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SURVEY ARTICLE

Comparison of ANNs, Fuzzy Logic and Neuro-Fuzzy Integrated Approach for Diagnosis of Coronary Heart Disease: A Survey

Nitin Kumari[1], Sunita[2], Smita[3]

[1]M.Tech Student, CSE, PDM College of Engineering for Women, Bahadurgarh affiliated to M.D.U, Rohtak, India

[2]Assistant Professor, CSE, PDM College of Engineering for Women, Bahadurgarh affiliated to M.D.U, Rohtak, India

[3]Assistant Professor, CSE, PDM College of Engineering for Women, Bahadurgarh affiliated to M.D.U, Rohtak, India

[1] nitinyadav8914@yahoo.co.in; [2] bhardwajsunita23@gmail.com; [3] 26.smita@gmail.com

Abstract— Data mining is an art of searching large databases to discover useful patterns and trends that go beyond simple analysis. Data mining plays an important role in health care. Health care industry comprises of large amount of data which has to be refined in order to get useful information from it. In this paper, we compare three techniques for mining health care data to predict whether a person suffers from coronary heart disease or not. These techniques are: ANNs, fuzzy logic and neuro-fuzzy integrated approach. Although ANN and fuzzy logic have a lot of advantages but they have some disadvantages too. Neuro-fuzzy is a combination of advantages of ANN and fuzzy logic. By comparing all these techniques, we conclude that neuro-fuzzy integrated approach is the best among these three techniques for diagnosis of coronary heart disease.

Key Terms: - CHD; Heart disease; ANNs; Data mining; Fuzzy logic; Neuro-Fuzzy approach

I. INTRODUCTION

Data Mining is the science of finding patterns in huge reserves of data, in order to generate useful information from it. Data Mining has potential applications in several fields, not the least of which is Health Care. The myriad possibilities of improvement in Health Care through Data Mining only further justify the need to apply data mining principles to clinical data. However, prior to applying data mining techniques to garner information from data, the data has to be 'prepared' to ensure the veracity of the information obtained. 'Preparing' the data involves removal of incorrect information or 'noise' from the data and ensuring that the data mining principles are applied on real data [1].

The influence of data mining on the quality of Health Care cannot be understated. All Health Care organizations retain detailed and comprehensive records of patient data. Trends and patterns identified in these records can positively impact the quality of Health Care. The huge amounts of patient data, makes identification of these trends an arduous task. However data mining applications, built for this purpose, can make this very simple and produce efficient results. There have been several cases, where application of data mining techniques, have helped resolve a problem in the health industry.

A. Artificial Neural Networks (ANNs)

In machine learning and computational neuroscience, an artificial neural network, often just named a neural network, is a mathematical model inspired by biological neural networks. A neural network consists of an interconnected group of artificial neurons, and it processes information using a connectionist approach to computation. In most cases a neural network is an adaptive system changing its structure during a learning phase. Neural networks are used for modeling complex relationships between inputs and outputs or to find patterns in data [17]. An ANN is typically defined by three types of parameters:

- The interconnection pattern between different layers of neurons
- The learning process for updating the weights of the interconnections
- The activation function that converts a neuron's weighted input to its output activation [17].

