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BATCH [08]

Diagnose heart diseases using a fuzzy expert system

تشخيص أمراض القلب باستخدام المنطق الضبابي الخبير

SUBMITTED BY

SOMIA NOURELDAIM ALTAIB

SUPERVISOR

DR. ELTAHER MOHAMED HUSSIEN

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Acknowledgment

Thanks to Almighty ALLAH for giving me strength and ability to understand, learn and complete this thesis.

I would like to express my thanks to my supervisor Dr. Eltaher Mohamed for his knowledge, guidance, patience and support, who helped me to get the expected results through continuous assessment of my work.

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Abstract

Heart disease has become one of the most prevalent diseases which people are being suffered from .According to statistics, it is one of the most important causes of deaths all over the world (CDC's) report.

The detection of heart disease is very difficult and human dependant, and there is no strict boundaries between the healthy and diseased heart, many errors may occur and the errors may relate to dangers result including death. To solve this problem fuzzy logic is used to build expert systems which include a many rules that determined patient case according to the entered patient data after being processed, compared to reference data, and finally analyzed to give the final result of the heart state.

After applying the system on data of 30 patients, there disease was diagnosed by a doctor and by a fuzzy expert system and the results obtained by the these two methods were compared and found that twenty nine of the results were identical and of the result were different, and this difference was due to the fact that the fuzzy expert system depends on the rules must be included to in all the possibilities.

The proposed system is more effective compare to previous systems because the accuracy is increased to 97%.

المستخلص

أمراض القلب أصبحت من الأمراض الشائعة التي يعاني منها البشر وفقا للإحصائيات وهي من الأسباب الرئيسية لحدوث الوفيات حول العالم .تشخيص أمراض القلب ليس بالأمر السهل لأنه يعتمد علي تشخيص بشري وهنالك مساحه صغيره بين صحة القلب ومرضه.

قد تحدث أخطاء كثيرة وهذه الأخطاء ستقود لنتائج خطيرة تصل للموت.حتى نحل هذه المشكلة المنطق الضبابي استخدم لبناء نظام خبير يحتوي علي قواعد تحدد حاله المريض وفقا للمعلومات بعد معالجتها ومقارنتها ب معلومات مرجعيه وأخيرا تحليل النتائج للحصول علي حاله القلب.

بعد تطبيق النظام علي 30 مريض وتشخيص المرض بواسطة الطبيب والنظام الضبابي الخبير ومقارنه نتائج الطبيب والنظام ووجود 29تشخيص متشابه وتشخيص واحد غير متشابه وهذا الاختلاف يرجع إلى أن النظام الضبابي الخبير يعتمد علي قواعد يجب أن تعتمد علي كل الاحتمالات.

النظام المعني هو نظام مؤثر مقارنه بالدراسات السابقة لان دقته زادت إلي 97%.

Chapter one

Introduction

1.1General view:

Heart disease has become one of the most prevalent diseases which people are being suffered from. According to statistics, it is one of the most important causes of deaths all over the world (CDC's) report. [1]

Risk Factors for Heart Disease:

There are several factors for heart disease some are controllable some are not.

Uncontrollable risk factors include:

- Male sex.
- Older age.
- Family history of heart disease.

Controlled factors:

- Smoking.
- High LDL or "bad" cholesterol and low HDL or" good "cholesterol.
- Uncontrolled hypertension (high blood pressure).[3]

Fuzzy expert systems:

Fuzzy system:

Fuzzy systems are an alternative to traditional notions of set membership and logic that has its origins in ancient Greek Philosophy, and applications at the leading edge of artificial intelligence.[5]

Fuzzy logic:

Fuzzy logic is a multi-valued logic which deals with vague and indecisive ideas. It has been described as an extension to the conventional Aristotelian and Boolean logic as it deals with "degrees of truth" rather than absolute values of "0 and 1" or "true, false" [6].

Fuzzy expert system

Fuzzy expert system is a form of artificial intelligence that uses a collection of membership function (fuzzy logic) and rules (instead of Boolean logic) to reason about data.

1.2 Problem Statement

Sometimes heart disease diagnosis is hard for experts. In the other word, there exists no strict boundary between what is Healthy and what is diseased, having so many factors to analyze to diagnose the heart disease of the a patient makes the physician's job difficult

1.3 Objectives

The main objective of this research to design a fuzzy expert system for diagnosis heart disease

1.4 Methodology

The proposed system start by patient data inserting (age, low density lipoprotein ,high density lipoprotein , exercise ,type of chest pain ,gender, past history, family history, blood purser. blood sugar ,smoking, maximum heart rate ,resting ECG ,…,etc.) then processing the data{(Fuzzication(convert the input to fuzzy set)and compare the data with reference in the system and get the result in fuzzy set ,Defuzzication(convert the result to real data)} to diagnose heart condition..

as we see to it been hard to gather the information especially with this project because it teaks week or more to complete one patient data

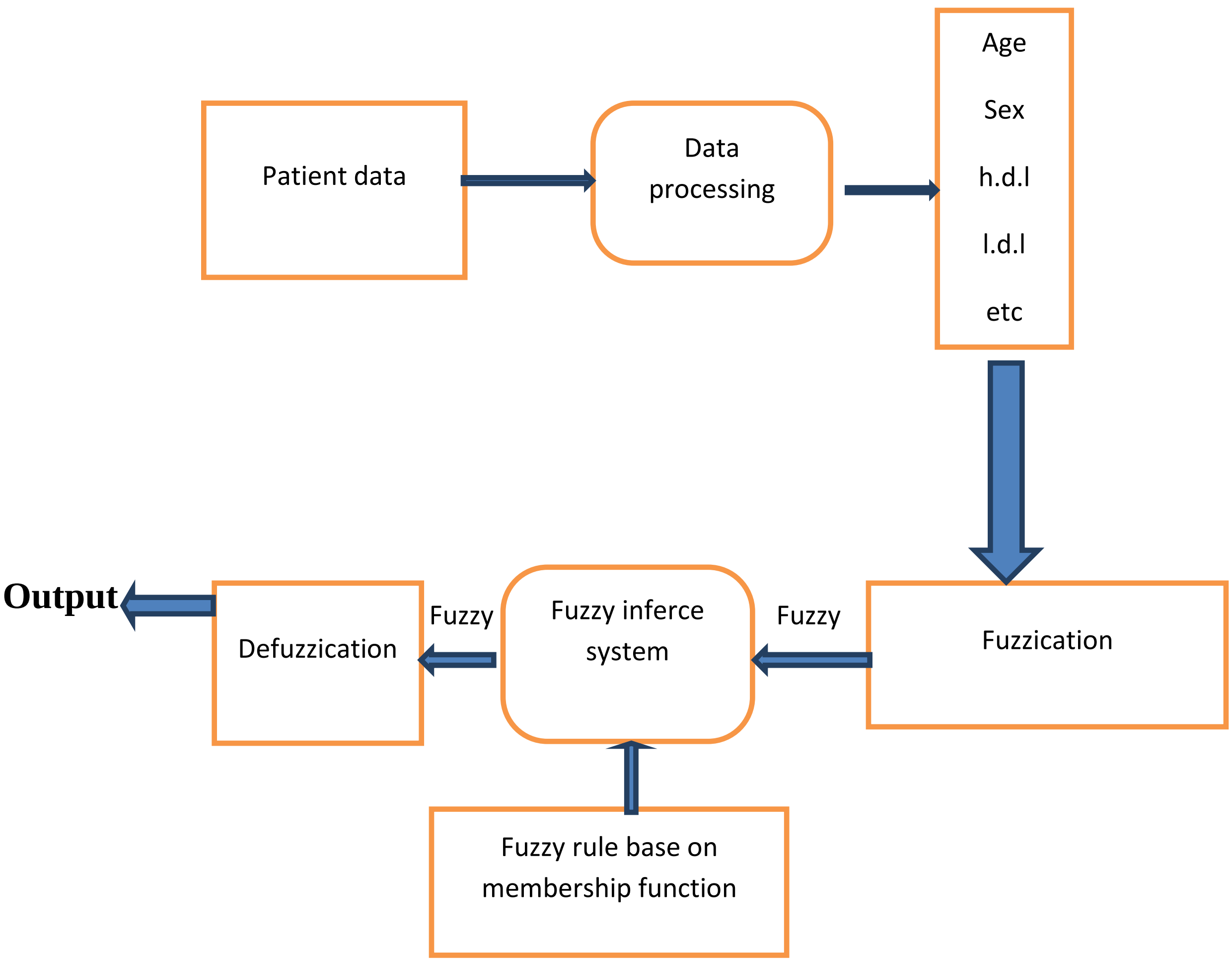

Figure 1.1: methodology

1.5 This layout:

This thesis consists of five chapter’s chapter one is an introduction, Chapter two is theoretical background, Chapter three is speak about literature reviews , Chapter four consists of Methodology, Chapter five is results and discussion, Finally conclusion and recommendation in chapter six.

Chapter Two

Literature Reviews

(1) Smitha Sikua Suhil Sikuha MS Ali Design of Fuzzy Expert System for Diagnosis of Cardiac Disease (2012) [7]

The logical thinking of medical practitioners play significant role in decision making about diagnosis. It exhibits variation in decisions because of their approaches to deal with uncertainties and vagueness in the knowledge and information. Fuzzy logic has proved to be the remarkable tool for building intelligent decision making systems for approximate reasoning that can appropriately handle both the uncertainty and imprecision. The aim of this paper is develop a generic fuzzy expert system framework that can be used to design specific fuzzy expert systems for particular medical domain.

The method: is generic fuzzy expert system has been designed for diagnosis of cardiac diseases. The interface between visual basic and Mat Lab is powerful feature of the system that offers user friendly graphical user interface. The result: need to arrive at the most accurate medical diagnosis in a timely manner is the main outcome that may reduce the further complications. A generic fuzzy expert system for the diagnosis of various heart diseases yields better result than the classic designed systems, because this system simulates the manner of an expert in true sense. The particular focus is on diagnosis of heart disease by employing the fuzzy logic in expert systems. The system has been designed and tested successfully. Exhaustive rule base specifically formed for almost all heart diseases ensures the accuracy to arrive at certain decision

(2) Novruz Allhidre Sehrat Torunisail Sataas Design A fuzzy Expert for Determine of Coronary Disease Risk (2012) [8]

The aim this study is to design a fuzzy expert to determine coronary heart disease (CHD) risk of patient for the next ten-years. The designed system gives the user the ratio of the risk and may recommend using one of three results; normal live; diet; drug treatment. Date (risk ratio) obtained from designed system are compared with the data in the literature and better results are observed in the designed system. The system can be viewed as an alternative for existing methods to determine CHD risk.

(3) Rehana Parvin Dr Abdolreza Abhairr fuzzy database for Heart Disease diagnosis (2009)[9]

Using a Database is a well-known for storing information. In regular database system, sometimes because of existence of huge data is it not possible to fulfill the user’s criteria and to provide them with the exact the information that need to make a decision. In this paper, a medical fuzzy database is introduced in order to help users in providing accurate information when there is inaccuracy in database. Inaccuracy in data represents imprecise or vague values (like the words use in human conversation) or uncertainty in using the available information required for decision making. In this paper, a fuzzy database management system is introduced to diagnose the severity of the heart disease of a patient by using existing data in the common database systems. Data sizes are becoming large day by day. So, it is a challenge to deal with these large amounts of data stored in databases regular database is based on Boolean logic, which means that the information is either completely true or completely false. It is impossible to deal imprecise information in classical data base management systems. Having fuzzy data management capability in a database is important to be able to store vague data. Ignoring vague data management means the risk of losing important information, which may be useful for some applications. A database that supports vague, imprecise and uncertain information is called a fuzzy database. It is based on fuzzy logic and fuzzy set theory.

(4)Yun-Chi Yeh, Wen-June Wang, and Che Wun Chiou Heartbeat Case Determination Using Fuzzy Logic Method on ECG Signals (2009)[10]

This study proposes Fuzzy Logic Method (FLM) to analyze ECG signals for determining the heartbeat case. The proposed method can accurately classify and distinguish both normal heartbeats (NORM) and abnormal heartbeats. The so called abnormal heartbeats include the left bundle branch block (LBBB), the right bundle branch block (RBBB), the ventricular premature contractions (VPC), and the a trial premature contractions (APC). ECG signal analysis comprises three main stages: (i) the qualitative features stage for qualitative feature selection of an ECG signal; (ii) fuzzy rules base establishment; and (iii) the classification stage for determining patient heartbeat cases. The fuzzy rules base receives four qualitative features of an ECG signal as its inputs and generates one output "heartbeat case". Through fuzzy inference engine and defuzzification operations, we can make a decision to determine the heartbeat case of the patient's heart disease. The ECG records available in the MIT-BIH arrhythmia database are utilized to illustrate the effectiveness of the proposed method. In the experiments, the sensitivities of total classification accuracy (TCA) was approximately 93.78%.

(5) ArashKhormehr MSc student of Software Engineering Department of Computer Engineering Sanandaj Branch, Islamic Azad University, Sanandaj, Kurdistan, Iran Vafa Maihami Faculty member Department of Computer Engineering Sanandaj Branch, Islamic Azad University, A Novel Fuzzy Expert System Design for Predicting Heart Diseases(2013).[11]

The volume of data generated by rapid technological progress also on the rise is too fast, use, the selection of useful data and its analysis of the issues that have been of interest to researchers, obtain conclusive results due to the uncertainty of this information to resolve these issues also are research priorities. Forecast diseases, including the risk factors in the selection of important and complex issues that concern is to get the correct result is that Heart disease is no exception. In this paper, using a fuzzy system a model is designed to predict heart disease that using design rules based on medical science works. By a physician, a series of rules designed, with this rules and fuzzy systems a good model with more efficient for predicting heart disease is presented. The proposed algorithm is based on data obtained from several cardiac patients and healthy individuals were tested in Tohid Hospital in Sanandaj city, the proposed algorithm's accuracy from 95% in people prone to heart disease to be identified with precision.

