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IoT based Heart Disease Prediction using Higher Order Boltzmann Deep Belief Neural Network

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Abstract: ***Heart disease is considered as one of the major causes of death throughout the world. Heart problems cannot be easily predicted by the medical practitioners as it is a difficult task which demands expertise and higher knowledge for prediction. Several data mining techniques and artificial intelligence techniques are applied for heart disease prediction. But existing automatic systems for heart disease diagnosis are hampered by the need of big data. Therefore, here introduces an Internet of Things-based medical device for collecting heart details of patients and processed using Higher Order Boltzmann Deep Belief Neural Network (HOBDBNN).***

Keywords: Cardio Vascular Diseases, Data mining, Machine Learning, Deep Learning, Higher Order Boltzmann Deep Belief Neural Network

1. Introduction

Cardio Vascular Disease (CVD) is a critical disease that affects the functionality of the heart, and gives rise to complications such as infection of the coronary artery and decreased blood vessel function. Heart attack is the primary cause of death throughout the world for the past decades and increasing of heart diseases mainly due to the negligence of their health because they don't have time for themselves and forget about their health protection due to massive workload. Along without changing lifestyle there are so many factors such as smoking, alcohol, obesity, high blood pressure, cholesterol, family history of heart disease, diabetes etc. which are responsible for the risk of having heart problems. The seriousness of heart disease necessitates a screening process to diagnose it. During the screening process, doctors conduct blood glucose level test, cholesterol test, blood pressure test, Electrocardiography (ECG), ultrasound, Cardiac computer tomography (CT), calcium scoring, stress test etc. This screening process requires numerous time-consuming manual activities and human intervention. Building an effective disease management strategy requires analysis of large amount of data, early detection of the disease, assessment of the severity and early prediction of adverse events.

Researchers have been using several data mining techniques to help health care professionals in the diagnosis of heart disease. However, existing automatic systems for diagnosing heart disease are hampered by the requisite of bigdata. Therefore, here introduces an Internet of Things-based medical device for collecting heart details of patients before and after heart disease. The information, which is continuously transmitted to the health care center, is processed using the Higher Order Boltzmann Deep Belief Neural Network (HOBDBNN). The gigantic quantity of information is being formed through the IoT devices in the medical field and cloud computing techniques have been used to manage the massive amount of data. The development of intelligent devices in healthcare has more benefits like reduced cost, improved medical understanding of patients as well as decrease the workload of the hospital staffs . Machine learning (ML) algorithms plays a vital role in the decision making process even dealing with massive amount of data. In this study, a wearable watch is used as the IoT device for collecting patient data. The device collects patients' ECG, blood pressure, chest pain typology, cholesterol level, vessel information, and minimum and maximum heart rate. This information is analyzed using the automated heart disease prediction system that utilizes the optimized machine learning algorithm.

Research Problem

Heart disease is one of the critical diseases that can reduce the lifespan of human beings nowadays. Prediction of occurrences of heart diseases in medical field is a significant work since it is required more experience and knowledge .All doctors cannot be equally skilled in every subspecialty and at many places and we don't have skilled and specialist doctors available easily. Therefore several automatic recognition systems for identifying the human heart functionality have been developed by several researchers and it can also reduce costs. However, those automatic systems sometimes require large amount of data, or fail to analyze big data that create system complexity, which leads to reduced overall recognition efficiency. Therefore an automatic system which is integrated with a smart device based on the Internet of Things (IoT) to collect the patient information needs to be developed.

2. Objective

- Design an efficient Heart Disease Prediction System using optimized machine learning algorithm.
- Enhance heart disease recognition rate using a large volume of data,
- Reduce time complexity while analyzing heart disease, and
- Ensure minimum false classification rate while predicting heart data.

3. Review of Literature

Literature review was conducted in order to obtain the knowledge of previous researches. Many papers have been implemented by using different data mining techniques for the diagnosis of heart disease such as Naives Bayesian classification, Support Vector Machines (SVM), Decision

Trees, Artificial Neural Network (ANN) etc showing different levels of accuracies.

In [1], authors used a machine learning algorithm named Support Vector Machine (SVM) for heart failure prediction and obtained the highest accuracy of 77.63%.SVM is a classification method makes use of hyper planes. The main advantage of SVM is it overcomes the high dimensionality problem. This problem arises when the number of input variables is relatively more than number of observations. The robustness of this model is verified with the help of Leave One Out Cross Validation (LOOCV). The main drawback of SVM is that it requires a huge amount of training data to select an affective decision boundary and computational cost is very high even if we restrict ourselves to single pose (frontal) detection.

In [2], authors developed an effective decision tree approach for early diagnosis of heart disease. This algorithm is of a tree like structure, which partitions the data set into smaller subsets. Root node is the topmost node of decision tree. A decision node has two or more branches and decision is represented by Leaf node. This algorithm uses entropy and information gain. Entropy is used to calculate homogeneity of the sample. Decision tree construction is about finding attributes that returns largest information gain. Finally, choose the attribute having largest information gain as decision node and the branch with zero entropy as leaf node. Experimental results showed that their decision support system achieved high accuracy in the diagnosis of heart disease. The advantage of this algorithm is easy to understand and code as well. But it is very sensitive to noise.