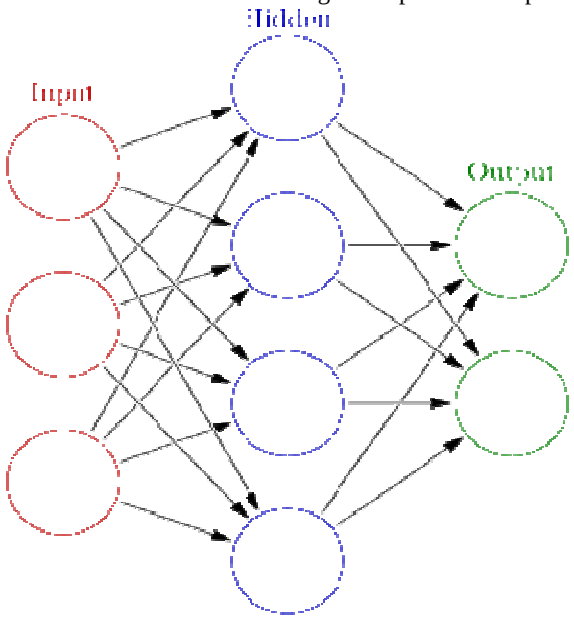

Fig. 1 A simple ANN with 3 input nodes, 4 hidden nodes and 2 output nodes

B. Fuzzy Logic

The term "**fuzzy logic**" was introduced with the 1965 proposal of fuzzy set theory by Lotfi A. Zadeh. Fuzzy logic is a form of many-valued logic or probabilistic logic; it deals with reasoning that is approximate rather than fixed and exact. Compared to traditional binary sets (where variables may take on true or false values) fuzzy logic variables may have a truth value that ranges in degree between 0 and 1. Fuzzy logic has been extended to handle the concept of partial truth, where the truth value may range between completely true and completely false. Furthermore, when linguistic variables are used, these degrees may be managed by specific functions [17]. The **membership function** of a fuzzy set is a generalization of the indicator function in classical sets. In fuzzy logic, it represents the degree of truth as an extension of valuation. For example membership function for temperature is given below:

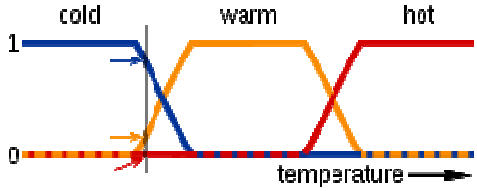

Fig. 2 Membership function for temperature [17]

C. Neuro-fuzzy Integrated Approach

In the field of artificial intelligence, **neuro-fuzzy** refers to combinations of artificial neural networks and fuzzy logic. Neuro-fuzzy was proposed by J. S. R. Jang. Neuro-fuzzy hybridization results in a hybrid intelligent system that synergizes these two techniques by combining the human-like reasoning style of fuzzy systems with the learning and connectionist structure of neural networks. Neuro-fuzzy hybridization is widely termed as Fuzzy Neural Network (FNN) or Neuro-Fuzzy System (NFS) in the literature. Neuro-fuzzy system (the more popular term is used henceforth) incorporates the human-like reasoning style of fuzzy systems through the use

of fuzzy sets and a linguistic model consisting of a set of IF-THEN fuzzy rules. The main strength of neuro-fuzzy systems is that they are universal approximators with the ability to solicit interpretable IF-THEN rules [17].