(6) A. M. Abushariah, Assal A. M. Alqudah, Omar Y. Adwan, Rana M. M. Yousef Automatic Heart Disease Diagnosis SystemBased on Artificial Neural Network(2001)[12] The Cleveland data set for heart diseases was used as the main database for training and Testing the developed system. In order to train and test the Cleveland data set, two systems were developed. The first system is based on the Multilayer Perceptron (MLP) structure on the Artificial Neural Network (ANN), whereas the second system is based on the Adaptive Neuro-Fuzzy Inference Systems (ANFIS) approach. Each system has two main modules, namely, training and testing, where 80% and 20% of the Cleveland data set were randomly selected for training and testing purposes respectively. Each system also has an additional

module known as case-based module, where the user has to input values for 13 required attributes as specified by the Cleveland data set, in order to test the status of the patient whether heart disease is present or absent from that particular patient. In addition, the effects of different values for important parameters were investigated in the ANN-based and Neuro-Fuzzy-based systems in order to select the best parameters that obtain the highest performance. Based on the experimental work, it is clear that the Neuro- Fuzzy system outperforms the ANN system using the training data set, the accuracy for system was 87.74%, respectively.

(7) Monish Kumar Choudhury1, NeelanjanaBaruah Fuzzy Logic Based Expert System for Determination of Healthy Risk Level Of patient (2010).[13]

Design a fuzzy expert system for calculating the health risk level of a patient. The fuzzy logic system is a simple, rule-based system and can be used to monitor biological systems that would be difficult or impossible to model with simple, linear mathematics. The designed system is based on the modified early warning score (MEWS).The system has 5 input field and 1 output field. The input fields are blood pressure, pulse rate, SPO2 (it is an estimation of the oxygen saturation level in blood.), temperature, and blood sugar. The output field refers the risk level of the patient. The output ranges from 0 to 14. This system uses Mamdam inference method. A larger value of output refers to greater degree of illness of the patient. This paper describes research results in the development of a fuzzy driven system to determine the risk levels of health for the patients. The implementation and simulation of the system is done using MATLAB fuzzy tool box.

(8)X.Y. Djam, and Y.H. Kimbi: Fuzzy Expert System for The Management of Hypertension (2011)[14]. This paper focused on the use of information and communication technology (ICT) to design a web-based fuzzy expert system for the management of hypertension using the fuzzy logic approach. In this paper, systolic blood pressure, diastolic blood pressure, age, and body mass index (BMI) were taken as input parameters to the fuzzy expert system and ―hypertension risk‖ was the output parameter. The resultant hypertension risk was based on fuzzy rules that were developed for the expert system. The input triangular membership functions are Low, Normal, High, and Very High for blood pressure. The output triangular membership functions are mild, moderate and severe. The defuzzification method used in this paper is the Root Sum Square. The expert system was designed based on clinical observations, medical diagnosis, and the experts‘ knowledge. The expert system provides a web-based interface that was designed using PHP as a scripting language with MySQL relational database on Apache Sever under Windows operating system platform, and using Java Script and HTML to archive the system design. Unified Modeling Language was used to describe the logical design of the system. We selected 50 patients with hypertension and computed the results that were in the range of predefined limit by the domain experts.

(9) E.P.Ephzibah, Dr. V. Sundarapandian An International Journal (CSEIJ),Expert System for Diagnosis of Myocardial Infarction (2012). [15]

This paper is based on the heart disease diagnosis in patients with the help of evolutionary techniques like genetic algorithms, Fuzzy rule based expert system and Neural networks. This expert system will help the doctors to arrive at conclusion about the presence or absence of heart disease in patients. This is an enhanced system that accurately classifies the presence of the heart disease. It is proved that the generated neuro-fuzzy rule based classification system is capable of diagnosing the heart disease in an effective and efficient method than any other classifiers.

(10) Kemal polat,sahlihGunes Diagnoses of heart disease using artificial immune recognition system and fuzzy weighted preprocessing (2006).[14]

This paper presents a novel method for diagnosis of heart disease. The proposed method is based on a hybrid method that uses fuzzy weighted pre-processing and atrtificial immune recognition system (AIRS). Artificial immune recognition system has showed an effective performance on several problems such as machine learning benchmark problems like breast cancer, liver disorders classification. The robustness of the proposed method is examined using classification accuracy is 92% and it is very promising compared to the previously reported classification techniques.

Table 2.1 Literature review summary

Author/Date	Method	Accurse
Smitha Sikua Suhil Sikuha MS AliDesign of Fuzzy Expert System for Diagnosis of Cardiac Disease	fuzzy expert system	90%
Novruz Alherdei Serrate Torun IsailSattas Design A fuzzy Expert for Determine of Coronary Disease Risk	Nero-fuzzy-network	88.65%
Rehana Parvin DrAbdoalzaraAbhareder Used Data Base for Heart Disease Base For Heart DiseaseDiagnoses Used Data Base for Heart Disease Diagnosis	fuzzy logic	87%
Yun-Chi Yeh, Wen-June Wang, and CheWunChiou Heartbeat Case Determination Using Fuzzy Logic Method on ECG Signals (2007).	fuzzy logic method	93.78%.
ArashKhormehr MSc student of Software Engineering Department of Computer Engineering Sanandaj Branch, Islamic Azad University, Sanandaj, Kurdistan, Iran Vafa Maihami Faculty member Department of Computer Engineering Sanandaj Branch, Islamic Azad University, A Novel Fuzzy Expert System Design for Predicting Heart Diseases.	a fuzzy system a model	95%
A. M. Abushariah, Assal A. M. Alqudah, Omar Y. Adwan, Rana M. M. Yousef Automatic Heart Disease Diagnosis SystemBased on Artificial Neural Network.	Neural Network	90.74 %for each system 87.04% respectively
Monish Kumar Choudhury1, NeelanjanaBaruah Fuzzy Logic Based Expert System for Determination of Healthy Risk Level Of patient .	fuzzy expert system	88,97%
X.Y. Djam, and Y.H. Kimbi: Fuzzy Expert System for The Management of Hypertension.	fuzzy expert system	90%
E.P.Ephzibah, Dr. V. Sundarapandian An International Journal (CSEIJ), Vol.2, No.1, February.	Fuzzy rule based expert system and Neural networks	91.38%
Kemal polat,sahlihGunesDignosis of heart disease using artificial immune recognition system and fuzzy weighted preprocessing.	Fuzzy Wight and neural network	92%

- most of this paper use a mamdni method so I use it too.
- Some of study focus on heart rate and heart peak and ignore risk factor(in my proposal I focus on both) .
- Some of study diminish the input and focus on patient number(try to focus on both).
- Some study use neural network .

Chapter three

Theoretical background

The heart is a powerful muscle that pumps blood throughout the body by means of a coordinated contraction. The contraction is generated by an electrical activation, which is spread by a wave of bioelectricity that propagates in a coordinated manner throughout the heart. Under normal conditions, the sinoatrial node initiates an electrical impulse that propagates through the atria to the atrioventricular node, where a delay permits ventricular filling before the electrical impulse proceeds through the specialized His-Purkinje conduction system that spreads the electrical signal at speeds of meters per second throughout the ventricles. This electrical impulse propagates diffusively through the heart and elevates the voltage at each cell, producing an action potential, during which a surge in intracellular calcium initiates the mechanical contraction. The normal rhythm is altered when one or more spiral (reentrant) waves of electrical activity appear. These waves are life-threatening because they act as high-frequency sources and underlie complex cardiac electrical dynamics such as tachycardia and fibrillation [1].

3.1 Anatomy Of Heart

The heart has four chambers:

Right Ventricle: The lower right chamber of the heart during the normal cardiac cycle, the right ventricle receives deoxygenated blood as the right atrium contracts. During this process the pulmonary valve is closed, allowing the right ventricle to fill. Once both ventricles are full, they contract. As the right ventricle contracts, the tricuspid valve closes and the pulmonary valve opens. The closure of the tricuspid valve prevents blood from returning to the right atrium, and the opening of the pulmonary valve allows the blood to flow into the pulmonary artery toward the lungs for oxygenation of the blood The right and left ventricles contract simultaneously; however, because the right ventricle is thinner than the left, it produces a lower pressure than the left when contracting [2]. This lower pressure is sufficient to pump the deoxygenated blood the short distance to the lungs.

Left Ventricle: the lower left chamber of the heart during the normal cardiac cycle, the left ventricle receives oxygenated blood through the mitral valve from the left atrium as it contracts. At the same time, the aortic valve leading to the aorta is closed, allowing the ventricle to fill with blood. Once both ventricles are full, they contract. As the left ventricle contracts, the mitral valve closes and the aortic valve opens. The closure of the mitral valve prevents blood from returning to the left atrium, and the opening of the aortic valve allows the blood to flow into the aorta and from there throughout the body. The left and right ventricles contract simultaneously; however, because the left ventricle is thicker than the right, it produces a higher pressure than the right when contracting. This higher pressure is necessary to pump the oxygenated blood throughout the body

Right Atrium: the upper right chamber of the heart during the normal cardiac cycle, the right atrium receives deoxygenated blood from the body (blood from the head and upper body arrives through the superior vena cava, while blood from the legs and lower torso arrives through the inferior vena cava).

Once both atria are full, they contract, and the deoxygenated blood from the right atrium flows into the right ventricle through the open tricuspid valve.

Left Atrium: the upper left chamber of the heart during the normal cardiac cycle, the left atrium receives oxygenated blood from the lungs through the pulmonary veins. Once both atria are full, they contract, and the oxygenated blood from the left atrium flows into the left ventricle through the open mitral valve [2].

Blood flow:

The flow of blood through the heart is controlled by opening and closing of valves and the contraction and relaxation of the myocardium [1] Heart valves are controlled by pressure changes within each chamber and contraction and relaxation are controlled by the heart's conduction system.

Blood that has traveled through the tricuspid valve into the right ventricle .the right ventricle pumps the blood to the lungs, where it absorbs oxygen. Oxygen-rich blood returns from the lungs and enters the heart through the left atrium. Blood passes from the left atrium through the mitral valve and into the left ventricle.

The left ventricle, the largest and most muscular of the four chambers, is the main pumping chamber of the heart when the left ventricle contracts, blood is pumped through the aortic valve into the main artery of the body (aorta) .[2] The aorta supplies blood to smaller arteries that travel to the head, arms abdomen, and legs. These arteries supply

Oxygen -rich blood to the organs and tissues of the body, which require oxygen of function. The coronary arteries supply oxygen-rich blood to the tissues of the heart.

Oxygen-poor blood travels from organs and tissues to the heart through veins the vena cave is the major vein that returns blood to the right atrium of the heart. The vena cave superior returns blood from the head, neck upper extremities', and chest. The vena cava inferior returns blood from the lower extremities, the pelvis, and the abdomen. The coronary sinus drains blood from the coronary arteries into the right atrium [1]

Arrhythmias:

During normal rhythm, the heart beats regularly, producing a single coordinated electrical wave that can be seen as a normal electrocardiogram (ECG). During arrhythmias such as ventricular tachycardia and ventricular fibrillation, this normal behavior is disrupted and the ECG records rapid rates with increased complexity. The underlying cause of many arrhythmias is the development of a reentrant circuit of electrical activity that repetitively stimulates the heart and produces contractions at a rapid rate. During tachycardia, a single wave can rotate as a spiral wave, producing fast rates and complexity. During fibrillation, a single spiral wave can degenerate into multiple waves. Because contraction is stimulated by the pattern of electrical waves, arrhythmias can compromise the heart's ability to pump blood and sometimes may be lethal [2]

Sinus rhythm: is the normal rhythm of the heart and results from proper activation of the entire heart in proper sequence. The sinoatrial (or sinus) node located in the right atrium spontaneously beats periodically to begin each activation which proceeds to activate both atria before reaching the atrioventricular (AV) node. At the AV node, which under normal circumstances is the only electrical connection between the atria and ventricles, activation proceeds more slowly to allow for optimal ventricular filling[2]. The activation then enters the His-Purkinje system, which allows a rapid spreading throughout the ventricles and induces a strong, synchronized contraction. Any variation from normal sinus rhythm is termed an arrhythmia.

Ventricular fibrillation: is an immediately life-threatening arrhythmia in which the heart's electrical activity and associated contraction become disordered and ineffective. It is characterized by rapid, irregular activation of the ventricles and thereby prevents an effective mechanical contraction. Blood pressure instantaneously drops to zero, leading to death within minutes due to lack of cardiac output unless successful electrical defibrillation is performed; spontaneous conversion to sinus rhythm is rare. During ventricular fibrillation, the ECG has no distinctive QRS complexes but instead consists of an undulating baseline of variable amplitude. Although the sinus node continues to function properly, P waves cannot be discerned in the VF waveform. Ventricular tachycardia in many cases can degenerate to ventricular fibrillation. One mechanism believed to be responsible for the rapid, unsynchronized contraction of the ventricles is the continuous reactivation of one or more electrical circuits in the ventricles, which can appear as three-dimensional spiral or scroll waves of electrical activity. These waves prevent the ventricles from contracting in a coordinated manner, thereby compromising the heart's ability to pump blood [2]

3.2 Diseases Of The Heart

Coronary artery disease: Over the years, cholesterol plaques can the arteries supplying blood to the heart. The narrowed arteries are at higher risk for complete blockage from a sudden clot (this blockage is called a heart attack) [3]

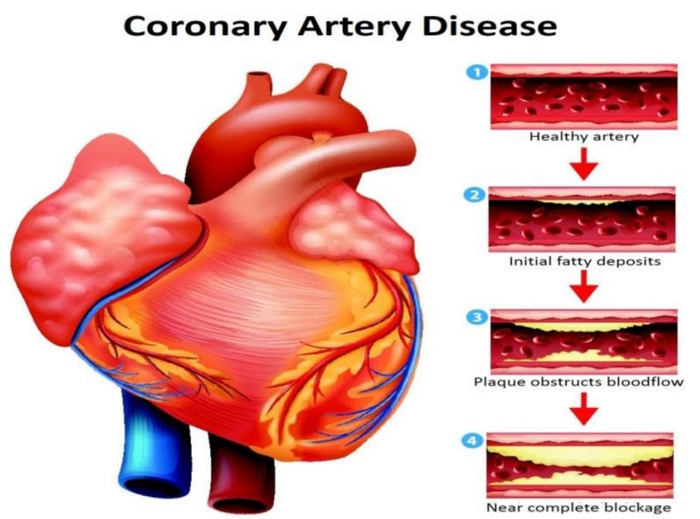

Figure 3.1 coronary artery diseases

Stable angina pectoris: Narrowed coronary arteries cause predictable chest pain or discomfort with exertion the blockages prevent the heart from receiving the extra oxygen needed for strenuous activity. Symptoms typically get better with rest.

