertainty in decision making, so it is very difficult to reach to certain result for our proposed solution. Aim of this study is to design a Fuzzy Expert System to determine coronary heart disease (CHD) risk of patients in India. The system designed on Matlab Software. The designed system gives the person the ratio of the risk and may recommend whether person has to live life normally or with diet or with drug treatment. The system can be viewed as an alternative for existing methods to determine CHD risk.
KEY WORDS: Heart Disease, Fuzzy Expert System, blood pressure, cholesterol, diabetes, age.

INTRODUCTION

Secand half of the 20th century has witnessed a global spread of coronary artery disease(CAD), especially in developing countries including India as per world health organization report India is going to be hub of heart disease[7] Recently the subject of CAD in Indians has become a challenge for many research centers worldwide. The prevalence of CAD has progressively increased in India during the latter half of last century particularly among urban population. The risk of CAD in Indians is 3-4 times higher than white Americans, 6 times higher than Chinese and 20 times higher than Japanese. CAD is affecting Indians 5-10 years earlier than other communities. The prevalence of CAD is two times higher (10%) in urban than in rural India [8].

The imprecise information available for the diagnosis of any disease is completely a vague process and that leads to uncertainty in decision making process. Having so many factors to analyze the diagnosis of the heart disease makes the physician's job difficult. Therefore experts are advised to have the help of advance mathematical tools in which considering number of risk factors which are expressed in undefined terms. These terms are in the mathematical format for analysis purpose. In order to handle such situations, role of fuzzy theory emerges as a powerful tool to measure uncertainties and competent enough to provide better and sharp results that will help a lot to physicians in sharping their results. Earlier, Novryz Allahverdi et al.2007, Ali Adeli et al 2010 proposed a fuzzy expert system for determination of heart disease on the basis of limited input variables [1, 3]. D.Pandey et al. 2006 proposed a rule based system for cardiac analysis in which model developed on ECG based analysis [4]. In this paper, we have considered systolic and diastolic blood pressure, PPS and FBPS blood sugar, Total cholesterol, age, exercise, smoking, sex etc as input variables to evaluate various phases of risk factor in cardiac disease analysis. The result obtained from designed system is nearly matches with database results. So fuzzy tools are an ideal choice in decision making process as it is similar to human thinking and decision making in spirit. Thus a fuzzy tool enables physicians for better diagnosis.

REVIEW OF LITERATURE

The early works on fuzzy logic and cardiology were concerned with cardiovascular investigation and fuzzy concepts.[13] The use of fuzzy set theory in evaluation of cardiac function[12] and electrocardiography (ECG) analysis[11] and analysis of cerebrovascular disease[10]. In mid 1990's several workers pointed to the concept of fuzzy theory in cardiovascular medicine. Implementation of fuzzy control of total artificial heart was one application [9].

In 1965, Lotfi zadeh proposed fuzzy set theory [14] during the decade 1975-85 a group of Chinese scientists applied fuzzy system to model diagnostic processes and acupuncture related therapy. In 1986 the first book on fuzzy system related to human factors was published namely "Application of fuzzy set theory in human factors", Elsevier 1986. In 1980-90 numerous groups of scientists performed significant research using fuzzy methods in biology and medical applications.

In 2004, Dr. R. Vig et al proposed a intuitions tic fuzzy set theory (which is generalization of fuzzy set theory) is used for medical diagnosis of coronary artery disease. The methodology is developed to assist general

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practioners in diagnosing and predicting patient's condition from certain 'rule' based on 'experience'. The intuition is based on Doctor's ability to make initial judgment based on his study and experience [6]

In 2007, B. Hema kumar developed a fuzzy expert system for different sounds produced by different organs in the human body. She also constructed a unique electronic stethoscope. Such FES system helps the medical doctor in arriving at appropriate decision in different difficult clinical situations [5]

METHOD AND METHODOLOGY

The most important application of fuzzy system is in uncertain issues. The key component of fuzzy analysis is fuzzy expert system.[1] The rules have linguistic variables replacing quantitative values (Baskaran Abhirami & Karthikeyan Dhivya & Swarmy Anusha T., 2010) When a problem has dynamic behavior, fuzzy logic is a suitable tool that deals with this problem.[2] Fuzzy logic enables us to produce definitive outputs or decision for fuzzy input sets.

Fuzzy logic is based on fuzzy sets. A fuzzy set is a universe of discourse can be characterized by a membership function (μ) which takes values between 0 and 1. $\mu: U \longrightarrow [0, 1]$

This value of variable is referred to as the degree of membership. The key components are knowledge base, fuzzification, decision making system and defuzzification.

In this study we have taken in to account age, cholesterol level, blood pressure, blood sugar, sex, exercise, smoking as essentially features to determine the CHD risk. So these parameters will be used as input to design a system.