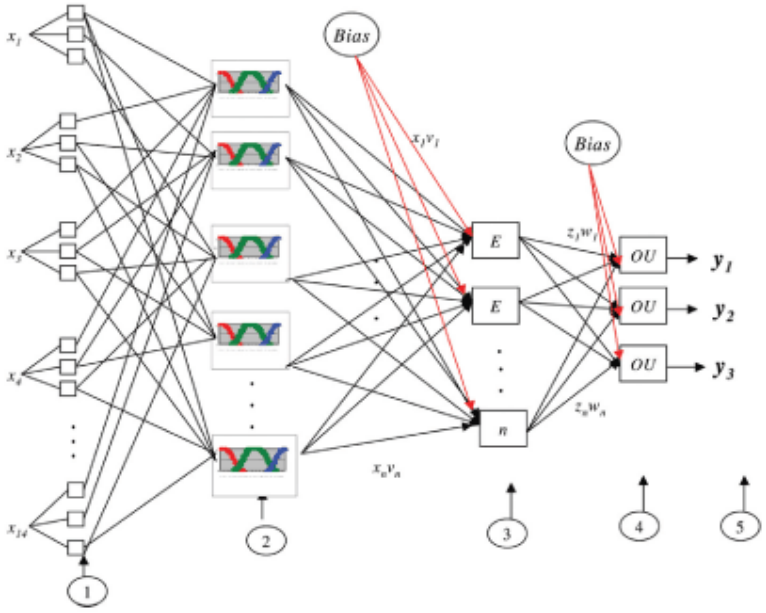

Fig. 3 A network of nodes using neuro-fuzzy integrated approach

D. Coronary Heart Disease

Coronary Heart Disease (CHD) occurs when plaque builds up inside the coronary arteries. These arteries supply heart muscle with oxygen-rich blood. Plaque is made up of fat, cholesterol, calcium, and other substances found in the blood. Over time, plaque hardens and narrows the arteries, reducing blood flow to your heart muscle. Eventually, an area of plaque can rupture, causing a blood clot to form on the surface of the plaque. If the clot becomes large enough, it can mostly or completely block the flow of oxygen-rich blood to the part of the heart muscle fed by the artery. This can lead to angina or a heart attack. Angina is chest pain or discomfort that occurs when not enough oxygen-rich blood is flowing to an area of your heart muscle. Angina may feel like pressure or squeezing in your chest. A heart attack occurs when blood flow to an area of your heart muscle is completely blocked. This prevents oxygen-rich blood from reaching that area of heart muscle, causing it to die. Without treatment, a heart attack can lead to serious problems or death [17].

II. LITERATURE SURVEY

Classification of Heart Disease Database using Multilayer Feed forward back propagation Algorithm[15].

In year 2013, Manjusha B. Wadhonkar proposed multilayer feed-forward network with Back-propagation algorithm for classification of heart disease. Artificial Neural Network (ANN) is widely used data mining method to extract patterns. Data mining is the process of automating information discovery .Its main aim is to find relationships in data and to predict outcomes. Classification is one of the important data mining techniques for classifying given set of input data. Many real world problems in various fields can be solved by using classification approach such as business, science, industry and medicine. For analysis the medical data related to Heart diseases is considered and analyzed using artificial neural network (ANN). To perform classification task of medical data, the neural network is trained using back propagation algorithm with momentum. To increase the efficiency of the classification process parallel processing approach is also applies on each neuron in different layers.

A Data Mining Approach for Prediction of Heart Disease using Neural Networks [14]. In year 2012, Chaitrali S. Dangare and Dr. Sulabha S. Apte proposed a Heart Disease Prediction system (HDPS) using Neural network. The HDPS system predicts the likelihood of patient getting a Heart disease. For prediction, the system uses sex, blood pressure, cholesterol like 13 medical parameters. Here two more parameters are added i.e. obesity and smoking for better accuracy. From the results, it has been seen that neural network predict heart disease with nearly 100% accuracy.

A Novel Approach for Heart Disease Diagnosis using Data Mining and Fuzzy Logic [12]. In year 2012, Nidhi Bhatla and Kiran Jyoti proposed an efficient heart disease diagnosis system. Cardiovascular disease is a term used to describe a variety of heart diseases, illnesses, and events that impact the heart and circulatory system. A clinician uses several sources of data and tests to make a diagnostic impression but it is not necessary that all the tests are useful for the diagnosis of a heart disease. The objective of our work is to reduce the number of attributes used in heart disease diagnosis that will automatically reduce the number of tests which are required to be taken by a patient. Our work also aims at increasing the efficiency of the proposed system. The observations illustrated that Decision Tree and Naive Bayes using fuzzy logic has outplayed over other data mining techniques.

Coronary heart disease diagnosis by artificial neural networks including genetic polymorphisms and clinical parameters [13]. In year 2012, Oleg Yu. Atkov develop an artificial neural networks-based (ANNs) diagnostic model for coronary heart disease (CHD) using a complex of traditional and genetic factors of this disease. The original database for ANNs included clinical, laboratory, functional, coronary angiographic, and genetic [single nucleotide polymorphisms (SNPs)] characteristics of 487 patients (327 with CHD caused by coronary atherosclerosis, 160 without CHD). By changing the types of ANN and the number of input factors applied, we created models that demonstrated 64–94% accuracy. The best accuracy was obtained with a neural networks topology of multilayer perceptron with two hidden layers for models included by both genetic and non-genetic CHD risk factors.

