Artificial Intelligence Model for Earlier Prediction of Cardiac Functionalities Using Multilayer Perceptron

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Abstract—Cardiovascular Disease is the silent killer and it is one of the leading cause for global death annually. The percentage of premature death varies from 7% in high-income countries and 43% in low-income countries. It is mainly due to lifestyle changing factors such as obesity, diabetes, etc. While working to reduce earlier deaths, it is revealed, how important the earlier prediction of heart disease is. In the medical field, diagnosing heart disease earlier is a difficult task for medical practitioner since it depends on combining clinical and pathological data. The purpose of this paper is to implement a medical prediction support system for predicting cardiac disease. Deep learning approach based computational model is designed for diagnosis. This proposed system has three main steps. First, a dataset with 13 attributes (13 clinical features) from the website is collected. Second, the datasets are trained using an algorithm called artificial neural network with backpropagation technique. It can have one or more hidden layers in order to get higher accuracy. Finally, Cardiac Function Prediction System (CFPS) which is an interactive GUI is developed, where the user can enter the clinical features and get to know the current status of a patient’s health. This system enhances medical care and reduces the treatment cost. This system will act as a promising tool for the medical practitioner for proper diagnosis.

Keywords—Cardiovascular disease, earlier diagnosis, Artificial Neural Network (ANN), Cardiac Function Prediction System (CFPS).

1. INTRODUCTION

Health is utterly about physical strength and mental strength not only the absence of disease. In the modern world, people are affected by non-communicable diseases which increase the mortal rate. Among the non-communicable disease, cardiac disease is the main reason account for earlier death in today’s world. Based on the statistics given by the American Health Association (AHA), one out of four deaths is due to CVD (Cardiovascular Disease). According to the World Health Organization (WHO), 12 millions of people could die every year due to cardiac disease, and nearly 40% of the total population suffer from this disease. If it could be predicted before, lots of death would be controlled. So, immediate action is required for health care. Health care systems have to be designed in order to improve their health.

At the age of above 35, CVD is the common problem that can be seen in both male and female. It is mainly due to lifestyle changing factors such as smoking, alcohol, obesity, diabetes, high blood pressure, cholesterol level, etc. Recent research in the medical field proved that these risk factors are the only reason to a heart attack [6]. The heart attack is the number one killer disease which occurs when the supply of blood to the heart is blocked. It impairs the capability to fill or eject blood from the ventricle and it affects the heart functioning system. If the pumping of blood to the heart is improper, then the organs like kidneys, eyes, and brain will suffer and if the heart stops its
working, within a fraction of minute’s death occurs.

It is very important to predict when the person is at high risk. Medical diagnosis is an important task that has to be carried out well effectively and precisely. Automation of the same is much needed that would help physicians for better diagnosing, since human intelligence may give false presumptions and unpredictable results. This automation not only helps Physicians but also it gives warning to patients about his physical health whether he has to go for a medical checkup or not. So, analyzing a disease plays a major role in the healthcare industry. A hospital can have a huge database which contains the patient's details and have a bulk of hidden information and knowledge remains unexplored.

For the prediction of a disease from the collected data, a deep learning approach can be applied. It is simply defined as exploring the hidden information available in the dataset and the knowledge obtained should be new and it must be able to use by others [15]. Deep learning technique has many methods that transform a large dataset into useful information. This technique can be applied for knowledge discovery, knowledge application and knowledge-based prediction. The prediction is done mainly based on the trained data. The dataset can be trained using Artificial Neural Network with Backpropagation technique. It is designed using multilayer perceptron which is a basic processing unit and it can able to solve nonlinear problems, whereas single perceptron solves only linear problems. In the healthcare industry, deep learning plays a major role in prediction.

The organization of the paper is as follows: In the second section, related works to this paper and their comparison are discussed. The dataset used, data preprocessing techniques and the algorithm are discussed in the third section. Collection of real-time data followed by architecture and implementation are discussed in the fourth, fifth and sixth section. A conclusion is given in the last section. And finally, references are included.