Input variables are:

a. **Blood Pressure:** Different values of blood pressure change the result easily. In this field we use systolic and diastolic BP. Generally diastolic blood pressure is more important but above 50 years age, systolic BP is more important. This input variable has divided to 7 fuzzy sets. Fuzzy sets are 'Normal', 'Above Normal', 'Moderate', 'Above Moderate', 'Little High', 'High' and 'Very high' sets and membership function of 'Normal' and 'Very high' sets are trapezoidal and membership function of 'Above Normal', 'Moderate', 'Above Moderate', 'Little High', 'High' sets are triangular. We have defined fuzzy membership expression for blood pressure input field.

	Systolic BP in mm Hg	**Diastolic BP in mm Hg**
Normal	< 120	< 80
Above Normal	120- 129	80- 84
Moderate	130- 139	85- 89
Above Moderate	140-149	90-94
Little High	150-159	95-99
High	160-169	100-109
Very High	> 170	> 110

$$\mu_{normal}(x) = \begin{cases} 1 & X < 100 \\ 120 - X/20 & 100 < X < 120 \end{cases}$$

$$\mu_{little\ high}(x) = \begin{cases} X-150/5 & 150 < X < 155 \\ 1 & X = 155 \\ 160 - X/5 & 155 < X < 160 \end{cases}$$

$$\mu_{above\ normal}(x) = \begin{cases} X-100/20 & 100 < X < 120 \\ 1 & X = 125 \\ 130 - X/5 & 125 < X < 130 \end{cases}$$

$$\mu_{high}(x) = \begin{cases} X-160/5 & 160 < X < 165 \\ 1 & X = 165 \\ 170 - X/5 & 165 < X < 170 \end{cases}$$

$$\mu_{moderate}(x) = \begin{cases} X-130/5 & 130 < X < 135 \\ 1 & X = 135 \\ 140 - X/5 & 135 < X < 140 \end{cases}$$

$$\mu_{very\ high}(x) = \begin{cases} X-170/10 & 170 < X < 180 \\ 1 & X > 180 \end{cases}$$

$$\mu_{above\ moderate}(x) = \begin{cases} X-140/5 & 140 < X < 145 \\ 1 & X = 145 \\ 150 - X/5 & 145 < X < 150 \end{cases}$$

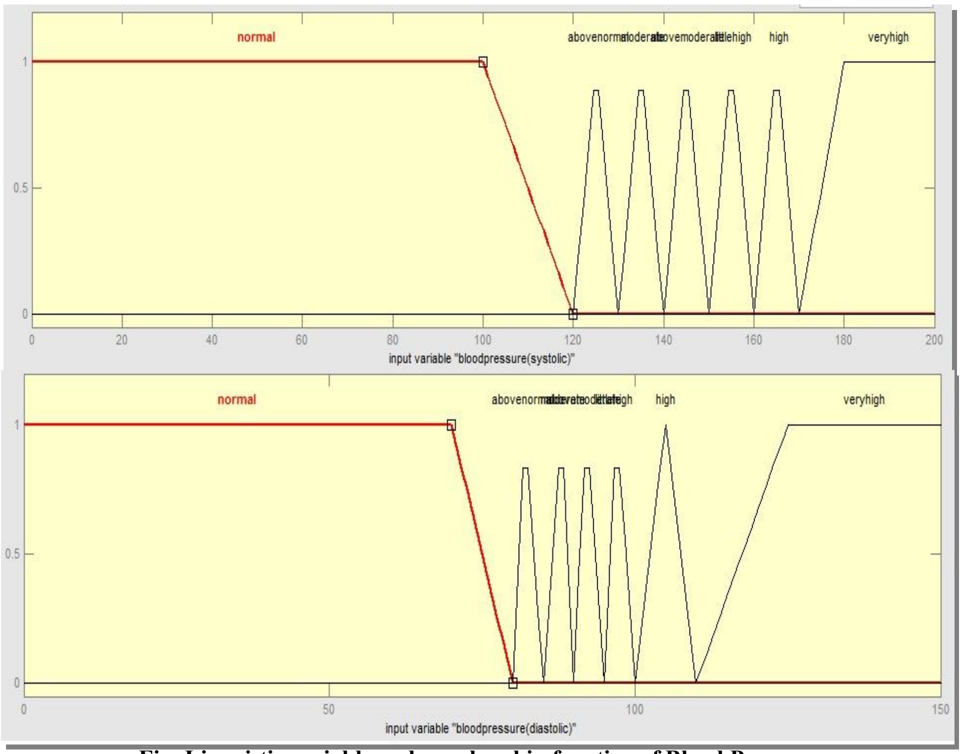

Fig- Linguistic variable and membership function of Blood Pressure

b. Total Cholesterol: Cholesterol has salient affect on the result and can change it easily. For this input field we use the value of total cholesterol. Cholesterol level has been classified in 6 fuzzy sets (Very low, low, Desirable, Borderline high, high and very high). These fuzzy sets have been shown in table. Membership functions of very low and very high sets are trapezoidal and membership functions of low, Desirable, Borderline high, high are triangular. Membership function of cholesterol field will be shown in figure. 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.