Unstable angina pectoris : chest pain or discomfort that is new, worsening or occurs at rest .this an emergency situation as it can precede a heart attack, serious abnormal heart rhythm, or cardiac arrest [3]

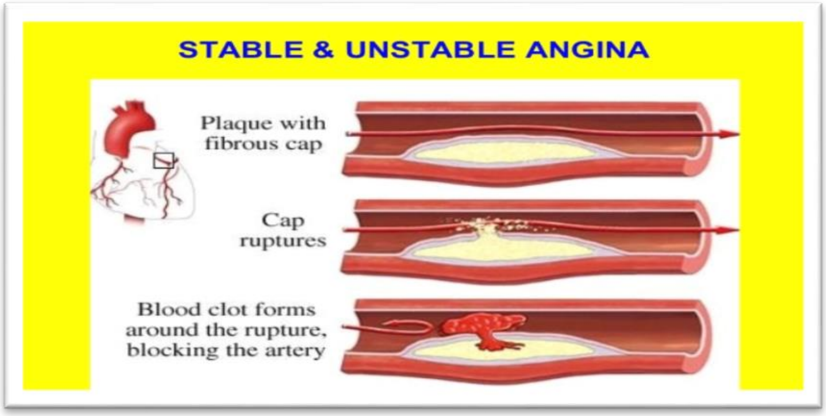

Figure 3.2 stable and unstable angina

Myocardial infarction (heart attack): A coronary artery is suddenly blocked starved of oxygen, part of the heart muscle dies.

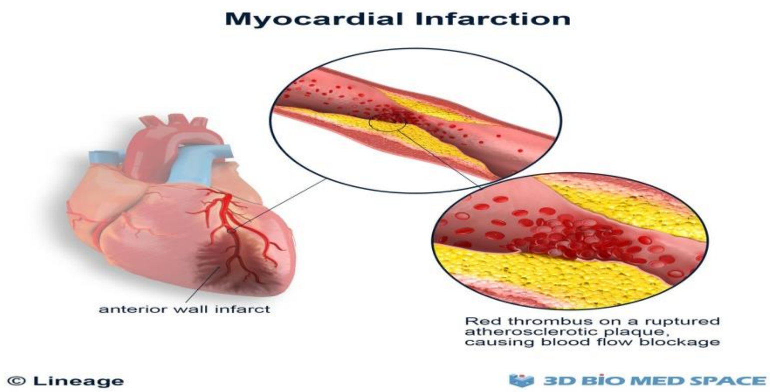

Figure 3.3 Myocardial infarction

Arrhythmia (dysrhythmia): An abnormal heart is either too weak or too stiff to effectively pump blood through the body. Shortness of breath and leg swelling are common symptoms[3]

Cardiomyopathy: A disease of heart muscle in which the heart is abnormally enlarged, thickened, and\or stiffened. As a result the heart's ability to pump blood is weakened.

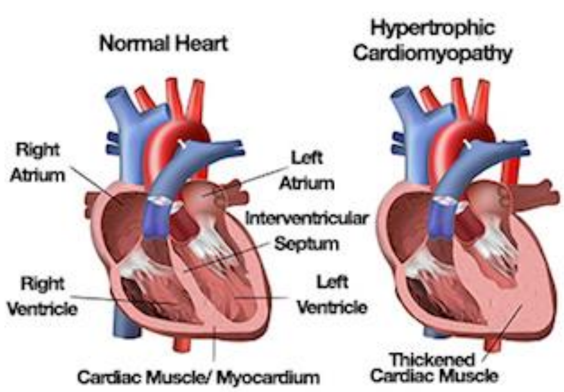

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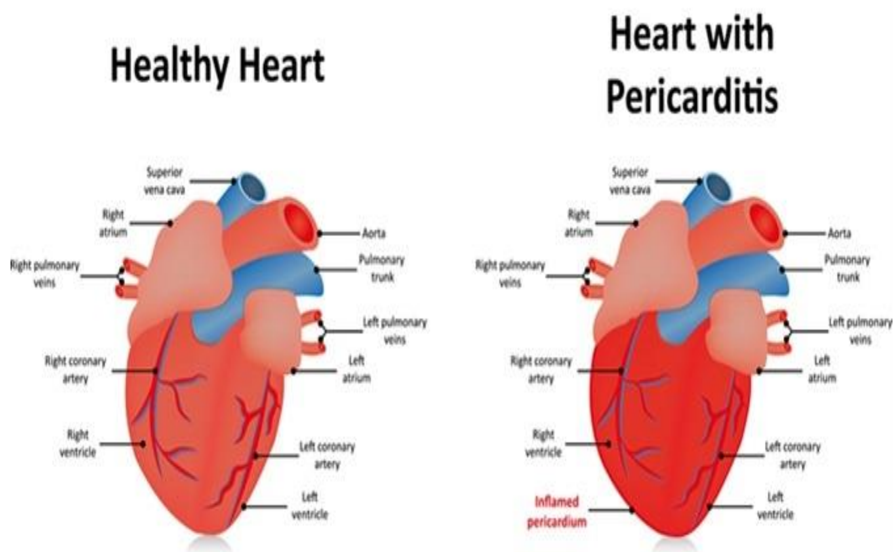
Figure 3.4 Cardiomyopathy

Myocarditis: Inflammation of the heart muscle, most often due to a viral infection.

Pericarditis: Inflammation the lining of the heart (pericardium). Viral infection, kidney failure, and autoimmune conditions are common causes.



- Figure 3.5 Pericarditis

Pericardial effusion: fluid between the lining of the heart (pericardium) and the heart itself. Often, this is due to pericarditis

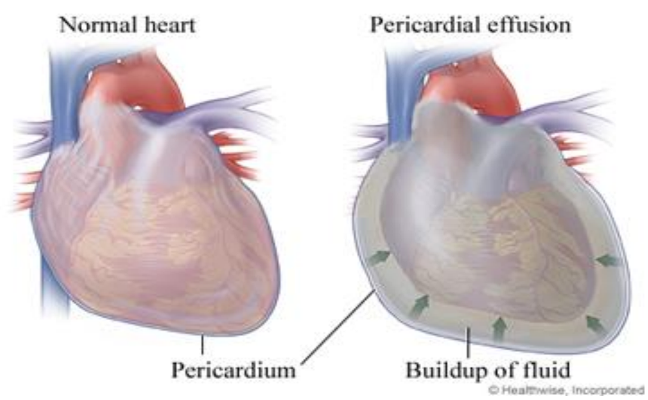


Figure 3.6 Pericardial effusion

Atrial fibrillation : Abnormal electrical impulses in the atria cause an irregularheartbeat. Atrial fibrillation is one of the most common arrhythmias.

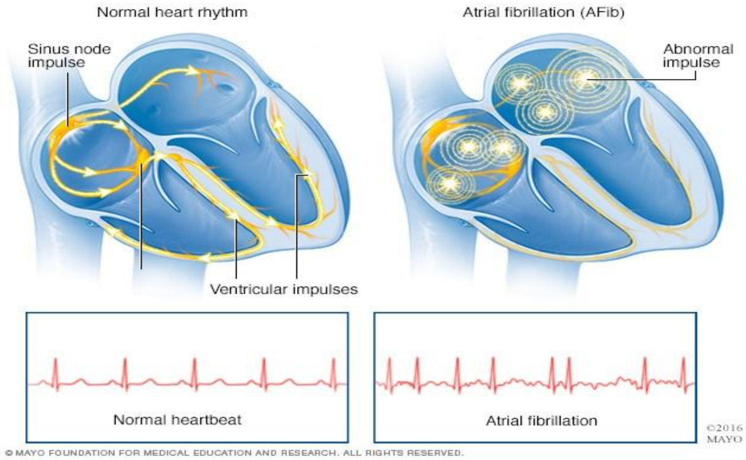


Figure 3.7 **Atrial fibrillation**

Pulmonary embolism: Typically a blood clot travels through the lungs .Heart valve disease there is four heart valves, and each can develop problems. If severe, valve disease can cause congestive heart failure [2].

Heart murmur: An abnormal sound heard when listening to the heart with a stethoscope some heart murmurs are being, others suggest heart disease.

Endocarditis: inflammation of the inner lining or heart usually, endocarditic is due to a serious infection of the heart valve.

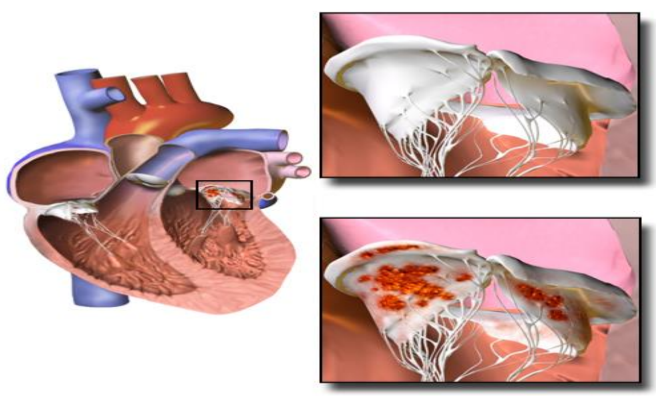


Figure 3.8 Endocarditic

Valve prolapsed: the mitral valve is forced backward slightly after blood has passed through the valve.

Sudden cardiac death: Death caused by a sudden loss of heart function (cardiac arrest).

3.3 Risk Factors for Heart Disease

Risk factors are traits and lifestyle habits that increase your chance of having a disease

There are several risk factors for heart disease some are controllable others are not

3.3.1 Uncontrollable risk factors include:

1. Male sex
2. Older age
3. Family history of heart disease

Still, there are many heart disease risk factors that can be controlled. By making changes in your lifestyle, you can actually reduce your risk for heart disease [4].

3.3 .2 Controllable risk factors include:

1-Blood pressure

Blood pressure is the force put on artery walls when your heart pumps and relaxes with each heartbeat. It is measured with a blood pressure cuff.

High blood pressure is also called hypertension. It is caused by the narrowing of arteries from plaque deposits. The harder it is for your blood to flow through your arteries, the higher your blood pressure[16].

Having high blood pressure puts you at risk for heart disease, kidney disease and stroke.

- Normal blood pressure: systolic less than 120 and diastolic less than 80.
- Elevated blood pressure: systolic 120 to 129 and diastolic less than 80.
- High blood pressure (hypertension) stage 1: systolic 130 to 139 or diastolic 80 to 89.
- High blood pressure (hypertension) stage 2: systolic 140 or higher or diastolic 90 or higher. Hypertensive crisis (consult your doctor right away): systolic higher than 180 and/or diastolic higher than 120.

2-Cholesterol and triglycerides

Cholesterol and triglycerides are different types of fats found in your blood. Too much cholesterol or triglycerides in your blood can be harmful and increase your risk for heart disease and stroke. Total cholesterol is a measure of the total amount of cholesterol in your blood and is based on HDL, LDL and triglycerides numbers (HDL + LDL + 20 percent of your triglycerides level). A healthy level is below 200. • LDL cholesterol makes up the majority of your body's cholesterol. It is known as "bad" cholesterol because it causes plaque to build up on artery walls, making it hard for blood to flow. The higher the level of (LDL cholesterol) in your blood the greater your risk of heart disease and stroke [16]

3-Stress and tension

Stress is a normal part of our lives. Stress causes the release of adrenalin, which speeds up your heart rate, narrows your blood vessels and increases your blood pressure. Stress makes you heart work harder. It is not the stressful situation, but your reaction to stress that is important. People who feel time pressures and who are hard-driving are more prone to heart disease. Those who are calm, unhurried and easy-going are at less risk

4-Diabetes

Diabetes results in high blood sugar levels (glucose). Diabetes occurs when the pancreas does not produce enough insulin or the body cannot use insulin properly. With diabetes, there is an abnormal amount of lipoprotein, which speeds up atherosclerosis and raises the risk of heart attack. Having high blood pressure and being overweight are more common in people with diabetes [16]

5-Smoking

6-Physical inactivity

7-Obesity (more than 20% over one's ideal body weight)

8-High C-reactive protein

9-Excessive alcohol use

3.4 Fuzzy Expert System

3.4.1 Fuzzy system

Fuzzy systems are an alternative to traditional notions of set membership and logic that has its origins in ancient Greek philosophy and applications at the leading edge of Artificial Intelligence. Yet despite its long-standing origins, it is a relatively new field [5].

3.4.2 FUZZY Logic

Fuzzy logic is an extension of Boolean logic by Lotfi Zadeh professor for computer science at the University of California in Berkeley in 1965 based on the mathematical theory fuzzy Logic (FL) is a multivalued logic that allows intermediate values to be defined between conventional evaluations like true/false, yes/no, high/low, etc. Notions like rather tall or very fast can be formulated mathematically and processed by computers, in order to apply a more human−like way of thinking in the programming of computers. A fuzzy system is an alternative to traditional notions of set membership and logic that has its origins in ancient Greek philosophy. The precision of mathematics owes its success in large part to the efforts of Aristotle and the philosophers who preceded him. [4] In their efforts to devise a concise theory of logic, and later mathematics, the so−called "Laws of Thought" were posited. One of these, the "Law of the Excluded Middle," states that every proposition must either be true or false. Even when Parmenides proposed the first version of this law (around 400 B.C.) there were strong and immediate objections: for example, Heraclitus proposed that things could be simultaneously true and not True. It was Plato who laid the foundation for what would become fuzzy logic, indicating that there was a third region (beyond True and False) where these opposites "tumbled about." Other, more modern philosophers echoed his sentiments, notably Hegel, Marx, and Engels. But it was Lukasiewicz who first proposed a systematic alternative to the bi−valued logic of Aristotle. Even in the present time some Greeks are still outstanding examples for fussiness and fuzziness, (note the connection to logic got lost somewhere during the last 2 millenniums. Fuzzy Logic has emerged as profitable tool for the controlling and steering of systems and complex industrial processes, as well as for household and entertainment electronics, as well as for other expert systems and applications like the classification of SAR data.[6]

Fuzzy sets

Fuzzy logic is based on the theory of fuzzy sets, which is a generalization of the classical set theory. Saying that the theory of fuzzy sets is a generalization of the classical set theory means that the latter is a special case of fuzzy sets theory. To make a metaphor in set theory speaking, the classical set theory is a subset of the theory of fuzzy sets [5].