### 2. LITERATURE SURVEY

Heart Disease Prediction System [34] was developed using artificial neural network backpropagation algorithm. The dataset has 13 clinical features and 303 instances collected from Cleveland database that can be used as input data. Training was done using backpropagation technique. Input layer contains 13 neurons and a hidden layer has 3 neurons at the starting stage. And it can be increased up to 13 neurons. And finally, the output layer contains 2 neurons. After the training process is done, accuracy, recall, and precision are calculated. While increasing the number of hidden layers, the recall, precision, and accuracy are increased proportionally [34]. Another study on prediction system [2] has been proposed and implemented using learning vector Quantization Algorithm which is one of the artificial neural network learning technique. The dataset was collected from the UCI repository. It has 14 clinical features and 303 instances. This dataset is trained using an algorithm. The front end was designed and it has three panels [2]. First one is a data input panel for entering patient’s data, then ROC curve display section and finally performance display section. Sensitivity, Accuracy, and specificity were also calculated. This prediction system got the accuracy of about near 80%[2].

For predicting heart disease, the author Syed Umar Amin, Kavita Agarwal and Rizwan Beg used two algorithms: neural network and Genetic algorithms [39]. The risk factors related to heart disease involved are age, blood cholesterol, person's fitness, blood pressure, stress and etc. The dataset has been collected from the database which has these risk factors as an attribute. The dataset is split into training and testing data [39]. The model is trained using the neural network and genetic algorithm, implemented in MATLAB GUI and the resulting model gets an accuracy of about 89%. Heart Attack Prediction System [31] was proposed using deep learning algorithm called Cascaded Neural Network. It is a self-organized one. Here the dataset is collected from the UCI machine learning repository which has a patient’s medical record. It contains 76 attributes about 270 patients, but only 13 attributes were chosen by using feature selection technique. Cleaning and filtering were done in order to remove the noise and many duplicate records[31]. From 270 records, 120 were used to test
the data and 150 were used as a train the data. Then the attributes are classified using Cascaded Neural Network. In the classification stage, the algorithm classifies the data into two, whether the patient is having a disease or not. The result of this system was getting an accuracy of about 84%.

Jayshri S. Sonawane and D.R. Patil [12] came up with another methodology for heart disease prediction. The network was trained using the technique called Vector Quantization Algorithm using random order incremental training. They used three layers. The input layer has 13 neurons which are equal to the number of attributes in the dataset. The number of neurons in the hidden layer can be varied based on error obtained. And finally, there is a single neuron in the output layer which indicates whether the heart disease is present or not [12]. The Performance of the system was improved by varying the epochs and the number of neurons. The result shows that the system can be obtained the accuracy of about 85.55%.

Majid Ghonjifeshki and Omid Sojoodi Shijani [15] proposed a method for heart disease prediction system. They used feature selection method to choose the most relevant attributes and the classification approach for a specific dataset. At scratch, the dataset is divided into two subsets. One is sick people and another one is healthy people. From that, 8193 subsets were extracted using the method called feature selection. Then the best subset was chosen using the PSO algorithm with Feed Forward Backpropagation Algorithm and a classifier algorithm [15]. Four classifier algorithms are used here. MultiLayer Perceptron, Feed Forward Backpropagation, Sequential Minimal Optimization, and C4.5. They concluded by saying the feature selection and Backpropagation with PSO algorithm as an efficient method for predicting heart disease. The result produced an accuracy of about 91.94%.

Heart Disease Prediction System using deep belief network [30] was proposed by Dr. T. Karthikeyan, V.A. Kanimozhi. The dataset was collected from the UCI database which has 300 records. From the dataset, only 16 attributes were chosen using a feature selection method. Dot product calculation was done to start the training phase. Their model has number of hidden layers in order to maintain its accuracy. Their model was designed using MATLAB GUI which is a more interactive and easy to design, packages have to be installed manually and it is time-consuming process. Anaconda Navigator has an inbuilt package to run which is purely based on python code.

3. TRAINING THE PREDICTION MODEL

The valuable data from the website can be collected and trained, to predict the health condition of the patient. The dataset is trained, fit the model to fit the parameters and its output is available to model. So, the test data can be used to evaluate the performance of this model. This section includes how the data are collected, preprocessed and how they are trained to make a prediction.

A. Data gathering

A predictive analysis system is developed with the help of a dataset which can be divided into training and testing data. 70% of a dataset is training data where the information is learned and
the remaining 30% is testing data that ensures to meet its accuracy. To develop a cardiac function prediction system, a dataset is collected from Cardiovascular Disease dataset. This dataset collected is a text file, so that it can be converted into a .csv file. It consists of 70,000 patients records and 13 featured attributes which explain the physical composition of every patient. The 13 featured attributes and its value is represented in Table I.