Total Cholesterol	
Very low	< 160
low	160-199
Desirable	200-229
Borderline high	230-239
High	240-259
Very high	> 260

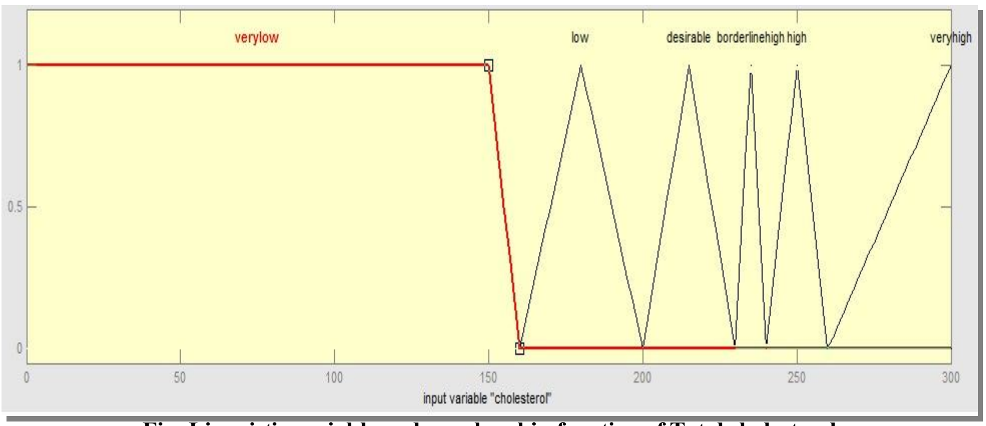

Fig- Linguistic variable and membership function of Total cholesterol

$$\mu_{\text{very low}}(x) = \left\{ \begin{array}{ll} 1 & X < 150 \\ \frac{160 - X}{10} & 150 < X < 160 \end{array} \right\}$$

$$\mu_{\text{low}}(x) = \left\{ \begin{array}{ll} \frac{X - 160}{20} & 160 < X < 180 \\ 1 & X = 180 \\ \frac{200 - X}{20} & 180 < X < 200 \end{array} \right\}$$

$$\mu_{\text{desirable}}(x) = \left\{ \begin{array}{ll} \frac{X - 200}{15} & 200 < X < 215 \\ 1 & X = 215 \\ \frac{230 - X}{15} & 215 < X < 230 \end{array} \right\}$$

$$\mu_{\text{borderline high}}(x) = \left\{ \begin{array}{ll} \frac{X - 230}{5} & 230 < X < 235 \\ 1 & X = 235 \\ \frac{240 - X}{5} & 235 < X < 240 \end{array} \right\}$$

$$\mu_{\text{high}}(x) = \left\{ \begin{array}{ll} \frac{X - 240}{10} & 240 < X < 250 \\ 1 & X = 250 \\ \frac{260 - X}{10} & 250 < X < 260 \end{array} \right\}$$

$$\mu_{\text{very high}}(x) = \left\{ \begin{array}{ll} \frac{X - 260}{40} & 260 < X < 300 \\ 1 & X > 300 \end{array} \right\}$$

c. **Blood Sugar (Diabetes):** Blood Sugar field is one of the most important factors in this system that changes the result. This input field has just one fuzzy set. In this system, we have defined that if the amount value of blood sugar is higher than 120 then person has diabetes. Figure shows membership function of this fuzzy set is trapezoidal.