Membership function

A membership function describes the degree of membership of a value in a fuzzy set

The shape of the membership function is chosen arbitrarily by following the advice of the expert or by statistical studies: sigmoid, hyperbolic, tangent, exponential, Gaussian or any other form can be used.

Fuzzy Inference Systems

Fuzzy inference (reasoning) is the actual process of mapping from a given input to an output using fuzzy logic. The process involves all the pieces that we have discussed in the previous sections: membership functions, fuzzy logic operators, and if-then rules Fuzzy Inference Systems have been successfully applied in fields such as automatic control, data classification, decision analysis, expert systems, and computer vision. Because of its multi-disciplinary nature, the fuzzy inference system is known by a number of names, such as fuzzy-rule-based system, fuzzy expert system, fuzzy model, fuzzy associative memory, fuzzy logic controller, and simply fuzzy system

The steps of fuzzy reasoning (inference operations upon fuzzy IF–THEN rules) performed by FISs are:

1. Compare the input variables with the membership functions on the antecedent part to obtain the membership values of each linguistic label. (This step is often called (fuzzification)).

2. Combine (usually multiplication or min) the membership values on the premise part to get firing strength (deree of fullfillment) of each rule.

3. Generate the qualified consequents (either fuzzy or crisp) or each rule depending on the firing strength.

4. Aggregate the qualified consequents to produce a crisp output. (This step is called defuzzification.).

Fuzzy Inference Methods

The most important two types of fuzzy inference method are:

Mamdani and Sugeno fuzzy inference methods, Mamdani fuzzy inference is the most commonly seen inference method. This method was introduced by Mamdani and Assilian (1975). Another well-known inference method is the so- called Sugeno or Takagi–Sugeno–Kang method of fuzzy inference process. This method was introduced by Sugeno (1985). This method is also called as TS method. The main difference between the two methods lies in the consequent of fuzzy rules**.**

Mamdani Fuzzy models

To compute the output of this FIS given the inputs, six steps has to be followed

1. Determining a set of fuzzy rules

2. Fuzzifying the inputs using the input membership

3. Combining the fuzzified inputs according to the fuzzy rules to establish a rule strength (Fuzzy Operations)

4. Finding the consequence of the rule by combining the rule strength and the output membership function (implication)

5. Combining the consequences to get an output distribution (aggregation)

6. Defuzzifying the output distribution (this step is only if a crisp output (class) is needed).

Sugeno Fuzzy models:

Also known as TSK fuzzy model – Takagi, Sugeno & Kang • Goal: Generation of fuzzy rules from a given input-output data set.

3.4.3 Fuzzy Expert System

A fuzzy expert system is a form of artificial intelligence that uses a collection of membership functions (fuzzy logic) and rules (instead of Boolean logic) to reason about data.[4]

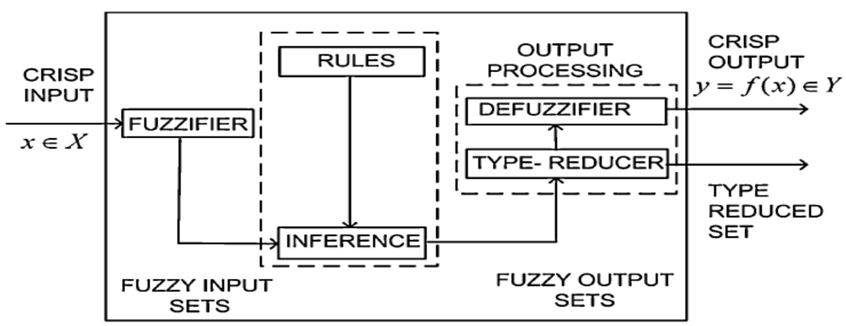


Figure 3.11 fuzzy logic[20]

Rules of Fuzzy Expert System

The rules in a fuzzy expert are usually of a form similar to this:

If X is low and Y is high then Z=medium

Where X and Y are input variables (names for noun date values), Z is an output variable (a name for a data value to be computed), low is a membership function (fuzzy subset) defined on X, high is a membership function defined on Z

3.4.4 Advantage and Disadvantages of fuzzy logic

Fuzzy logic is a solution to complex problems in all fields of life, including medicine as it resembles human reasoning and decision making it looks in to, all shades of gray and answers uncertainties and ambiguities created by human language where everything cannot be described in precise and discrete terms. Fuzzy systems help define disease extent and severity and answer questions related to individual patients taking into account their risk factors and co-morbidities.

On the other hands, it has a number of disadvantages too.it is tedious to develop fuzzy rules and membership functions and fuzzy outputs can be interpreted in a number of ways making analysis difficult. In addition, it requires lot of data and expertise to develop a fuzzy system, it does not give generalizable results and the program has to be run for each individual patient therefore, its clinical applicability and utilization is difficult without the availability of preprogrammed software for different pathologies and the basic training of clinicians to use these programs.[17]

Table 3.1Difference between conventional logic and fuzzy logic [6]

Boolean and conventional Logic	Fuzzy logic
Uses sharp distinction. Exp: max height for short = 170 cm. 170.5 cm is considered tall.	No distinct values. Exp: John is very tall.
Draw lines between members of a class and non-members.	Do not distinguish members of a class and non-members.
Can be absurd. Is 170cm really short?	Avoids absurdities. Reflects on how people think. Creates a model based on Sense of words. Decision making. Common sense.
Has only two values (0 or 1)	Has an extended range of value Between 0 and 1

Chapter four

Proposed system

4.1 Fuzzy Expert System designing

The most important application of fuzzy system (fuzzy logic) is in uncertain issues .when a problem has dynamic behavior, fuzzy logic is a suitable tool that deals with this problem. First step of fuzzy expert system designing is determination of input and output variables. There are' 14' input variables and '1' output variable. After that, we must design membership functions (MF) of all variables, these membership functions determine the membership of objects to fuzzy sets. At first, we will describe the input variables with their membership functions in second step, we introduce the output variable with is membership functions .In next chapter, we'll show the rules of system [6]

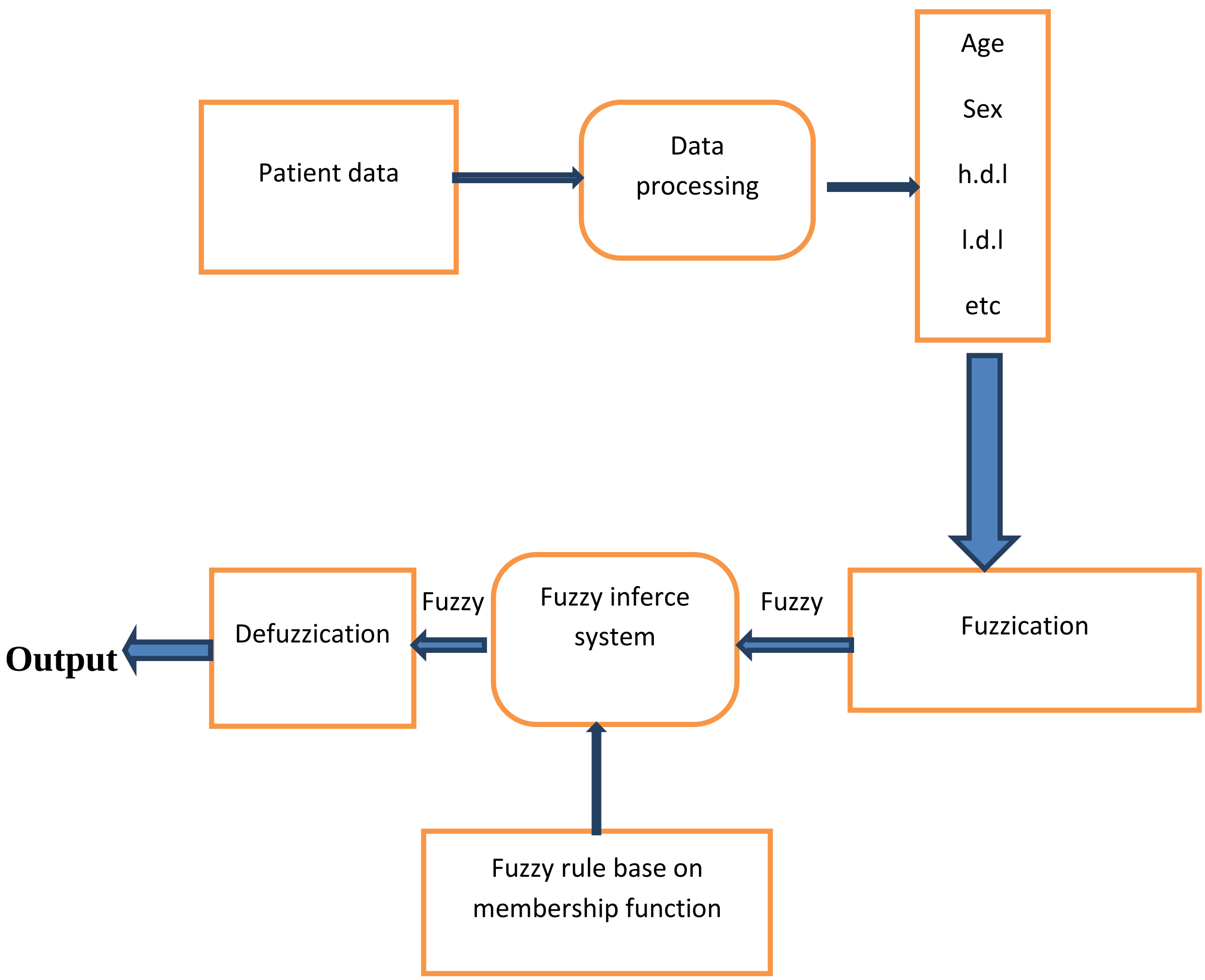


Figure 4.1 the fuzzy system[11]

4.2 Input variable are:

1-Blood pressure:

Different values of blood pressure change that result easily. In this field, we use systolic blood pressure. This input variable has divided to 4 fuzzy sets. Fuzzy sets are "LOW", "Medium", "High" and "Very high". Membership function of "LOW" and "Very high" sets are trapezoidal and membership functions of " medium" and "high" sets are triangular these fuzzy sets will be shown in Table1 . Membership function of blood pressure field will be shown in fig.2.

Table 4.1 Classification of systolic blood pressure

INPUT FIELD	RANGE	FUZZY SETS
Systolic Blood Pressure	<134 127-153 142-172 >154	Low Medium High Very high

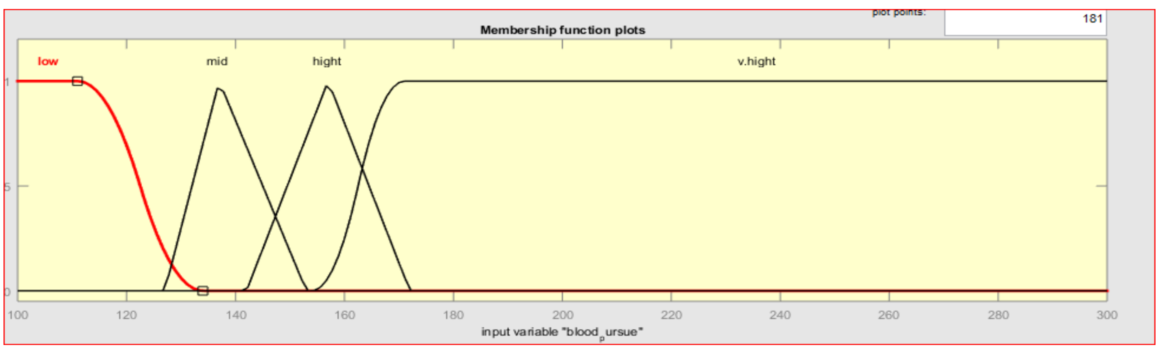


Figure 4.2 function of blood pressure

$$low\ (x) = \begin{Bmatrix} 1 & x < 111 \\ 134 - {}^{x}/_{23} & 111 \leq x < 134 \end{Bmatrix}$$

$$medium\ (x) = \begin{Bmatrix} \frac{(x-127)}{12} & 127 \leq x < 139 \\ 1 & x = 139 \\ 153 - {}^{x}/_{14} & 139 \leq x < 534 \end{Bmatrix}$$

$$\text{High}(x) = \begin{cases} (x-142)/15 & 142 \le x < 157 \\ 1 & x = 157 \\ (172-x)/15 & 157 \le x < 172 \end{cases}$$

$$v.high(x) = \begin{cases} x - 154/17 & 154 \le x < 171 \\ 1 & x \ge 171 \end{cases}$$

2- Low Density Lipoprotein (LDL) :

Cholesterol has salient effect on the result can change it easily. For this input field, we use the value of low density lipoprotein (LDL) cholesterol. Cholesterol field has 4 fuzzy sets (low, medium, high and very high) these fuzzy sets have been shown in table 2. Membership functions of “Low” and “very high” sets are trapezoidal and membership functions of “Medium” and “High” sets are triangular. Membership functions of cholesterol field will be shown in fig.3.