Automated Diagnosis of Coronary Heart Disease Using Neuro-Fuzzy Integrated System [11]. In year 2011, A.Q. Ansari and Neeraj Kumar Gupta presents neuro-fuzzy integrated system for coronary heart disease. Computational intelligence combines fuzzy systems, neural network and evolutionary computing. In order to show the effectiveness of the proposed system, Simulation for automated diagnosis is performed by using the realistic causes of coronary heart disease. The results suggest that this kind of hybrid system is suitable for the identification of patients with high/low cardiac risk.

Use of Modular Neural Network for Heart Disease [9]. In year 2010, Harsh Vazirani et. al. proposed a modular neural network for diagnosis of heart disease. The medical field is very versatile field and one of the interested research areas for the scientist. It deals with many medical disease problems starting with the diagnosis of the disease, preventing from the disease and treatment for the disease. There are various types of medical disease and accordingly various types of treatment methods. In this paper we mostly concern about the diagnosis of the heart disease. Mainly two types of the diagnosis method are used one is manual and other is automatic diagnosis which consists of diagnosis of disease with the help of intelligent expert system. In this paper the modular neural network is used to diagnosis the heart disease. The attributes are divided and given to the two neural network models Back-propagation Neural Network (BPNN) and Radial Basis Function Neural Network (RBFNN) for training and testing. The two integration techniques are used two integrate the results and provide the final training accuracy and testing accuracy. The modular neural network with probabilistic product method gave an accuracy of 87.02% over training data and 85.88% over testing accuracy and with probabilistic product method gave an accuracy of 89.72% over training data and 84.70% over testing accuracy, which was experimentally determined to be better than monolithic neural networks.

A Fuzzy Expert System for Heart Disease Diagnosis [10]. In year 2010, Ali.Adeli and Mehdi.Neshat proposed a Fuzzy Expert System for heart disease diagnosis. The designed system based on the V.A. Medical Center, Long Beach and Cleveland Clinic Foundation data base. The system has 13 input fields and one output field. Input fields are chest pain type, blood pressure, cholesterol, resting blood sugar, maximum heart rate, resting electrocardiography (ECG), exercise, old peak (ST depression induced by exercise relative to rest), thallium scan, sex and age. The output field refers to the presence of heart disease in the patient. It is integer valued from 0 (no presence) to 4 (distinguish presence (values 1, 2, 3, 4)). This system uses Mamdani inference method. The results obtained from designed system are compared with the data in upon database and observed results of designed system are correct in 94%. The system designed in Matlab software. The system can be viewed as an alternative for existing methods to distinguish of heart disease presence.

Automated diagnosis of coronary artery disease based on data mining and fuzzy modeling [7]. In year 2008, Tsipouras MG presents a fuzzy rule-based decision support system (DSS) for the diagnosis of coronary artery disease (CAD). The system is automatically generated from an initial annotated dataset, using a four stage methodology: 1) induction of a decision tree from the data; 2) extraction of a set of rules from the decision tree, in disjunctive normal form and formulation of a crisp model; 3) transformation of the crisp set of rules into a fuzzy model; and 4) optimization of the parameters of the fuzzy model. The dataset used for the DSS generation and evaluation consists of 199 subjects, each one characterized by 19 features, including demographic and history data, as well as laboratory examinations. Tenfold cross validation is employed, and the average sensitivity and specificity obtained is 62% and 54%, respectively, using the set of rules extracted from the decision tree (first and second stages), while the average sensitivity and specificity increase to 80% and 65%, respectively, when the fuzzification and optimization stages are used. The system offers several advantages

since it is automatically generated, it provides CAD diagnosis based on easily and noninvasively acquired features, and is able to provide interpretation for the decisions made.