Blood Sugar (Diabetes)	
FBS	> 126 mg/dl
PPBS	> 200 mg/dl

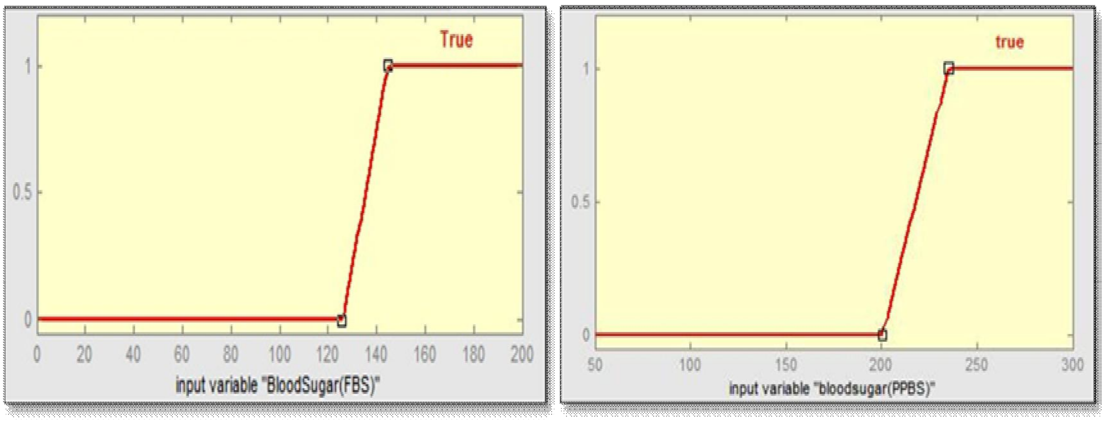

Fig- Linguistic variable and membership function of Blood Sugar (Diabetes)

For FBS: $$\mu_{\text{Very High}}(x) = \left\{ \begin{array}{ll} \frac{X - 90}{36} & 90 < X < 126 \\ 1 & X > 126 \end{array} \right\}$$

For PPBS $$\mu_{\text{Very High}}(x) = \left\{ \begin{array}{ll} \frac{X - 175}{25} & 175 < X < 200 \\ 1 & X > 200 \end{array} \right\}$$

d. **Age:** This input field is classified in 6 fuzzy sets (young, Adult, Midaged, Aged, old, very old). The fuzzy sets with their range given in table. Membership function of young and very old are trapezoidal and membership function of other are triangular.

Age	
Young	< 25
Adult	25- 45
Midaged	45-55
Aged	55-65
Old	65-85
Very Old	> 85

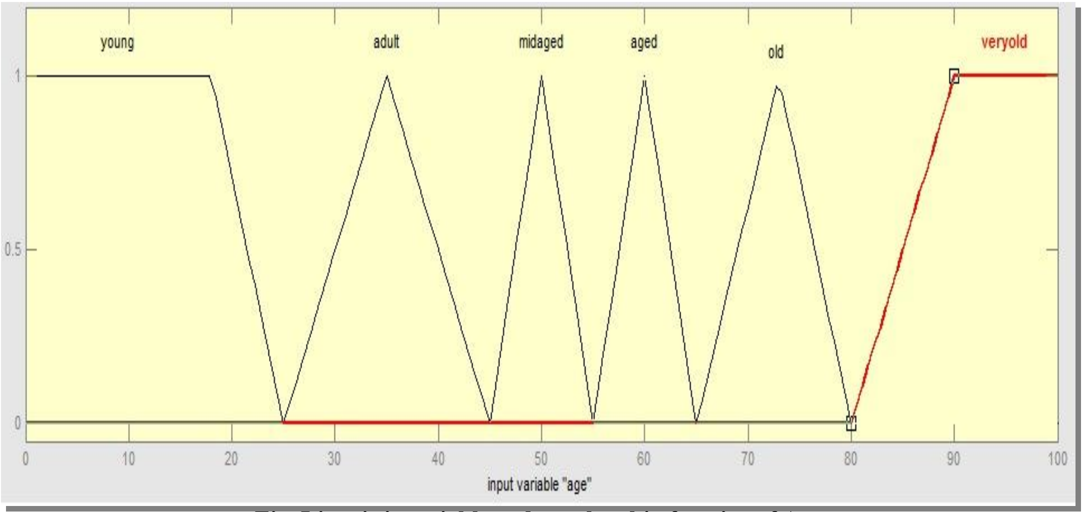

Fig- Linguistic variable and membership function of Age

$$\mu_{Young}(x) = \begin{cases} 1 & X < 18 \\ 25-X/7 & 18<X<25 \end{cases}$$

$$\mu_{aged}(x) = \begin{cases} X-55/5 & 55<X<60 \\ 1 & X=60 \\ 65-X/5 & 60<X<65 \end{cases}$$

$$\mu_{Adult}(x) = \begin{cases} X-25/10 & 25<X<35 \\ 1 & X=35 \\ 45-X/10 & 35<X<45 \end{cases}$$

$$\mu_{Old}(x) = \begin{cases} X-65/10 & 65<X<75 \\ 1 & X=75 \\ 85-X/10 & 75<X<85 \end{cases}$$

$$\mu_{midaged}(x) = \begin{cases} X-45/5 & 45<X<50 \\ 1 & X=50 \\ 55-X/5 & 50<X<55 \end{cases}$$

$$\mu_{very\ old}(x) = \begin{cases} X-85/10 & 85<X<95 \\ 1 & X>95 \end{cases}$$

e. **Sex:** This input field just has 2 values 0 and 1 and sets are male and female. Value 0 means patient is male and value 1 means patient is female.

f. **Exercise:** This input field is classified in 6 fuzzy sets. The fuzzy sets with their range are shown in table. Membership functions are given below. If person is not doing exercise then input value is 0.