Table 4.2 classification of LDL cholesterol

INPUT FIELD	RANGE	FUZZY SETS
LDL	<197 188-250 217-307 281>	Low Medium High Very high

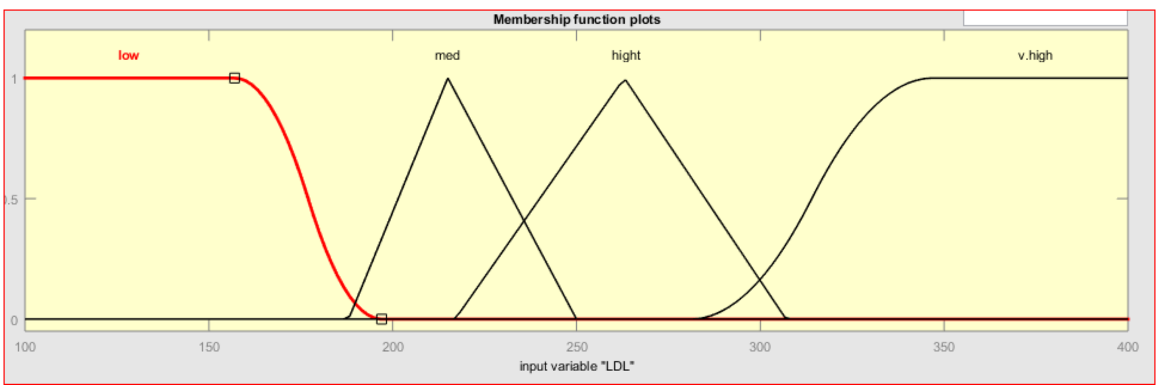


Figure 4.3 function of low density lipoprotein

$$\text{Low}(x) = \begin{cases} 1 & x < 151 \\ (197-x)/46 & 151 \le x < 197 \end{cases}$$

$$\text{Medium(x)} = \begin{Bmatrix} (x-188)/_{31} & 188 \le x < 219 \\ 1 & x = 219 \\ (250-x)/_{35} & 219 \le x < 250 \end{Bmatrix}$$

$$\text{High(x)} = \begin{Bmatrix} (x-217)/_{15} & 217 \le x < 263 \\ 1 & x = 263 \\ (307-x)/_{15} & 263 \le x < 307 \end{Bmatrix}$$

$$\text{Height(x)} = \begin{Bmatrix} (x-281)/_{66} & 281 \le x < 347 \\ 1 & x \ge 347 \end{Bmatrix}$$

3-High Density LipoproteinHDL:

Cholesterol has salient effect on the result can change it easily. For this input field, we use the value of high density lipoprotein (HDL) cholesterol. Cholesterol field has 3 fuzzy sets (very low, low and normal) these fuzzy sets have been shown in table '3'. Membership functions of "Very Low" and "Normal" sets are trapezoidal and membership functions of "low"" sets is triangular.

Table 4.3 classification of HDL cholesterol

INPUT FIELD	RANGE	FUZZY SETS
HDL	<30 30-50 >50	Very low Low Normal

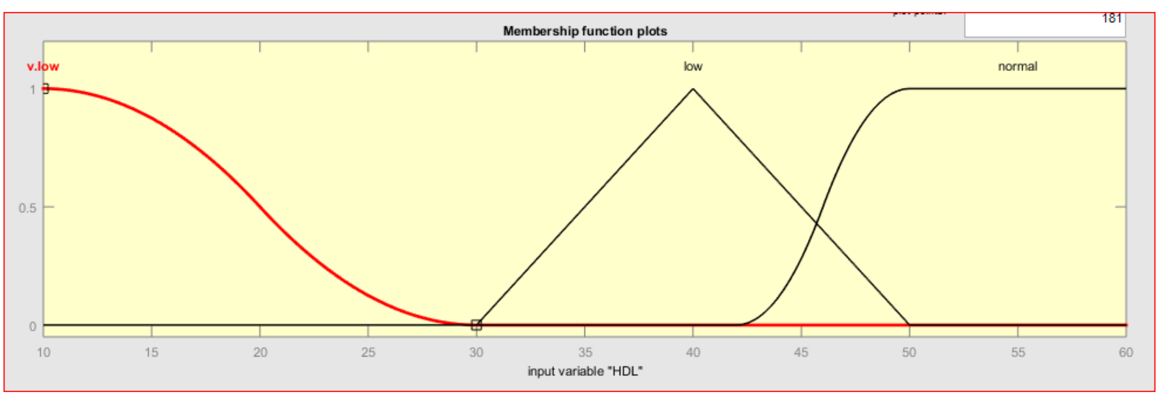


Figure 4.4 function of high density lipoprotein

$$\text{V.Low(x)} = \begin{Bmatrix} 1 & x < 13 \\ (30-x)/_{17} & 13 \le x < 30 \end{Bmatrix}$$

$$\text{Low(x)} = \begin{cases} (x-30)/_{10} & 30 \le x < 40 \\ 1 & x = 40 \\ (50-x)/_{10} & 40 < x \le 50 \end{cases}$$

$$\text{Normal} = \begin{cases} (x-43)/_{7} & 43 \le x < 50 \\ 1 & x \ge 50 \end{cases}$$

4-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 (>120) then man has blood sugar. fig 5 shows the membership function of blood sugar.

Table 4.4 classification of Diabetes

Input Field	Range	Linguistic Representation
Blood sugar	>=120 <120	(1) yes (0) NO

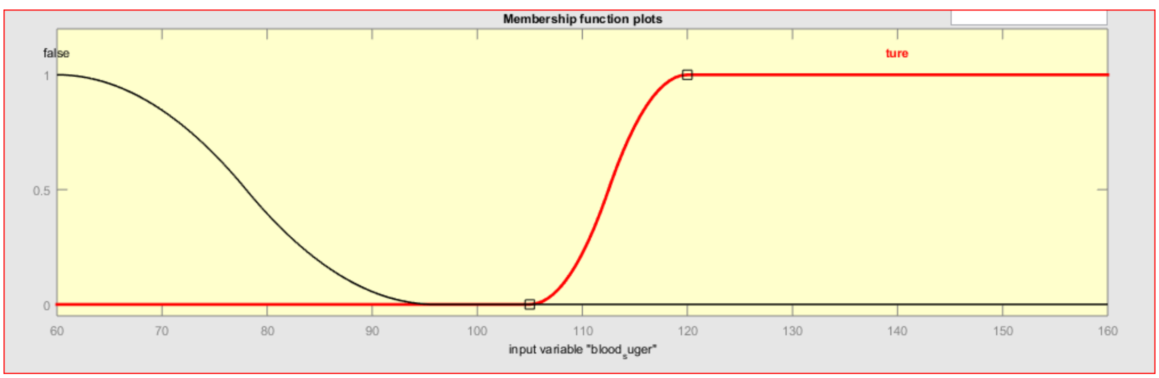


Figure 4.5 function of blood sugar

$$\text{True} = \begin{cases} (x-105)/_{15} & 105 \le x < 120 \\ 1 & x \ge 120 \end{cases}$$

$$\text{False} = \begin{cases} 1 & x < 60 \\ (100-x)/_{40} & 60 \le x < 100 \end{cases}$$

5-Resting Electrocardiography (ECG) :

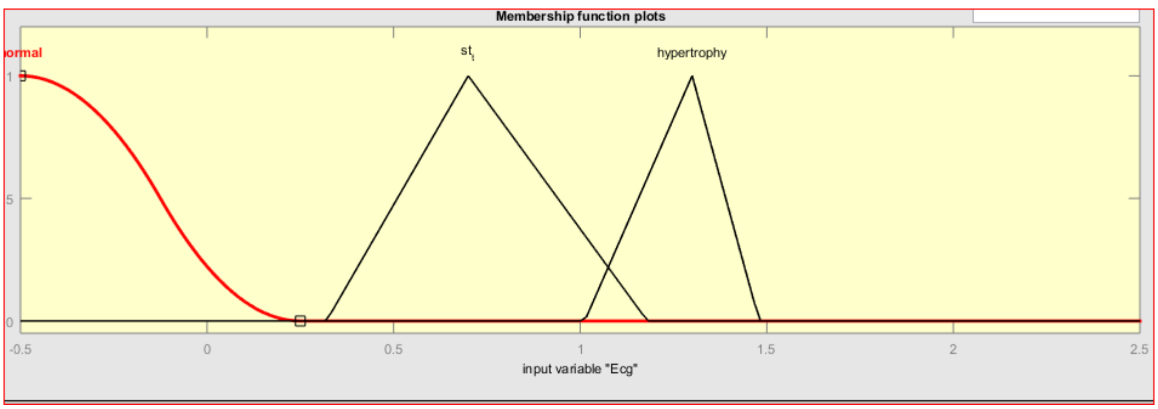
In this field, we have 3 fuzzy sets (Normal, ST_T abnorma1 and Hypertrophy) . Membership functions of “Normal” and “Hypertrophy” fuzzy sets are trapezoidal and membership function of “ST_T abnormal” fuzzy set is triangular. We see this membership in Fig 5. In Table4, We show fuzzy sets with their value. In this Table, “RANGE” column, we have defined a value for each fuzzy set in left side of each interval and we use just these values for system testing

Table 4.5 Classification of ECG

INPUT FIELD	RANGE	FUZZY SETS
Resting Electrocardiography (ECG)	(0) [-0.5,0.4] (1) [2.45,1.8] (2) [1.4,2.5]	Normal ST-T abnormal Hypertrophy

- ST_ T wave abnormality = T wave inversions and/or ST Elevation or depression of >0.05 mV .
- Hypertrophy = showing probable or definite left Ventricular hypertrophy by Estes’ criteria.

-



- Figure 4.6 function of ECG

- Normal= $\begin{cases} 1 & x < 0.4 \\ (0.4 - x)/_{0.9} & -0.5 \le x < 0.4 \end{cases}$

- ST-abnormal= $\begin{cases} (2.125 - x)/_{0.415} & 1.8 \le x < 2.125 \\ 1 & x = 2.125 \\ (x - 2.125)/_{0.325} & 2.125 \le x < 2.45 \end{cases}$

-

- Hypertrophy= $\begin{cases} (1.95 - x)/0.45 & 1.4 \le x < 1.95 \\ 1 & x = 1.95 \\ (x - 1.95)/_{0.55} & 1.95 \le x < 2.5 \end{cases}$

6- Maximum Heart Rate:

The value of this input field is maximum heart of man in 24 hour. By increasing of age in minimum, maximum of heart rate in 24hours decreases. In this field , we have 3 linguist variables (fuzzy sets) (Low , Medium and High) In tabl' 6' , we have defined these fuzzy sets Membership functions of "Low" and "High" fuzzy sets are trapezoidal and membership function of "Medium " fuzzy set is triangular that Will be shown in Fig . 7

Table 4.6 Classification of maximum heart rate

INPUT FIELD	RANGE	FUZZY SETS
Maximum Heart Rate	<141 194-111 152>	Low Medium High

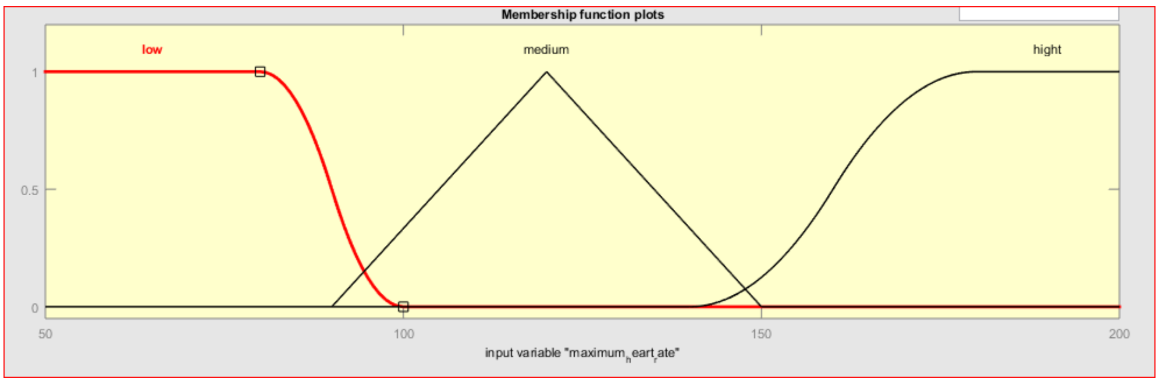


Figure4.7 Classification of maximum heart rate

$$\text{Low}=\begin{cases} 1 & x < 80 \\ 100 - x/20 & 80 \le x < 100 \end{cases}$$

$$\text{Medium}=\begin{cases} x - 90/30 & 90 \le x < 120 \\ 1 & x = 120 \\ 150 - x/30 & 120 \le x < 150 \end{cases}$$

$$\text{High}=\begin{cases} x - 140/40 & 140 \le x < 180 \\ 1 & x \ge 180 \end{cases}$$

7- Old Peak:

This input field means ST depression induced by exercise relative to rest Old peak field has 3 fuzzy sets (Low, Risk and Terrible). These fuzzy sets have been shown in table5 with their ranges.

Membership functions of " Low " and " Terrible " fuzzy sets are trapezoidal and membership function of "Risk" fuzzy set Old Peak is triangular that have been shown in Fig . 8.