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Using a Neurofuzzy Approach in a Medical Application [4]. In year 2007, Constantinos Koutsojannis and Ioannis Hatzilygeroudis states that hybrid computing is a popular framework for solving complex problems such as in medical domain. Hybrid intelligent systems are systems that combine two or more intelligent techniques. Medicine and health care are closely related domains, where the types of problems faced are suitable for application of hybrid intelligent techniques. In this paper we present the initial evaluation of FUzzy NEUrule System which is a Neuro Fuzzy approach based on fuzzy Adaline neurons and uses Differential Evolution for optimization of membership functions. According to our previous Neuro-fuzzy approaches and a well-defined hybrid system HYMES, FUNEUS is an attempt to the direction for integration of neural and fuzzy components with Differential evolution. Despite the fact that it remains difficult to compare neuro-fuzzy systems conceptually and evaluate their performance, early experimental results in a medical database proved a promising performance and the need for further evaluation in other medical applications.

Design of a Fuzzy Expert System for Determination of Coronary Heart Disease Risk [6]. In year 2007, Novruz Allahverdi, Serhat Torun and Ismail Saritas aimed to design a Fuzzy Expert System 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; (1) normal live; (2) diet; (3) drug treatment. The data (risk ratio) obtained from designed system are compared with the data in the literature [4] and better results are observed in the designed system. The system can be viewed as an alternative for existing methods to determine CHD risk.

Research on Diagnosing Coronary Heart Disease using Fuzzy Adaptive Resonance Theory Mapping Neural Networks [5]. In year 2007, Li Shi said that ST segment is the most important diagnostic parameter for finding coronary heart disease (CHD). Based on ST segment which has been extracted from electrocardiogram (ECG) data with wavelet transform, we investigated the classification of five different shapes of ST segment using fuzzy adaptive resonance theory mapping (ARTMAP) neural networks. The proposed method was demonstrated by the data from the standard MIT/BIH ECG database. The results show that fuzzy ARTMAP could be used to distinguish the shapes of ST segment successfully.

A Neuro-Fuzzy Approach to Classification of ECG Signals for Ischemic Heart Disease Diagnosis [3]. In year 2003, Victor-Emil Neagoe focuses on the neuro-fuzzy classifier called **Fuzzy-Gaussian Neural Network (FGNN)** to recognize the ECG signals for Ischemic Heart Disease (IHD) diagnosis. The proposed ECG processing cascade has two main stages: (a) Feature extraction from the QRST zone of ECG signals using either the Principal Component Analysis (PCA) or the Discrete Cosine Transform (DCT); (b) Pattern classification for IHD diagnosis using the FGNN. We have performed the software implementation and have experimented the proposed neuro-fuzzy model for IHD diagnosis. We have used an ECG database of 40 subjects , where 20 subjects are IHD patients and the other 20 are normal ones. The best performance has been of 100% IHD recognition score. The result is exciting as much as we have used only one lead (V5) of ECG records as input data, while the current diagnosis approaches require the set of 12 lead ECG signals.

Radial basis function neural network approach for the diagnosis of coronary artery disease based on the standard electrocardiogram exercise test [2]. In year 2001, Dr. K. Lewnstein proposed a radial basis function neural network as a tool for computer aided coronary artery disease diagnosis based on the results of the traditional ECG exercise test. The research was performed using 776 data records from an exercise test (297 records from healthy patients and 479 from ill patients) confirmed by coronary arteriography results. Each record described the state of the patient, provided input data for the neural network, included the level and slope of an ST segment of a 12-lead ECG signal made at rest and after effort, heart rate, blood pressure, load during the test, and occurrence of coronary pain, coronary arteriography, correct output pattern for the neural network, and verified the existence (or not) of more than 50% stenosis of the particular coronary vessels. Radial basis function neural networks for coronary artery disease diagnosis were optimised by choosing the type of radial

function, the method of training (setting the number of centres and their dimensions), and regularisation. The best network correctly recognised over 97% of cases from a 400-element test set, diagnosing not only the patients' condition (simple 'sane-sick' diagnosis), but also pointing out individual sick/stenosed vessels.

III. COMPARISON OF ANN, FUZZY LOGIC AND NEURO-FUZZY INTEGRATED APPROACH

A. Artificial Neural Network

1) Advantages

- *Adaptive learning:* An ability to learn how to do tasks based on the data given for training or initial experience.
- *Self-Organization:* An ANN can create its own organization or representation of the information it receives during learning time.
- *Real Time Operation:* ANN computations may be carried out in parallel, and special hardware devices are being designed and manufactured which take advantage of this capability.
- *Fault Tolerance via Redundant Information Coding***:** Partial destruction of a network leads to the corresponding degradation of performance. However, some network capabilities may be retained even with major network damage [5].