Exercise	
Very less effective	< 10 min
less effective	10-20 min
Moderate	20-45 min
Above Moderate	45-60 min
Highly effective	60-90 min
Very highly effective	> 90 min

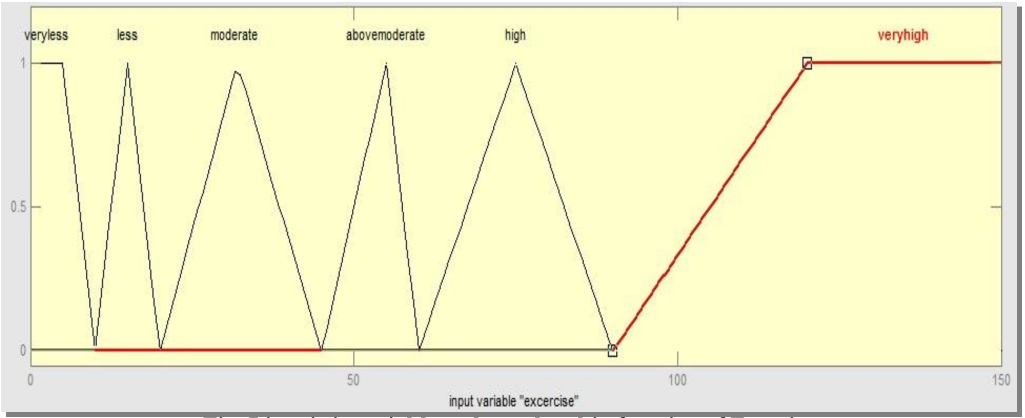

Fig- Linguistic variable and membership function of Exercise

$$\mu_{\text{very less}}(x) = \begin{cases} 1 & X < 5 \\ \frac{10-X}{5} & 5 < X < 10 \end{cases}$$

$$\mu_{\text{less}}(x) = \begin{cases} \frac{X-10}{5} & 10 < X < 15 \\ 1 & X = 15 \\ \frac{20-X}{5} & 15 < X < 20 \end{cases}$$

$$\mu_{\text{moderate}}(x) = \begin{cases} \frac{X-20}{12} & 20 < X < 32 \\ 1 & X = 32 \\ \frac{45-X}{5} & 32 < X < 45 \end{cases}$$

$$\mu_{\text{above moderate}}(x) = \begin{cases} \frac{X-45}{10} & 45 < X < 55 \\ 1 & X = 55 \\ \frac{60-X}{5} & 55 < X < 60 \end{cases}$$

$$\mu_{\text{high}}(x) = \begin{cases} \frac{X-60}{15} & 60 < X < 75 \\ 1 & X = 75 \\ \frac{90-X}{15} & 75 < X < 90 \end{cases}$$

$$\mu_{\text{very high}}(x) = \begin{cases} \frac{X-90}{10} & 90 < X < 120 \\ 1 & X > 120 \end{cases}$$

g. **Smoking:** This input field is classified in 6 fuzzy sets. The fuzzy sets with their range are shown in table. Membership functions are given below. If person is not doing smoking then input value is 0.

Smoking	
Low smoking	< 3 cigarettes
Moderate	3-7 cigarettes
Above moderate	7-12cigarettes
High	12-18 cigarettes
Very high	> 18 cigarettes

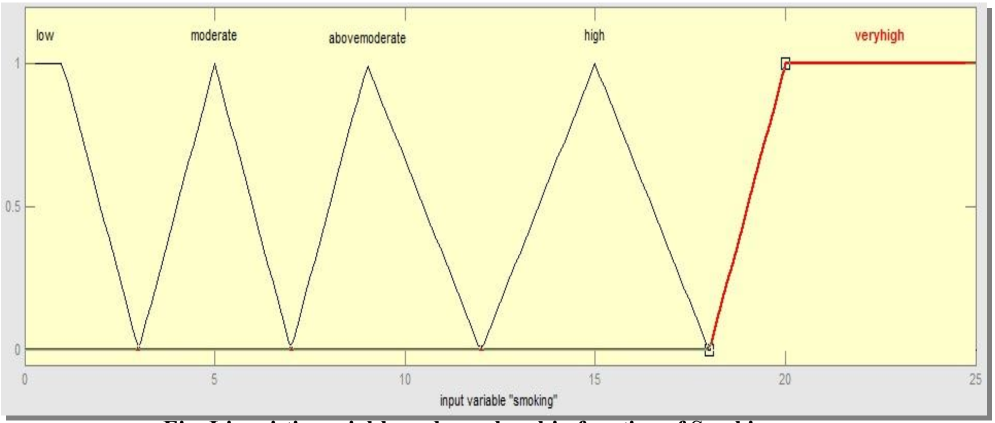

Fig- Linguistic variable and membership function of Smoking

$$\mu_{low}(x) = \begin{cases} 1 & X < 1 \\ {3-X}/{2} & 1<X<3 \end{cases}$$

$$\mu_{high}(x) = \begin{cases} {X-12}/{3} & 12<X<15 \\ 1 & X=15 \\ {18-X}/{3} & 15<X<18 \end{cases}$$