Table 4.7 classification of Old peak

INPUT FIELD	RANGE	FUZZY SETS
Old Peak	<2 1.5-4.2 2.55>	Low Risk Terrible

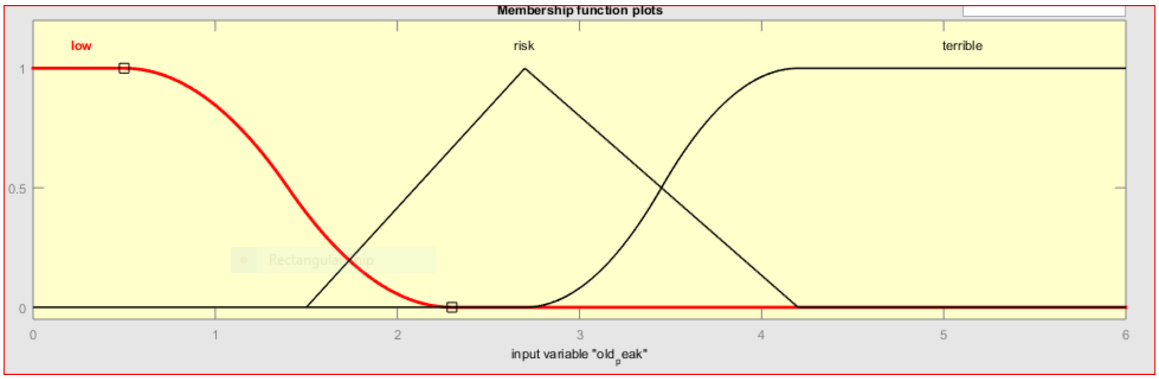


Figure 4.8 classification of Old peak

$$\text{Low}=\begin{Bmatrix} 1 & x < 1 \\ 2 - x/_1 & 1 \leq x < 2 \end{Bmatrix}$$

$$\text{Risk} =\begin{Bmatrix} (x-1.5)/_{1.3} & 1.5 \leq x < 2.8 \\ 1 & x = 2.8 \\ (4.2) - x/_{1.4} & 2.8 < x \leq 4.2 \end{Bmatrix}$$

$$\text{Terrible}=\begin{Bmatrix} (x-2.55)/_{1.45} & 2{,}55 \leq x < 4 \\ 1 & x \geq 4 \end{Bmatrix}$$

8-Age:

This input field divides to 4 fuzzy sets (Young, Mild, very old). These fuzzy sets with their ranges will be shown in table 7. Membership functions of " Young " and " very old " are trapezoidal and membership functions of " Mild " and " old " are triangular that have been shown in Fig . 9.

Table 4.8 classification of Age

INPUT FIELD	RANGE	FUZZY SETS
Age	<38 33-45 40-58 52>	Young Mild Old Very old

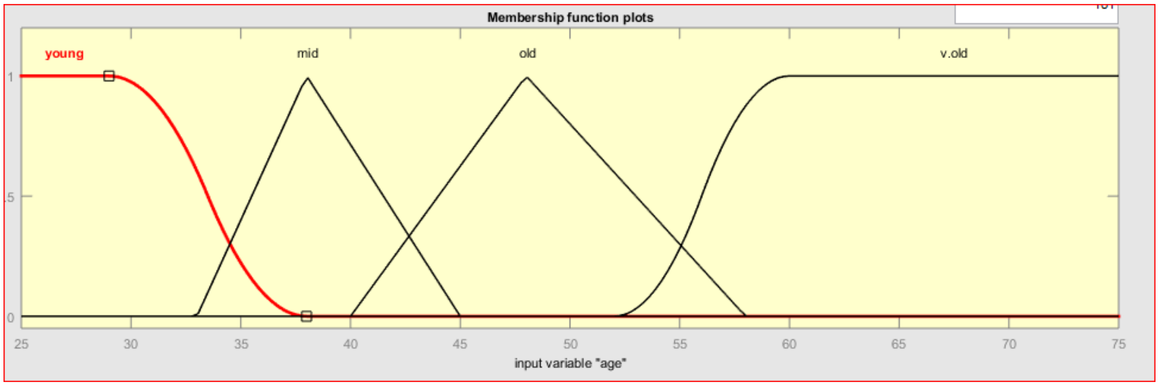


Figure 4.9 classification of Age

$$\text{Young}=\begin{cases} 1 & x < 25 \\ (38-x)/_{13} & 25 \le x < 38 \end{cases}$$

$$\text{Mild}=\begin{cases} (x-33)/_{7} & 33 \le x < 38 \\ 1 & x = 38 \\ (45-x)/_{7} & 38 \le x < 45 \end{cases}$$

$$\text{Old}=\begin{cases} (x-40)/_{9} & 40 \le x < 49 \\ 1 & x = 49 \\ (58-x)/_{9} & 49 \le x < 58 \end{cases}$$

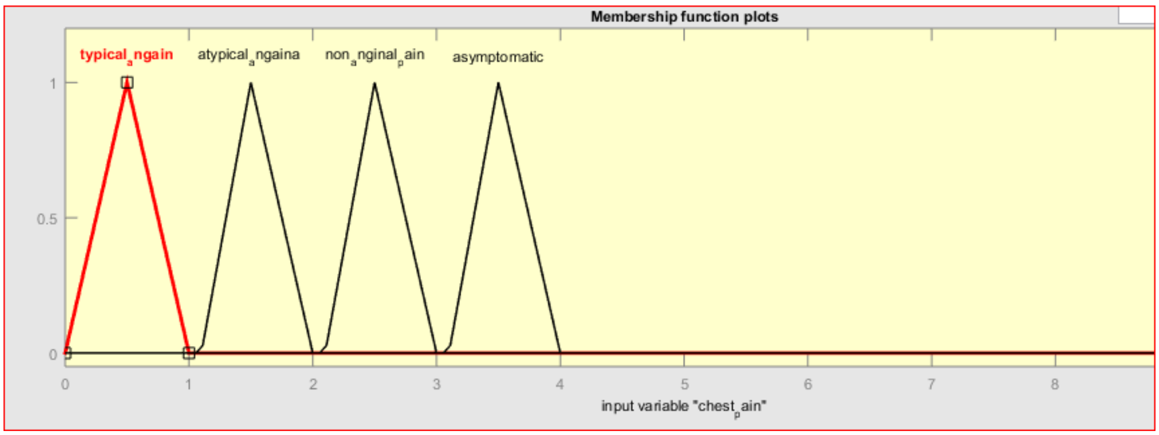
$$\text{v.old}=\begin{cases} (x-53)/_{6} & 53 \le x < 58 \\ 1 & x \ge 58 \end{cases}$$

9-Chest pain: This input variable supports 4 chest pain types. We have defined a value in this system for each chest pain type that we use these values for system testing. Each chest pain type is a fuzzy set. In this field, fuzzy sets do not have overlap and sets define in form of crisp because the patient has just one chest pain type on time. Chest pain types with their values have shown as follow

1=typical angina
2=atypical angina
3=non-anginal pain
4=asymptomatic

Table 4.9 classification of chest pain

Type of Chest pain	Value
Typical angina	1
Atypical angina	2
Non-anginal pain	3
Asymptomaic	4



$$\begin{cases} \mathbf{1} & \mathbf{0} \le \boldsymbol{x} \le \mathbf{1} \\ \mathbf{2} & \mathbf{1} < x \le 2 \\ \mathbf{3} & \mathbf{2} < x \le 3 \\ \mathbf{4} & \mathbf{3} < x \le 4 \end{cases}$$

10-Gender: This input field just has 2 values (1,0) and sets (Female, Male). Value' 0' means that patient is male and value; 1' means that patient is female.

Table 4.10 classification of gender

Gender	Value
Male	**0**
Female	**1**

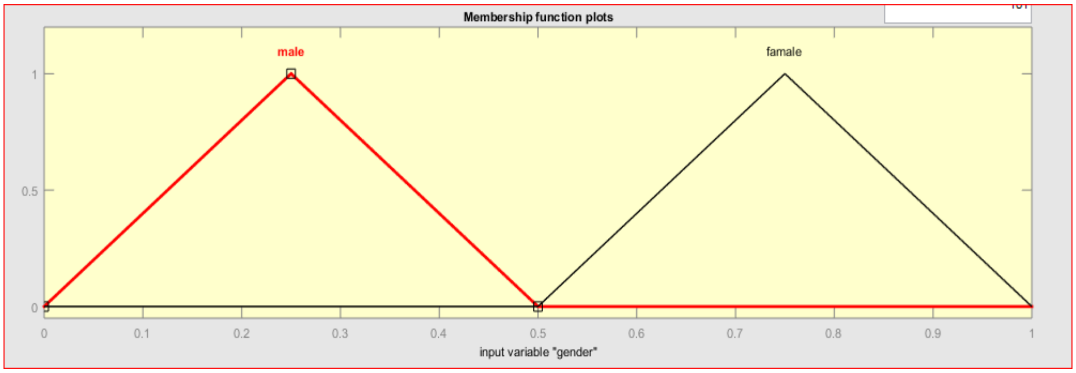


Figure 4.11 classification of gender

11-past history: This input field just has 2 values (0, 1) and sets (yes or no). Value' 0' means that patient hasn't past history in heart dieses and value '1' means that patient has past history in heart dieses

Table 4.11 classification of past history

Patient history	Value
Yes	**1**
No	**0**

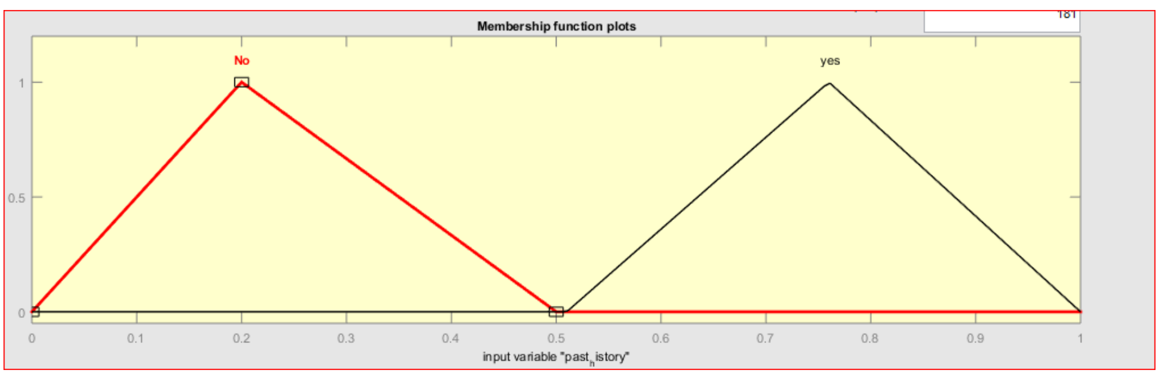


Figure 4.12 classification of past history

$$\begin{Bmatrix} \mathbf{0} & \mathbf{0} \leq \boldsymbol{x} \leq \mathbf{0.5} \\ \mathbf{1} & \mathbf{0.5} < x \leq 1 \end{Bmatrix}$$

12-smoking:

This input field just has 2 values (0, 1) and sets (yes or no). Value' 0' means that patient is not smoking and value '1' means that patient is smoking.

Table 4.12 classification of smoking

Smoking	Value
Yes	1
No	0

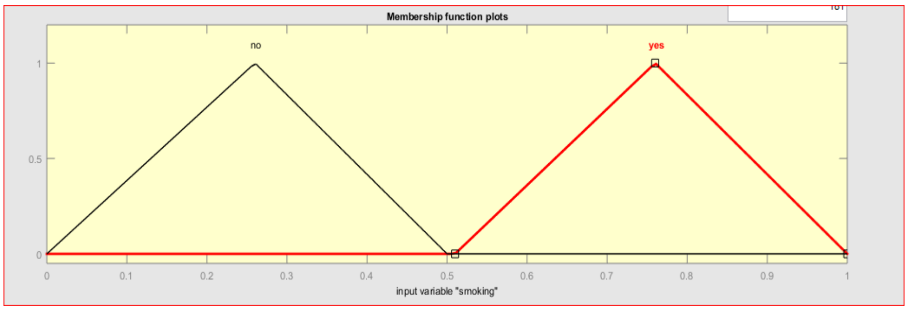


Figure 4.13 classification of smoking

$$\begin{Bmatrix} \mathbf{0} & \mathbf{0} \leq \boldsymbol{x} \leq \mathbf{0.5} \\ \mathbf{1} & \mathbf{0.5} < x \leq 1 \end{Bmatrix}$$

13-Excrsice:

This input field just has 2 values (0, 1) and sets (yes or no). Value' 0' means that patient is doing exercise and value '1' means that patient is not doing exercise.

Table 4.13 classification of past exercise

Exercise	Value
Yes	1
No	0

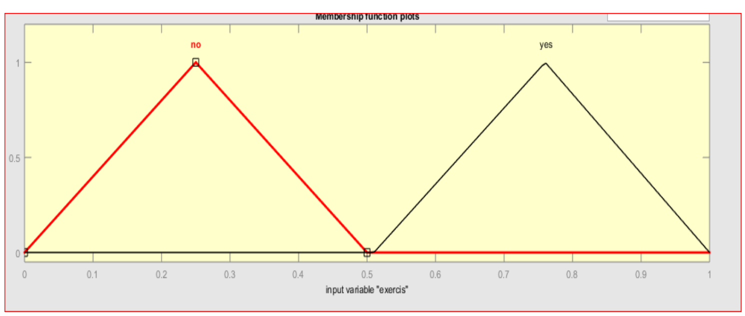


Table 4.14 classification of past exercise

$$\begin{Bmatrix} \mathbf{0} & \mathbf{0} \leq \boldsymbol{x} \leq \mathbf{0.5} \\ \mathbf{1} & \mathbf{0.5} < x \leq 1 \end{Bmatrix}$$

14-familly history:

This input field just has 2 values (0, 1) and sets (yes or no). Value' 0' means that patient has not a family history value '1' means that patient has a family history.

Table 4.14 classification of family history

Family history	Value
Yes	1
No	0

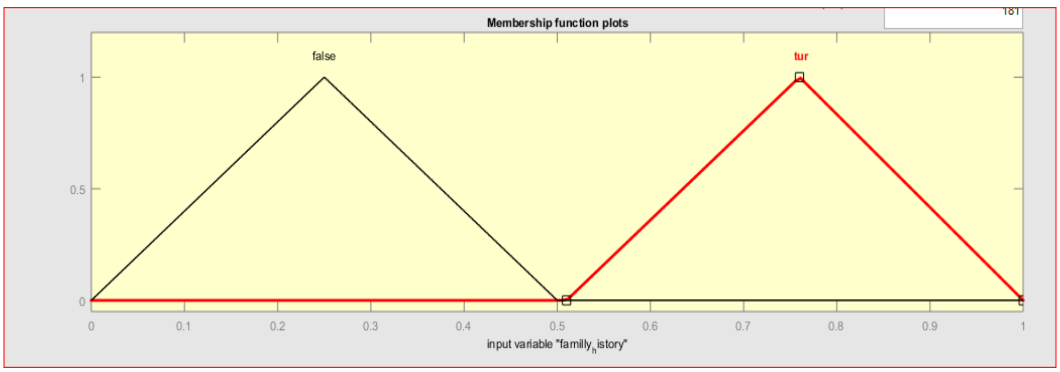


Figure 4.15 classification of family history

$$\begin{Bmatrix} \mathbf{0} & \mathbf{0} \leq \boldsymbol{x} \leq \mathbf{0.5} \\ \mathbf{1} & \mathbf{0.5} < x \leq 1 \end{Bmatrix}$$

4.3 Output Variable:

The "goal "field refers to the presence of heart disease in the patient It is integer value from 0 (no presence) to 4. BY increasing of integer value, heart disease risk increases in patient. In this system, we have considered a different output variable, which divides to 5 fuzzy sets (Healthy, sick (s1), Sick (s2) , sick (s3) , sick (s4)). Table 8 shows these fuzzy sets with their ranges Membership functions of" Healthy"

and "sick (s4) " fuzzy sets are trapezoidal and membership functions of " Sick (s1) " , " sick (s2) " , " sick (s3) " are triangular . These membership functions will be shown in Fig. 10.