### TABLE 1: ATTRIBUTES AND ITS RANGE

| ATTRIBUTES | VALUES |
|------------|--------|
| Id         | ID number |
| Age        | In days |
| Gender     | 1 – women, 2 – men |
| Height     | In cm |
| Weight     | In kg |
| Ap_hi      | Systolic blood pressure |
| Ap_lo      | Diastolic blood pressure |
| Cholesterol | 1- Normal, 2- above normal, 3- well above normal |
| Heartbeat  | Beats per minute |
| Smoke      | Whether patient smokes or not |
| cigsPerDay | Number of cigarettes smoked per day |
| Alco       | Binary feature |
| Active     | Binary feature |
| Cardio     | Target variable |

#### B. Data preprocessing:

Data preprocessing technique transforms raw data into machine-understandable format. The real world data that is collected about patients is often inconsistent, incomplete and likely to have many errors. These issues can be solved by data preprocessing techniques. The data preprocessing techniques that is used here are:

- Handling missing values
- Hot encoding
- Feature selection

1) **Handling missing values**

Data set contains incomplete and inconsistent data. Some attributes may have sensitive information about patients and it needs to be fixed because it helps the neural network to
generalize well. In the case of missing class label, that particular tuple can be ignored. When a particular value is missed other than the class label, that value can be filled manually. Missing values can also be filled by using attribute mean. Since it is a time-consuming process, here missing values can be filled by using constant term 0.0. i.e df.columns=df.columns.astype(float).fillna(0.0)

2) Hot Encoding

Here, data are transformed into appropriate form which is suitable for analysing. The lower level data are replaced with the higher level by using the hierarchies concept. The integer encoded variable is removed and a new binary variable either 0 or 1 is added for each integer value. From the dataset, the attribute data are scaled up to fall in the range of 1 or 0. For example, the lower level data age can be mapped into young (0), middle-aged (1) and senior (2). The attribute data smoker can be mapped into 0 (when a person don’t smoke) and 1 (when a person smokes)

3) Feature selection

Feature selection is the process of selecting the most important or relevant attributes. The attributes that are available in a cardiac dataset won’t contribute to a disease prediction. Even it requires more memory, more time to train and test the data and its accuracy can also vary. Minimizing the number of attributes can increase the accuracy of a model. A small number of attributes are enough to predict cardiovascular disease and it is much faster in prediction. There are many techniques for selecting the important attributes but information gain can be used since it can increase the accuracy of feature selection. Information gain is an entropy-based feature selection method, which removes the irrelevant attributes from the dataset. It also reduces the noise that occurs.

C. Artificial Neural Network

Artificial neural network (ANN) mainly like a human brain which has a higher processing ability since it has webs of connected neurons. It can be designed using perceptron which is a basic processing unit. Perceptron solves a linear separable problem. For nonlinear problems, multilayer perceptron is preferred. It consists of three layers: input layer, hidden layers, and output layer.

Input Layer: It can be designed to have 13 input neurons in the network. The total number of neurons were decided to be equal to the total number of attributes in the data set.

Hidden Layer: This network can have up to four or five hidden layers. Optimized one is chosen at the implementation part. Each layer was designed to contain 3 neurons. This number is set to be a startup point. This number can be increased one by one till it reaches the number of neurons in the input layer by comparing the performance of them and the best one can be selected. This approach is based on one of machine learning best practices that the number of neurons of hidden layer should be the mean of number of neurons in input and output layers.

Output Layer: It is designed to have 2 neurons in this network. This number is based on the dataset's class label i.e., disease presence (1)/disease absence (0).

D. Backpropagation Neural Network

Backpropagation is the most commonly used Artificial Neural Network's Learning Technique. It is mainly used to train neural networks. The dataset which is split into 7:3 ratio, that 70% of data is given to training the model. Initially, the weight for each neuron is initialized to some random values. From the set of training data, the input signal is received and it is transmitted to a hidden
In the hidden unit, the net input is calculated by using the equation mentioned in (1),

\[ z = b + \sum w_{ij} + v_i \]  \hspace{1cm} (1)

where \( b \) is the bias on each hidden unit, the value of \( I \) ranges from 1 to \( u \) and \( v_i \) is the input signal and \( w_{ij} \) is the weight.