$$\mu_{moderate}(x) = \begin{cases} {X-3}/{2} & 3<X<5 \\ 1 & X=5 \\ {7-X}/{2} & 5<X<7 \end{cases}$$

$$\mu_{very\ high}(x) = \begin{cases} {X-18}/{10} & 18<X<20 \\ 1 & X>20 \end{cases}$$

$$\mu_{above\ moderate}(x) = \begin{cases} {X-7}/{2} & 7<X<9 \\ 1 & X=9 \\ {12-X}/{3} & 9<X<12 \end{cases}$$

Output variable:

The output field refers to the presence of heart disease in the patient. It is classified in 5 terms; very low, low, Medium, High and very high and it will show CHD risk percentage. As this percentage increases, CHD risk factor increases. Membership function of very low and very high fuzzy sets is trapezoidal and membership function of low, medium, high fuzzy sets is triangular. These will be shown in figure.

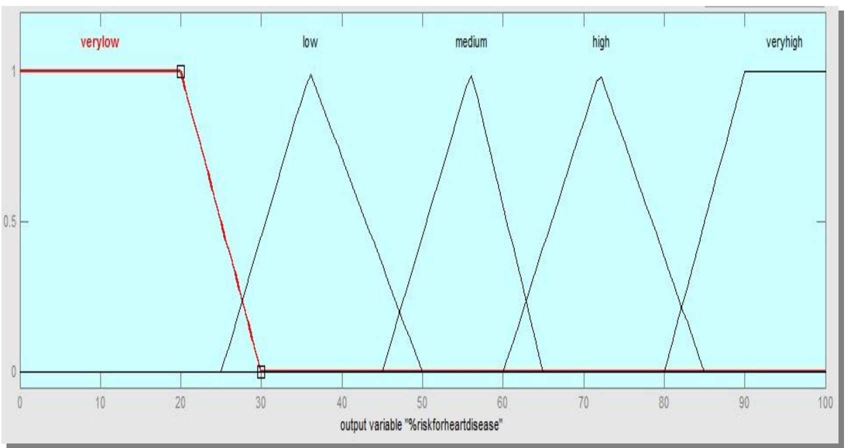

Fig- Linguistic variable and membership function of output Risk

Fuzzification and Defuzzification:
Designed system uses inference mechanism Mamdani approach. The validity degree (K) for each rule according to mamdani max- min rule is shown with formulas below.
K_1 = min (normal, very low, young, male, no, no, no)
K_2 = min (normal, very low, young, male, no, no, yes)

K_{100} = min (normal, borderline high, adult, no, no, no)

K_{500} = min (moderate, high, adult, no, no, no)

K_{825} = min (high, high, old, no, no, no)

K_{1024} = min (very high, very high, very old, no, no, no)

The maximum of validity degrees of triggered values are calculated with formulas below:
$K_{1,\,2,\,----n}$ = max (K_1, K_2, ---------------K_n)

Fuzzy Rule Base:
Rule base is the main part in fuzzy inference system and quality of result in fuzzy system depends on the fuzzy rules. Some rules have been below.