Table 4.15 classification of output variable

INPUT FIELD	RANGE	FUZZY SETS
Result	<1.78 1-2.51 1.78-3.25 1.5-4.5 3.25>	Healthy Sick (s1) Sick (s2) Sick (s3) Sick (s4)

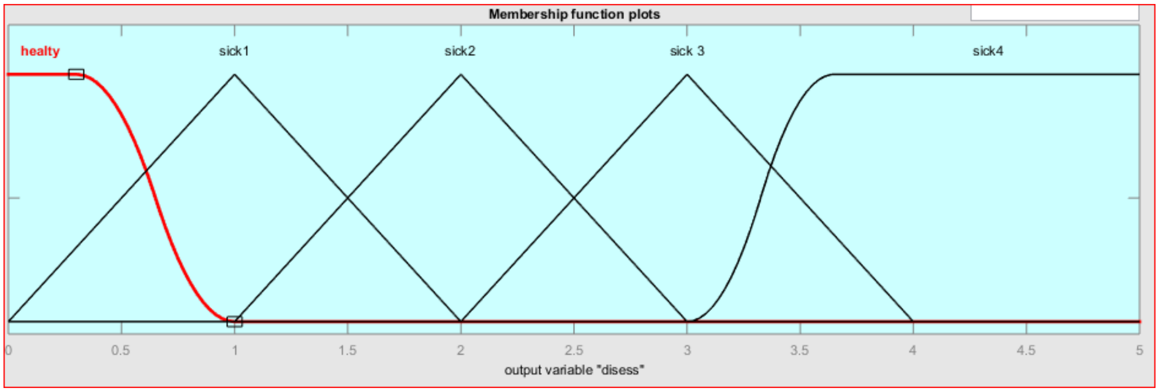


figure 4.16 classification of output variable

4.4 Fuzzy Rule Base

Rule base is the main part in fuzzy inference system and quality of results in a fuzzy system depends on the fuzzy rules .this system includes 67 rules the rules have been shown in Fig.

And the surface of system is show in fig

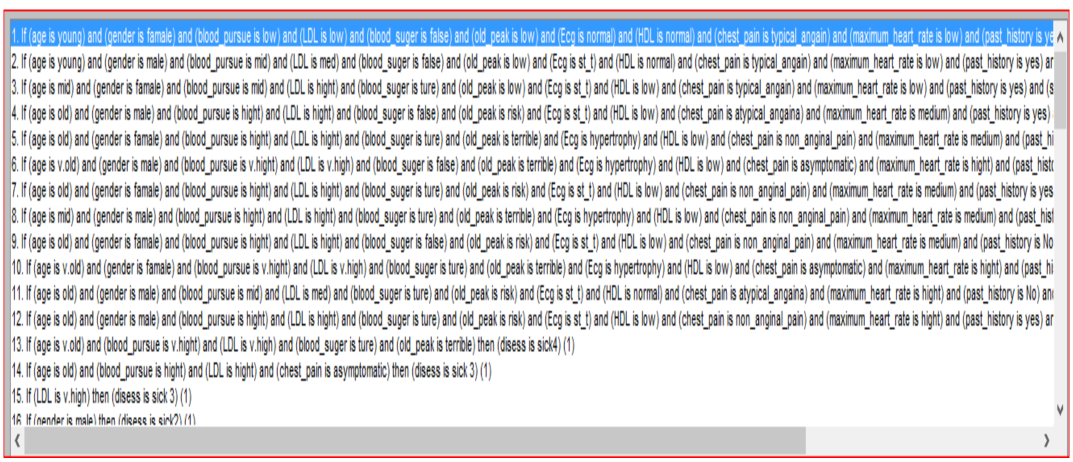


Figure 4.17 fuzzy rule

1. If (age is young) and (gender is famale) and (blood_pursue is low) and (LDL is low) and (blood_suger is false) and (old_peak is low) and (Ecg is normal) and (HDL is normal) and (chest_pain is typical_angain) and (maximum_heart_rate is low) and (past_history is ye
2. If (age is young) and (gender is male) and (blood_pursue is mid) and (LDL is med) and (blood_suger is false) and (old_peak is low) and (Ecg is st_t) and (HDL is normal) and (chest_pain is typical_angain) and (maximum_heart_rate is low) and (past_history is yes) ar
3. If (age is mid) and (gender is famale) and (blood_pursue is mid) and (LDL is hight) and (blood_suger is ture) and (old_peak is low) and (Ecg is st_t) and (HDL is low) and (chest_pain is typical_angain) and (maximum_heart_rate is low) and (past_history is yes) and (s
4. If (age is old) and (gender is male) and (blood_pursue is hight) and (LDL is hight) and (blood_suger is false) and (old_peak is risk) and (Ecg is st_t) and (HDL is low) and (chest_pain is atypical_angaina) and (maximum_heart_rate is medium) and (past_history is yes)
5. If (age is old) and (gender is famale) and (blood_pursue is hight) and (LDL is hight) and (blood_suger is ture) and (old_peak is terrible) and (Ecg is hypertrophy) and (HDL is low) and (chest_pain is non_anginal_pain) and (maximum_heart_rate is medium) and (past_hi
6. If (age is v.old) and (gender is male) and (blood_pursue is v.hight) and (LDL is v.high) and (blood_suger is false) and (old_peak is terrible) and (Ecg is hypertrophy) and (HDL is low) and (chest_pain is asymptomatic) and (maximum_heart_rate is hight) and (past_histo
7. If (age is old) and (gender is famale) and (blood_pursue is hight) and (LDL is hight) and (blood_suger is ture) and (old_peak is risk) and (Ecg is st_t) and (HDL is low) and (chest_pain is non_anginal_pain) and (maximum_heart_rate is medium) and (past_history is yes
8. If (age is mid) and (gender is male) and (blood_pursue is hight) and (LDL is hight) and (blood_suger is ture) and (old_peak is terrible) and (Ecg is hypertrophy) and (HDL is low) and (chest_pain is non_anginal_pain) and (maximum_heart_rate is medium) and (past_hist
9. If (age is old) and (gender is famale) and (blood_pursue is hight) and (LDL is hight) and (blood_suger is false) and (old_peak is risk) and (Ecg is st_t) and (HDL is low) and (chest_pain is non_anginal_pain) and (maximum_heart_rate is medium) and (past_history is No
10. If (age is v.old) and (gender is famale) and (blood_pursue is v.hight) and (LDL is v.high) and (blood_suger is ture) and (old_peak is terrible) and (Ecg is hypertrophy) and (HDL is low) and (chest_pain is asymptomatic) and (maximum_heart_rate is hight) and (past_hi
11. If (age is old) and (gender is male) and (blood_pursue is mid) and (LDL is med) and (blood_suger is ture) and (old_peak is risk) and (Ecg is st_t) and (HDL is normal) and (chest_pain is atypical_angaina) and (maximum_heart_rate is hight) and (past_history is No) and
12. If (age is old) and (gender is male) and (blood_pursue is hight) and (LDL is hight) and (blood_suger is ture) and (old_peak is risk) and (Ecg is st_t) and (HDL is low) and (chest_pain is non_anginal_pain) and (maximum_heart_rate is hight) and (past_history is yes) ar
13. If (age is v.old) and (blood_pursue is v.hight) and (LDL is v.high) and (blood_suger is ture) and (old_peak is terrible) then (disess is sick4) (1)
14. If (age is old) and (blood_pursue is hight) and (LDL is hight) and (chest_pain is asymptomatic) then (disess is sick 3) (1)
15. If (LDL is v.high) then (disess is sick 3) (1)
16. If (gender is male) then (disess is sick2) (1)

Figure 4.18 fuzzy rule

16. If (gender is male) then (disess is sick2) (1)
17. If (gender is famale) then (disess is sick 3) (1)
18. If (blood_pursue is low) then (disess is healty) (1)
19. If (blood_pursue is mid) then (disess is sick1) (1)
20. If (blood_pursue is hight) then (disess is sick2) (1)
21. If (blood_pursue is v.hight) then (disess is sick4) (1)
22. If (LDL is low) then (disess is healty) (1)
23. If (LDL is med) then (disess is sick1) (1)
24. If (LDL is hight) then (disess is sick2) (1)
25. If (LDL is hight) then (disess is sick 3) (1)
26. If (LDL is v.high) then (disess is sick4) (1)
27. If (gender is male) and (blood_suger is ture) then (disess is sick2) (1)
28. If (old_peak is low) then (disess is healty) (1)
29. If (old_peak is risk) then (disess is sick2) (1)
30. If (old_peak is terrible) then (disess is sick4) (1)
31. If (old_peak is risk) then (disess is sick 3) (1)

Figure 4.19 fuzzy rule

53. If (past_history is yes) and (smoking is yes) and (exercis is no) then (disess is sick1) (1)
54. If (gender is famale) and (blood_pursue is hight) then (disess is sick2) (1)
55. If (familly_history is tur) then (disess is sick2) (1)
56. If (age is old) and (familly_history is tur) then (disess is sick 3) (1)
57. If (gender is famale) and (familly_history is tur) then (disess is sick 3) (1)
58. If (blood_pursue is mid) and (smoking is yes) and (familly_history is tur) then (disess is sick 3) (1)
59. If (blood_pursue is mid) and (smoking is yes) and (exercis is no) and (familly_history is tur) then (disess is sick 3) (1)
60. If (blood_pursue is mid) and (smoking is yes) and (exercis is yes) and (familly_history is tur) then (disess is sick2) (1)
61. If (age is young) then (disess is healty) (1)
62. If (age is mid) then (disess is sick1) (1)
63. If (age is old) then (disess is sick2) (1)
64. If (age is old) then (disess is sick 3) (1)
65. If (age is v.old) then (disess is sick4) (1)
66. If (gender is male) then (disess is sick2) (1)
67. If (gender is famale) then (disess is sick 3) (1)
68. If (age is young) and (blood_pursue is low) and (old_peak is low) and (Ecg is normal) and (past_history is No) and (smoking is no) and (exercis is yes) and (familly_history is tur) then (disess is healty) (1)