Then, the output of a hidden unit is computed by applying activation function over \( z \) and it sends to output layer units. Without an activation function, it simply performs linear problems. For non-linear, it is necessary to use activation function. The activation functions are sigmoid, Tanh - Hyperbolic Tangent and ReLu - Rectified Linear units. The sigmoid function have the value between 0 and 1. It is a S-shaped curve, saturates and kills gradients and it is easy to use. But the best activation function can be selected during its implementation. The sigmoid, Tanh, ReLu equation is mentioned in (2), (3) and (4),

\[ S(z) = \frac{1}{1 + e^{-z}} \]  \hspace{1cm} (2)

\[ T(z) = \frac{1 - z}{1 + e^{-z}} \]  \hspace{1cm} (3)

\[ R(z) = \max(0, z) \]  \hspace{1cm} (4)

where \( S(z) \) is the sigmoid curve, \( T(z) \) is the tangent curve and \( R(z) \) is the ReLu curve, \( z \) is the weighted input value given and \( e \) is the base of natural algorithms. When the value is between 0 and 1, it gets fired and sends the target signal. Each output unit receives the target signal corresponding to the input signal and then the error factor is computed.

Here, the output obtained is compared with the expected output and the error is computed. Compute the error term between hidden and input layer unit and also calculate the change in weights and bias value. This computed error is then again given to the neural network (fed back or back propagated) and weights are adjusted using this error so that the resulting output will get closer to the target or expected output. A gradient descent tries to minimize loss function that occurs. This process is repeated for a number of times such that at each iteration the error value gets reduced and the output
gets more and closer to the target or expected output. This iteration stops when it gets closer to target value. Fig 1 represents the backpropagation model which minimizes the error function.

![Fig.1: Back Propagation model](image)

**Fig.1: Back Propagation model**

These sensors are connected to Arduino board which is an open source, easy to use and more flexible hardware. After the completion of proper connection and its execution, it collects continuous real-time data from the sensor. The continuous stream of data is collected and stored in a database. The implementation for collecting IoT data is represented in fig 3.

![Fig.2: Data collection module](image)

**Fig.2: Data collection module**

5. ARCHITECTURE

Fig 4 shows the architecture for the proposed model. It contains three phases. First, Data preprocessing and model generation phase followed by real-time data collection. And finally an interactive GUI. The integer in architecture represents the flow of a diagram.
6. IMPLEMENTATION

The cardiac function prediction system predicts whether the input data given by the user is either have a chance of getting a heart attack or not. It contains three main functions: Implementing an algorithm, Creating GUI, and predicting heart attack.

A. Implementation of Backpropagation

A platform called Anaconda navigator is installed and used because it has inbuilt python packages in it, it is user-friendly and it is easy to set up. It has spyder, Jupyter notebook in it. Here, Spyder with tensorflow is used and the program for artificial neural network runs in python code. Spyder makes the debugging process easier.

A multilayer perceptron is preferred which solves non-linear problems. It is a class of Artificial Neural network. As mention earlier, the algorithm has an input layer, hidden layers, and an output layer. Hidden layers can have any number of nodes but not more than input neurons. By varying the number of nodes in the hidden layer, the accuracy can be varied. The learning rate is 0.3, number of neurons in input layer is 13 and the number of training epochs is 70. The learning rate should be minimized because the higher learning rate makes the system complex. For each iteration, mean square error is calculated. At the end of epochs, the mean square error obtained is 30.36 and the cost function is 1.69. For each iteration, Mean square error value is decreasing. And also, on increasing the number of iterations, accuracy also gets increased, i.e Number of iteration is inversely proportional to the mean square error value and directly proportional to accuracy.

Fig: 5 represents the graph that shows a decrease of mean square value. Fig 6 indicates the graph between a number of epochs and accuracy.
B. Choosing the best activation function and number of hidden layers

If the number of hidden layers gets increased or decreased and for different activation function, the accuracy of testing and training data gets varied. So, the activation function plays a major role in getting higher accuracy. Comparison table for different activation function is represented in Table II. Fig 7,8,9 indicates bar chart for activation functions. Fig 10 represents the consolidated bar chart.

| Hidden layer | Activation function | Hidden Neurons | Testing Accuracy (%) |
|--------------|---------------------|----------------|----------------------|
| 2            | Sigmoid             | 4              | 92.09%               |
| 3            | Sigmoid             | 3              | 93.73%               |
| 4            | Sigmoid             | 4              | 96.15%               |
| 5            | Sigmoid             | 8              | 92.25%               |
| 2            | ReLu                | 3              | 68.34%               |
| 3            | ReLu                | 6              | 69.34%               |
| 4            | ReLu                | 4              | 70.38%               |
| 5            | ReLu                | 5              | 68.43%               |
| 2            | Tanh                | 3              | 45.76%               |
| 3            | Tanh                | 2              | 45.14%               |
| 4            | Tanh                | 3              | 47.13%               |
| 5            | Tanh                | 5              | 47.76%               |
Allegory:

While comparing the different activation functions (sigmoid, Tanh and ReLu), Sigmoid with four hidden layers is the best one. It gives the accuracy of about 96.15%. This sigmoid function tries to decrease the mean square value and kills the gradients. So, the sigmoid function included in code will be tf.nn.sigmoid (tf.add (tf.matmul (x,weights ['h1']),biases['b1'])). From the table and below bar chart it is clear that sigmoid is the best one. And the system having four hidden layers is the optimized one.