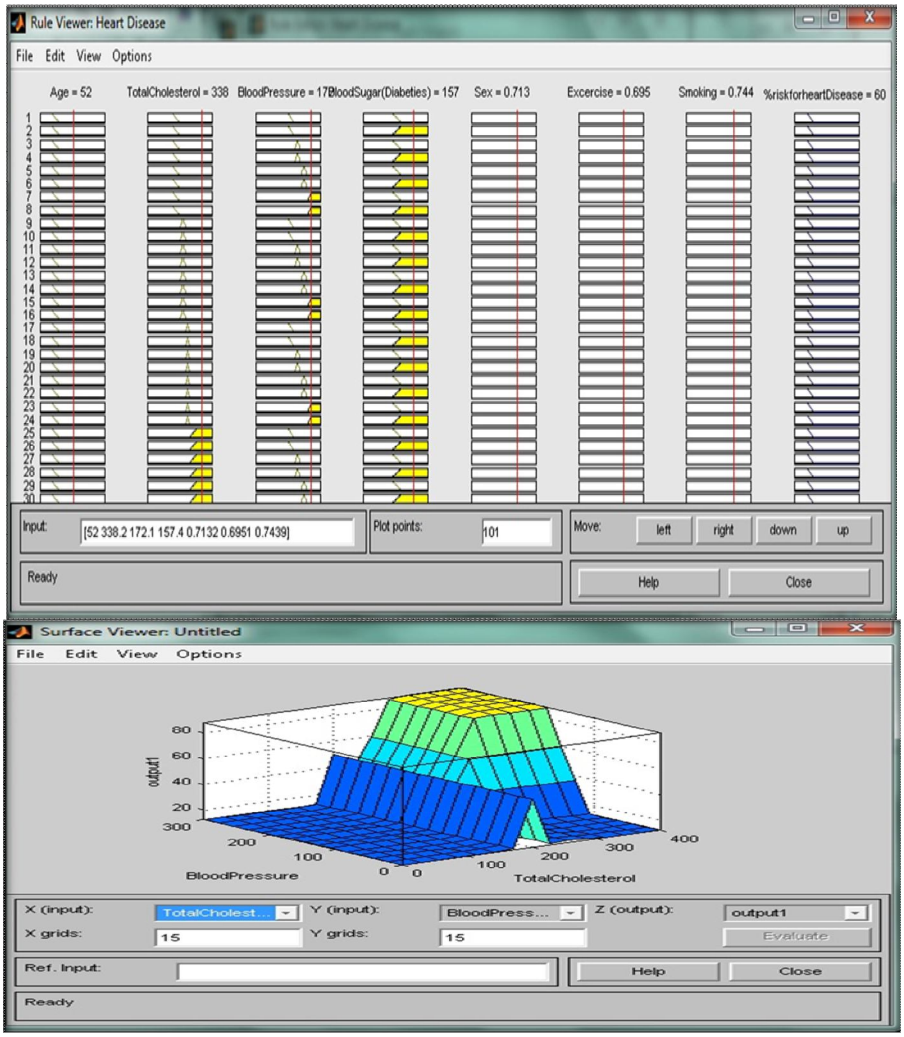

Fig- 3D Surface view of Fuzzy Expert System

Result:

The outputs can be defuzzified to obtain a crisp value by the 'Centre of Gravity' Method as given below:

$$z^* = \frac{\int \mu_c(z) \bullet z dz}{\int \mu_c(z) dz}$$

		Input variables					Output
Age	**Total Cholesterol**	**Blood pressure**	**Blood Sugar (Diabetes)**	**Sex**	**Exercise**	**Smoking**	**Risk**
Young	Very low	Normal	No	M	No	No	**Very Low**
Young	Very low	Above normal	No	F	No	3	**Very Low**
------	-------	--------	--------	---	---	---	**------**
Young	Low	Above normal	Yes	F	90 min	4	**Very low**
Young	Low	High	Yes	F	No	No	**Low**
---	------		---	--	---	----	**-----**
Young	Low	Very high	Yes	M	No	No	**Low**
-----	-----		---	---	----	----	**----**
Young	Desirable	Normal	No	F	No	No	**Low**
-----	-----		----	----	----	---	**---**
Young	Borderline high	Normal	No	F	No	3	**Low**
-----	------		---	---	----	----	**-----**
Young	Borderline high	Moderate	No	F	No	No	**Low**
Young	Very high	High	Yes	F	60 min	No	**Low**
------	------	-------	--------	---	---	---	**----**
Adult	Desirable	Normal	Yes	M	No	3	**Medium**
-----	------	-----	-	----	----	----	**-----**
Adult	Borderline high	Normal	Yes	M	No	No	**Medium**
Adult	High	Above moderate	Yes	F	80 min	No	**Medium**
-----	-----	-----	----	---	----	----	**-----**
Adult	Very High	Normal	Yes	F	No	3	**Medium**
Mid aged	Very High	Moderate	Yes	F	70 min	No	**Medium**
-----	-----	--------	----	----	----	----	**------**
Aged	Borderline high	High	Yes	M	45 min	No	**Medium**
-----	------	-----	----	---	----	----	**-----**
Old	Desirable	High	No	M	No	4	**High**
-----	------	------	----	----	-----	-----	**---------**
Old	Very high	Moderate	Yes	M	30 min	5	**High**
----	-----	-----	-----	----	-----	----	**---------**
Very old	Borderline high	Moderate	No	M	No	5	**Very high**
------	------	-------	--------	---	----	----	**----**
Very old	High	High	No	F	No	No	**Very high**
-----	----	-----	----	---	----	-----	**-----**
Very old	**Very high**	**Very high**	**Yes**	**F**	**No**	**5**	**Very High**

.

Where, μ_c (z) is the membership function and z is the degree of membership. For Example if we consider the case as below in the table, the output comes out to be high risk of Heart Disease.