2) Disadvantages

- Neural networks can be used only if training data is available. It is not necessary to have a mathematical model of the problem of interest, and there is no need to provide any form of prior knowledge.
- The solution obtained from the learning process usually cannot be interpreted.
- Most neural network architectures are black boxes. They cannot be checked whether their solution is plausible, i.e. their final state cannot be interpreted in terms of rules.
- A neural network usually cannot be initialized with prior knowledge if it is available, and thus the network must learn from scratch.
- The learning process itself can take very long, and there is usually no guarantee of success.

B. Fuzzy Logic

1) Advantages

- An intelligent approach with simplicity.
- Easy to understand and implement.
- Provide the user friendly approach of presentation.
- Ease of implementation.
- Provide more "user-friendly" and efficient performance.

2) Disadvantages

- Hard to develop a model from a fuzzy system
- Require more fine tuning and simulation before operational
- Problems of finding suitable membership values for fuzzy systems
- A fuzzy system can be used to solve a problem if knowledge about the solution is available in the form of linguistic if-then rules.
-

C. Neuro-Fuzzy integrated Approch

Neuro-Fuzzy computing which is judicious integration of the merits of neural and fuzzy logic, enables one to build more intelligent decision-making systems. This incorporates the generic advantages of artificial neural networks like massive parallelism, robustness, and learning in data-rich environments into the system. The modeling of imprecise and qualitative knowledge as well as the transmission of uncertainty is possible through the use of fuzzy logic. Besides these generic advantages, the neuro-fuzzy approach also provides the corresponding application specific merits. A notable contribution of neuro-fuzzy and soft computing is the exposure of adaptive neuro-fuzzy inference systems developed by Jang [11].

The basic idea of combining fuzzy systems and neural networks is to design an architecture that uses a fuzzy system to represent knowledge in an interpretable manner and the learning ability of a neural network to optimize its parameters. The drawbacks of both of the individual approaches - the black box behavior of neural networks, and the problems of finding suitable membership values for fuzzy systems - could thus be avoided. A combination can constitute an interpretable model that is capable of learning and can use problem-specific prior knowledge. Therefore, neuro-fuzzy methods are especially suited for applications, where user interaction in model design or interpretation is desired [19].

IV. CORONARY HEART DISEASE

Coronary Heart Disease (CHD) occurs when plaque builds up inside the coronary arteries. These arteries supply heart muscle with oxygen-rich blood. Plaque is made up of fat, cholesterol, calcium, and other substances found in the blood. This can lead to angina or a heart attack. A heart attack occurs when blood flow to an area of the heart muscle is completely blocked. This prevents oxygen-rich blood from reaching that area of heart muscle, causing it to die. Without treatment, a heart attack can lead to serious problems or death. Figure 4 shows the formation of Plaque inside coronary arteries.