Fig.7: Accuracy for Sigmoid activation function

Fig.8: Accuracy for ReLu activation function
C. Choosing the hidden neurons

When the activation function and the number of hidden layers are chosen, there is a need to choose the number of neurons in those hidden layers to improve accuracy. Since the neurons play a major role in the accuracy part. On varying the number of neurons, accuracy also gets varied. Table III represents the comparison table for neurons in hidden layers and fig 11 indicates the bar chart for table III. H1, H2, H3, and H4 are the hidden layers and A1, A2,...A11 are the input combination sets.

TABLE 3: HIDDEN LAYERS AND ITS ACCURACY

| I/P Combination | H1 | H2 | H3 | H4 | Testing Acc(%) |
|-----------------|----|----|----|----|----------------|
| A1              | 3  | 4  | 5  | 6  | 92.15%         |
| A2              | 4  | 5  | 5  | 7  | 92.50%         |
| A3              | 5  | 6  | 6  | 8  | 92.92%         |
| A4              | 6  | 7  | 8  | 8  | 93.92%         |
| A5              | 7  | 8  | 9  | 9  | 94.25%         |
|    | A6 | A7 | A8 | A9 | A10 | A11 |
|----|----|----|----|----|-----|-----|
| H1 | 9  | 10 | 11 | 12 | 13  | 13  |
| H2 | 10 | 11 | 11 | 12 | 13  | 13  |
| H3 | 9  | 10 | 11 | 12 | 13  | 13  |
| H4 | 9  | 10 | 11 | 12 | 13  | 13  |
| %  | 95.54% | 97.69% | 96.01% | 95.55% | 95.15% | 94.45% |

Allegory:

From the comparison table and bar chart it is cleared that, when $H1 = 9$, $H2 = 10$, $H3 = 10$, $H4 = 11$, the system produces an accuracy of about 97.69%. And the input combination set A7 is the optimized one.

D. Predicting Heart attack

The GUI for cardiac function prediction system is designed using QT designer which is mainly based on c++ framework. It is an inbuilt software in Anaconda Navigator and most popular and powerful cross-platform. The PyQt5 package is preinstalled in conda. It does not have the facility to clear bug or build an application. It just creates a GUI interface. The .ui file which is created in QT designer is converted into .py file by using the command `pyuic -x -o .filename.py .filename.ui`. And these bindings are implemented in a set of python modules. The patient’s clinical data is entered in the GUI. The GUI phase is represented in fig 12.
Fig.12: Cardiac function prediction system

The features such as height, weight, teetotaler, smoker, age, gender, alcoholic and real-time data collected are entered in GUI. These values are stored in a CSV file and given to the cardiac prediction model. Then the output from the model gives a prediction, whether a person has a chance of getting heart disease or not. If he has the chance of getting a disease, some suggestions are given. And the suggestions like which food items he has to avoid and what are all the items he has to take. An output of prediction is represented in fig13.

Fig.13: Prediction window

7. Results and Discussion

The dataset which is collected from cardiovascular Disease dataset is split into 7:3 ratio. The training data is trained using artificial neural network which uses backpropagation technique. And the testing data is tested with the ANN algorithm. The accuracy of an algorithm is tested with three activation functions and the best activation function is chosen from the bar chart which has the highest accuracy. A GUI is created using QT designer, where the user can enter the patient’s clinical data so that he can get to know about the patient's heart condition. The resulting cardiac prediction support system gave an accuracy of around 96.23% for training and 97.69% for testing.

8. Conclusion and Future Work

In today's world, keen attention has to be given to cardiac arrest since the statistics says that, in 2017 nearly 6, 17,000 deaths were encountered. Earlier prediction of heart attack and its precautionary measures are needed to prevent the earlier deaths. Artificial Neural Network with back propagation technique was used for training the model and finally, it produces an accuracy of
about 97.69%. This system uses important risk factors (smoker, teetotaler) and it does not require any medical tests which are costly. It is the most effective and precise system.

As a future work, this proposed system can be enhanced as a hybrid model which is the combination of other prediction algorithms in order to improve the accuracy.

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