Age	**Cholesterol**	**Blood pressure**	**Blood Sugar (Diabetes)**	**Sex**	**Exercise**	**Smoking**	**Result of System**
Adult	210(borderline)	120(medium)	122(true)	Male	No	No	Medium
Aged	230(high)	117(low)	130(true)	Female	No	No	High
Old	244(high)	114(low)	130(true)	Male	30 min	5 cig	High
Very old	255(high)	145(high)	130(true)	Male	No	5 cig	High
Very old	264(very high)	163(very high)	150(true)	Male	No	No	Very high

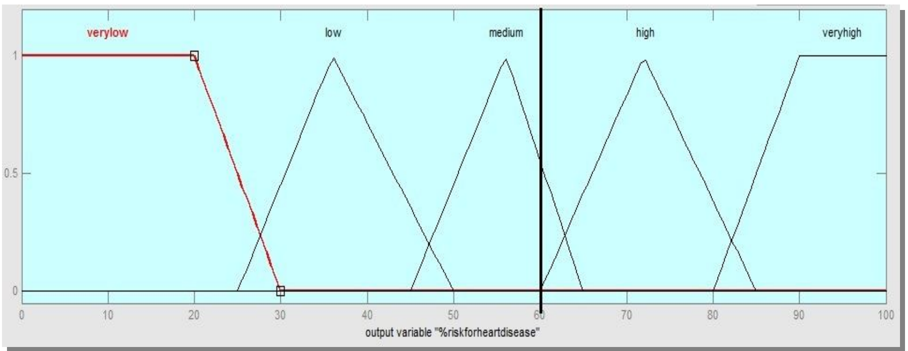

Fig- Linguistic variable and membership function of output Risk

Conclusion

The system designed in present paper has been verified with cardiac experts and results derived from system are logical and more efficient. The beauty of designing of such system is that a patient can use it himself. The developed system may act as support system for the experts for sharpening their medical diagnosis of patients. This proposed system will also help us to design an algorithm to design and development of new medical diagnosis machine for cardiac related problem analysis. In future, the designed system may be improved in order to classify various types of cardiac diseases and their analysis.

REFERENCES

[1] Ali.Adeli & Mehdi.Nehsat (2010) " A Fuzzy Expert System for heart Disease Diagnosis",Procedings to the Internatinal Multi conference of Engineers and Computer Scientists 2010, IMECS 2010, Volume1,March 17-19

[2] Baskaran Abhirami & Karthikeyan Dhivya & Swarmy Anusha T.(2010) "Modeling and Automation of Diagnosis & Treatment of Diabetes" SEAL 2010, LNCS 6457, pp. 339-348

[3] Novruz Allah Verdi & Serhat Torun & Ismail Saritus "Design of a Fuzzy Expert System for determination of Coronary Heart Disease Risk", International Conference on Computer System and Technologies-Comp Sys Tech 07, pp IIIA 14.1-14.8, 2007

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

[5] Hema Kumar B. (2007) "A fuzzy expert system design for analysis of body sounds and design of an unique electronic stethoscope (development of HILSA kit)", Biosensors and Bioelectronics, Volume 22, pp 1121–1125

[6] Vig R, Handa N M, Bali H K, Sridhar(2004) "Fuzzy Diagnostic System for Coronary Artery Disease", IE(I) Journal-ID, Vol 85, pp41-46

[7] Singh S.P. & Sen P. (2003) "Coronary Heart Disease the Changing Scenario", Indian J. Prev. Soc. Med. Vol. 34 No. 1 &2, pp74-80

[8] Rissam H S, Kishore S & Trehan N,(2001) "Coronary Artery Disease in Young Indians- The missing link", Journal, Indian Academy of Clinical Medicine, Volume 2, No. 3, pp 128-132

[9] Kauffmann, R., Reul H., and Rau G.(1994) "The Helholtz Total Artificial Heart Lab type" Artificial Organs, Volume 18, No. 7, pp. 537–542

[10] Dong, W., Zhou S., and Wang L.(1987) "A Fuzzy Relation Model for Multifactorial Analysis of Cerebrovascular Diseases" Proceedings of the Ninth Annual Conference of the IEEE Engineering in Medicine and Biology Society, IEEE, New York, Volume 1, pp. 307–308

[11] Jagannathan, V. et al(1982) "Artificial Intelligence Methods in Quantitative Electroencephalogram Analysis," Computer Programs in Biomedicine, Volume 15, No. 3, pp. 249–257

[12] Joly, H. et al.(1980) "Application of Fuzzy Set Theory to the Evaluation of Cardiac Functions," MEDINFO 80, Proc. 3rdWorld Conference on Medical Information, Tokyo: North Holland Publications, Volume 1, pp. 91–95

[13] Kalmanson, D., and Stegall F. (1975) "Cardiovascular Investigation and Fuzzy Concepts," Amer J. Cardio., Volume 35, pp. 30–34

[14] Zadeh, L.A. (1965) "Fuzzy sets", Information and Control, Volume 8 (3), pp338—353.