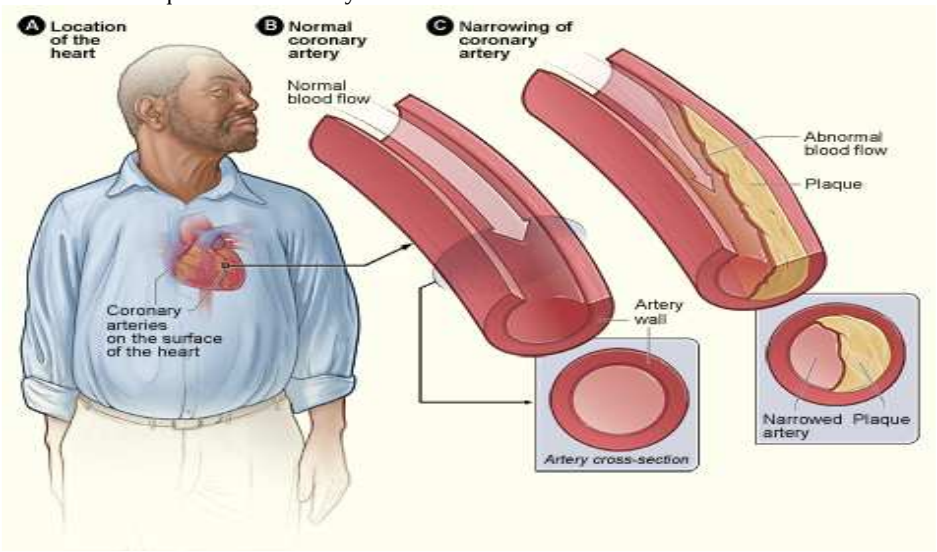

Fig. 4 Formation of Plaque inside Coronary Arteries [18]

A. Risk Factors

Following are the risk factors for coronary heart disease [16]:

1) *Age:* Simply getting older increases your risk of damaged and narrowed arteries.
2) *Sex:* Men are generally at greater risk of coronary artery disease. However, the risk for women increases after menopause.
3) *Family history***:** A family history of heart disease is associated with a higher risk of coronary artery disease, especially if a close relative developed heart disease at an early age. Your risk is highest if your father or a brother was diagnosed with heart disease before age 55, or your mother or a sister developed it before age 65.
4) *Smoking:* Nicotine constricts your blood vessels, and carbon monoxide can damage their inner lining, making them more susceptible to atherosclerosis. The incidence of heart attack in women who smoke at least 20 cigarettes a day is six times that of women who've never smoked. For men who smoke, the incidence is triple that of nonsmokers.
5) *High blood pressure:* Uncontrolled high blood pressure can result in hardening and thickening of your arteries, narrowing the channel through which blood can flow.
6) *High blood cholesterol levels:* High levels of cholesterol in your blood can increase the risk of formation of plaques and atherosclerosis. High cholesterol can be caused by a high level of low-density lipoprotein (LDL), known as the "bad" cholesterol. A low level of high-density lipoprotein (HDL), known as the "good" cholesterol, also can promote atherosclerosis.
7) *Diabetes:* Diabetes is associated with an increased risk of coronary artery disease. Both conditions share similar risk factors, such as obesity and high blood pressure.
8) *Obesity:* Excess weight typically worsens other risk factors.
9) *Physical inactivity: Lack* of exercise also is associated with coronary artery disease and some of its risk factors, as well.
10) *High stress:* Unrelieved stress in your life may damage your arteries as well as worsen other risk factors for coronary artery disease.

B. Diagnosis

There are three soft computing techniques which can be used for the diagnosis of coronary heart disease. These are:

- Artificial Neural Network
- Fuzzy Logic

- Neuro-Fuzzy integrated approach

Out of these three, Neuro-Fuzzy integrated approach is the best one for diagnosis of coronary heart disease. This is because neuro-fuzzy integrated approach combines the advantages of both artificial neural network and fuzzy logic.

In this approach, neural network will be first trained with training dataset and then tested with testing dataset. After that, fuzzy logic will be used to predict the disease chances with the help of membership function and linguistic variables.

V. CONCLUSION

We have presented a survey on diagnosis of coronary heart disease using ANN, fuzzy logic and neuro-fuzzy integrated approach. All these techniques are compared to find out which one is better among the three. It has been found that although ANN and fuzzy logic have a lot of advantages but these techniques have some disadvantages too. Neuro-fuzzy approach is the combination of ANN and fuzzy logic. It comprises of advantages of both ANN and fuzzy logic. Advantages of artificial neural networks include massive parallelism, robustness, and learning in data-rich environment. The modeling of imprecise and qualitative knowledge as well as the transmission of uncertainty is possible through the use of fuzzy logic. So, neuro-fuzzy integrated approach is the best one for diagnosis of coronary heart disease.

This paper presents a survey on diagnosis of coronary heart disease diagnosis using three soft computing techniques. This paper will provide roadmap for researchers seeking to understand existing techniques for diagnosis of coronary heart disease and which one is better.

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