Figure 4.20 fuzzy rule

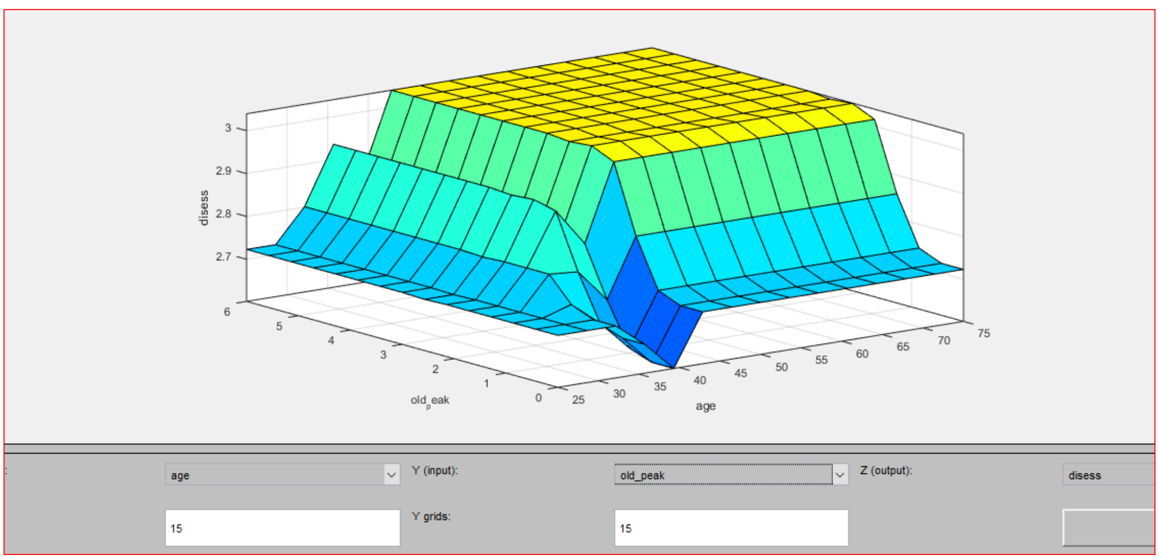


Figure 4.21 fuzzy surface

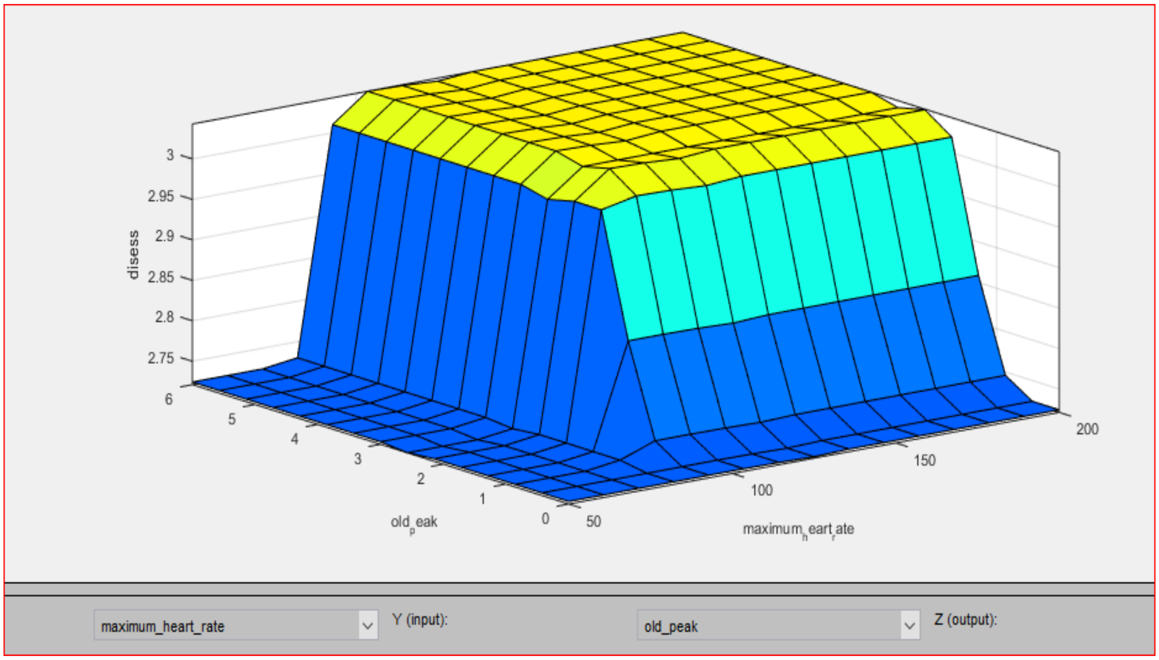


Figure 4.22 fuzzy surface

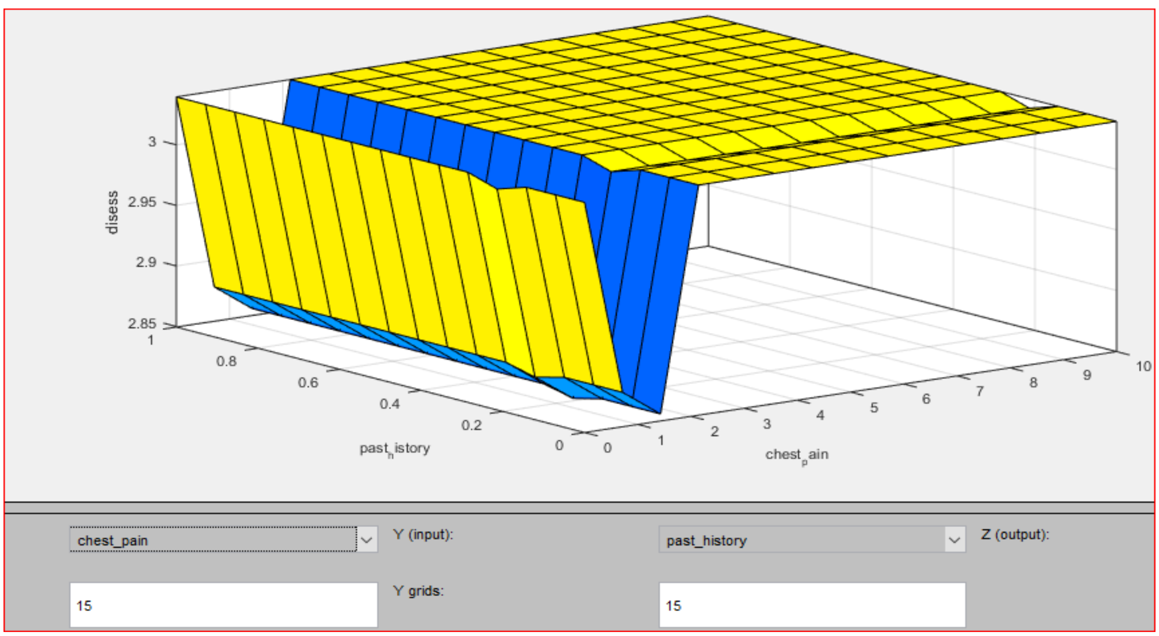


Figure 4.23 fuzzy surface

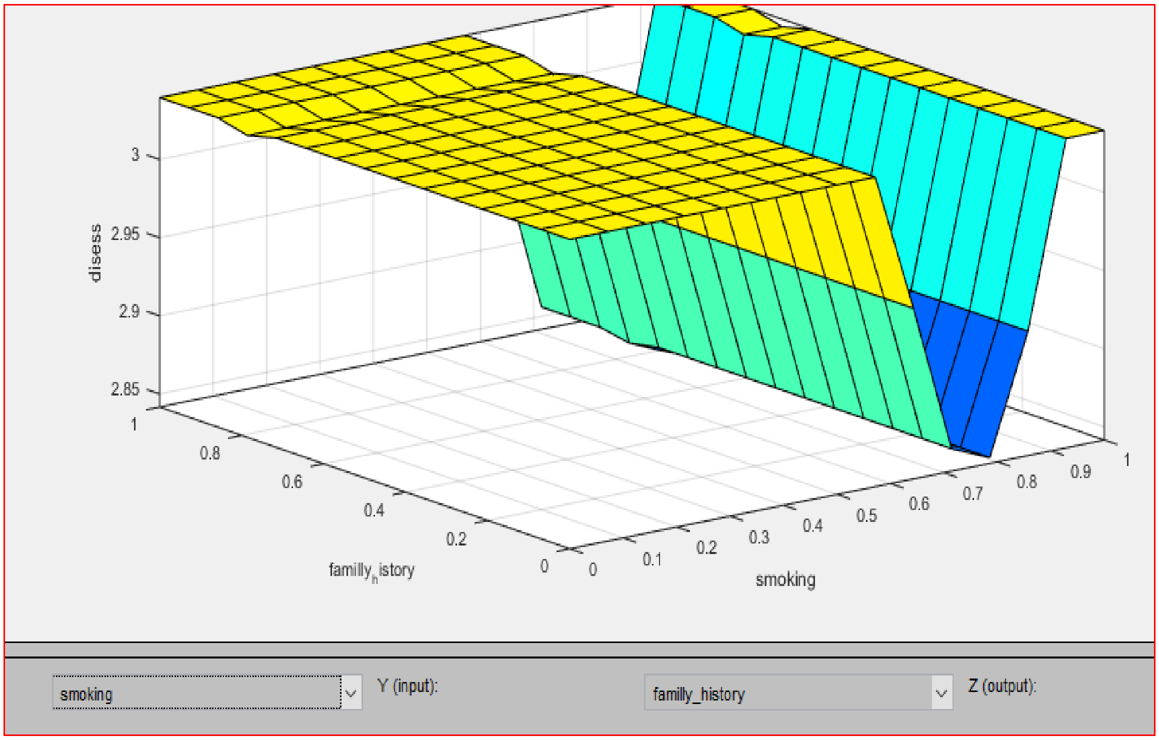


Figure 4.24 fuzzy surface

Chapter Five

Result and Discussion

5.1 Result

A data of 10 patients was collected from ALSHAHID FOUAD hospital .there diseases were diagnosed by both doctors and the fuzzy expert system. The results of both diagnoses are shown at table (5.1)

Table 5.1 the results of the diagnoses

NO	1	2	3	4	5	6	7	8	9	10
age	30	40	52	60	75	70	48	30	75	63
sex	M	F	F	M	M	M	F	M	F	M
LDL	100	230	189	281	132	150	328	300	200	180
B.B	140	133	190	130	220	200	197	184	150	143
HDL	54	45	34	55	42	28	38	49	43	37
Old Peak	0	0	2	2.88	1.87	6	3	2.43	2.8	0.66
ECG	-0.5	0.2	0.12	0.4	0.4	2.5	0.35	2.5	0.32	0.25
Past History	No	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes
Blood Suger	60	100	137	160	96	160	130	93	159	158
Family History	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Chest pain	angina	An angina	angina	Stable angina	angina	non-anginal pain	asymptomatic	stable angina	non-anginal pain	An angina
Smoking	Yes	No	No	Yes	Yes	No	No	Yes	No	Yes
exercise	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	No
Max Heart	75	123	88	174	145	107	190	90	190	78
Doctor	0	1	2	2	3	2	3	2	3	1
Sys.res	0.7	1.7	2.9	2.74	3.5	2.86	3.2	2.77	3.01	2.6

No	11	12	13	14	15	16	17	18	19	20
age	52	64	75	61	58	71	49	53	39	85
sex	F	M	M	F	M	F	M	M	F	M
LDL	233	370	204	294	254	202	197	285	248	256
B.B	147	163	142	134	155	157	178	220	150	140
HDL	40	51	49	38	48	54	47	50	48	37
Old Peak	2.3	0.5	1.4	1.9	3	1.7	3.7	2.8	2	0
ECG	2	0.92	0	1	1.3	2	-0.05	0.98	1.34	2
Past History	No	No	Yes	Yes	No	No	Yes	No	No	Yes
Blood Suger	120	155	90	112	89	118	100	120	98	120
Family History	No	Yes	No	Yes	No	No	Yes	Yes	Yes	No
Chest pain	**asymptomatic**	**angin**	**Stable angin**	**An angin**	**asymptomatic**	**An angin**	**Stable angin**	**An angin**	**angin**	**asymptomatic**
Smoking	No	No	Yes	Yes	No	No	Yes	Yes	No	No
exercise	Yes	No	No	No	No	No	No	No	Yes	No
Max Heart	150	106	186	178	208	114	187	165	148	111
Doctor	2	3	1	3	2	2	3	4	1	1
Sys.res	2.2	2.7	2.6	2.9	2.85	2.76	2.72	2.7	2.4	2.6

No		21	22	23	24	25	26	27	28	29
age		82	78	65	58	60	58	68	49	42
sex		F	F	F	M	M	M	F	M	F
LDL		190	270	209	248	270	222	201	176	268
B.B		189	176	139	169	201	207	170	240	180
HDL		46	30	61	47	50	57	49	59	69
Old Peak		1.7	2.7	0.76	3.6	1.8	3	2	1	0.89
ECG		1.67	0.87	-0.2	2	1.1	1.57	0.98	1.89	0.84
Past History		No	Yes	No	Yes	No	No	No	Yes	Yes
Blood Suger		134	129	118	130	110	113	129	93	173
Family History		No	Yes	No	Yes	No	No	Yes	Yes	No
Chest pain		An angin	asymptomatic	stable angin	asymptomatic	Anangin	Anangin	stable angin	An angin	angin
Smoking		No	No	No	No	No	No	Yes	Yes	No
exercise		No	Yes	No	Yes	No	Yes	No	Yes	No
Max Heart		180	158	186	123	156	148	177	152	190
Doctor		2	4	3	2	2	3	2	1	1
Sys.res		2	4	3	2	2.6	3	208	1	1

5.2 Discussion

The data of 10 patients was collected and there disease was diagnosed by a doctor and by a fuzzy expert system and the results obtained by the these two methods were compared and found that eight of the results were identical and of the result were different, and this difference was due to the fact that the fuzzy expert system depends on the rules must be included to in all the possibilities.

To calculate the accuracy the following rule is applied:

Accuracy = (Number of identical result / total number of results) x 100%

= (29/30) x 100%

= 97%

5.2 Table of Accuracy Comparison of Proposed System With Existing System:

Author/Date	**Method**	**Accurse**
Proposed system	Fuzzy expert system	97%
Smitha Sikua Suhil Sikuha MS AliDesign of Fuzzy Expert System for Diagnosis of Cardiac Disease(2012)	fuzzy expert system	90%
Novruz Alherdei Serrate Torun IsailSattas Design A fuzzy Expert for Determine of Coronary Disease Risk (2010).	Nero-fuzzy-network	88.65%
Rehana Parvin DrAbdoalzaraAbhareder Used Data Base for Heart Disease Base For Heart DiseaseDiagnoses Used Data Base for Heart Disease Diagnosis (2009).	fuzzy logic	87%
Yun-Chi Yeh, Wen-June Wang, and CheWunChiou Heartbeat Case Determination Using Fuzzy Logic Method on ECG Signals (2007).	fuzzy logic method	93.78%.
ArashKhormehr MSc student of Software Engineering Department of Computer Engineering Sanandaj Branch, Islamic Azad University, Sanandaj, Kurdistan, Iran Vafa Maihami Faculty member Department of Computer Engineering Sanandaj Branch, Islamic Azad University, A Novel Fuzzy Expert System Design for Predicting Heart Diseases(2013).	a fuzzy system a model	95%

A. M. Abushariah, Assal A. M. Alqudah, Omar Y. Adwan, Rana M. M. Yousef Automatic Heart Disease Diagnosis SystemBased on Artificial Neural Network(2014)	Neural Network	90.74 %for each system 87.04% respectively
Monish Kumar Choudhury1, NeelanjanaBaruah Fuzzy Logic Based Expert System for Determination of Healthy Risk Level Of patient (2015).	fuzzy expert system	88,97%
X.Y. Djam, and Y.H. Kimbi: Fuzzy Expert System for The Management of Hypertension (2011)	fuzzy expert system	90%
E.P.Ephzibah, Dr. V. Sundarapandian An International Journal (CSEIJ), Vol.2, No.1, February (2012)	Fuzzy rule based expert system and Neural networks	91.38%
Kemal polat,sahlihGunesDignosis of heart disease using artificial immune recognition system and fuzzy weighted preprocessing (2006)	Fuzzy Wight and neural network	92%

Chapter Six

Conclusion and Recommendation

6.1 Conclusion

The Heart disease is one of most important causes of deaths all over the world The detection of heart disease is more difficult because it is depending on human. To solve this problem fuzzy logic is used to build expert systems which include a many rules and membership function that determined patient case according to patient data.

This proposed system effective and it successfully tested in Elshahid Fouad hospital.

And the accuracy is increase compere to a priviouse system.

6.2 Recommendation

- Increase the number of data base to cover all the types of heart diseases
- Increase the rules to obtain more accurate results.
- Use graphical user interface to make the system easier in using for users.
- Add digital data to system to increase the accruy.

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