In [3], authors proposed Naive Bayesian Classification for detection of Heart Disease. This system responds quickly for diagnosis of heart disease and provides effective treatment by reducing its cost. This algorithm is based on Bayes theorem with some assumptions that the existence of a class is independent of another class. Bayes theorem gives the probability with which an event occurs with respect to another event that has occurred earlier. The advantage of this method is it requires small dataset. But this algorithm faces data scarcity problem and makes strong assumptions.

In [4], the authors proposed a classification methodology named Artificial Neural Network which is a combination of feed forward and back propagation algorithm for predicting heart disease. Neural Network is an iterative method which uses nonlinear data. The main objective is to reduce difference between actual output and predicted output value. Each of the input is assigned a random weightage. Then the corresponding output is calculated and compared it with desired output. The difference between them will give the error. This algorithm minimizes the error with successive iterations by adjusting the input parameters. The advantages of neural network include adaptive learning, fault tolerance etc. But this algorithm takes more time for the dataset training.

In [5], authors proposed a web based monitoring framework known as HealthCare Industrial IoT for observing the health. Their framework gathers the patient information which is fundamental for examination by utilizing sensors as well as medical devices.

In [6], authors introduced Higher Order Boltzmann Deep Belief Neural Network (HOBDBNN) method and IoT-based analysis to recognize heart diseases with 99.03% accuracy with minimum time complexity (8.5 s), effectively minimizing heart disease mortality by reducing the complexity of diagnosing heart disease.

In [7], authors proposed an efficient framework for IoT based heart disease prediction and diagnosis. They showed that J48 classifier is the best algorithm for IoT based healthcare prediction model for heart disease prediction compared to MLP (multilayer perception), SVM (support vector machine) and LR (logistic regression) classifiers.

In [8], authors provided an insight about heart disease detection risk rate using different data mining techniques. Using KNN (K-nearest neighbor algorithm) and ID3(Iterative Dichotomiser 3) algorithm the risk rate of heart disease was detected and provided the accuracy level for different number of attributes.

In [9], authors presented an efficient heart disease prediction system using data mining. Their system can help doctors in efficient decision making based on the given parameter. They have trained and tested the system using 10 fold method and find the accuracy of 87.3%.

In [10], authors have carried out a detailed discussion about the key challenges of various research works related to heart disease prediction.

4. Proposed System

The proposed system framework is depicted in figure 1. It comprises of five main parts like Medical IoT Sensors, Heart Disease Dataset, Patient Data, Cloud Database and Machine Learning based heart disease prediction system. The benchmark heart disease dataset from UCI repository is used. It includes the past logs of the medical data which are gathered from medical institutions. The patient records consist of medical old records of the patients which are collected from hospitals. The required data will be saved in the cloud to access at any time. The heart disease prediction system is responsible to predict heart diseases by the use of machine learning based classification algorithms.

The presented IoT based healthcare model operates in three stages. In the first stage, the data will be gathered by the use of IoT devices from human body, data from benchmark dataset and patient records. In the next stage, all the gathered data will be saved in the cloud database. In the last stage, the prediction of heart disease takes place by classifying the data. In this study, Heart disease detection system is created using the Higher Order Boltzmann Deep Belief Neural Network (HOBDBNN). Initially, the classification algorithm executes the training process which utilizes the heart disease dataset to train the classifier to identify the presence of heart disease or not. Then, the trained classifier is ready to test the incoming patient details to properly identify whether the

patient suffers from heart disease. Finally, the test report will be generated and available to the user.

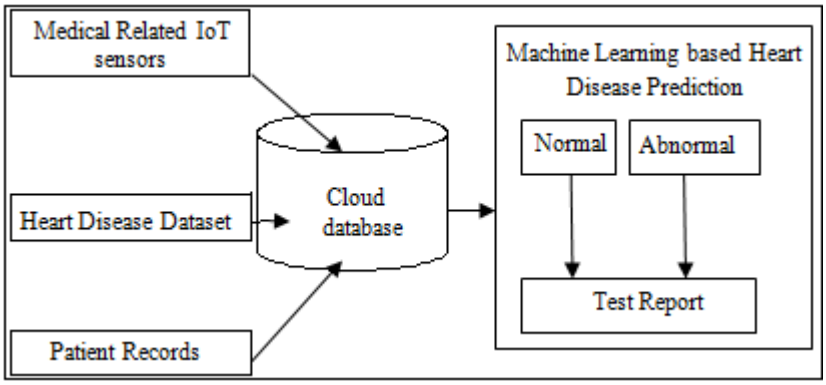

Figure 1: Block Diagram of the Proposed Model

5. Methodology

5.1 Deep Learning

Deep Learning is a set of machine learning methods that consist of multiple stacked layers and use data to capture hierarchical levels of abstraction. Advantages of Deep learning techniques against traditional machine learning techniques is that they require less domain knowledge for the problem they are trying to solve and they are easier to scale because increase in accuracy is usually achieved either by increasing the training dataset or the capacity of the network. Deep learning is better in visualizing complex patterns hidden in high dimensional medical data. Most of the deep learning architectures and algorithms are built with the Artificial neural network (ANN) framework which is composed of neurons. A neuron in the machine learning world is a placeholder for a mathematical function called an activation function .There have been 5 major activation functions like date, step, sigmoid, tanh and rectified linear unit (ReLU). Neuron and activation functions together form the basic building blocks of any neural network. A layer in a Neural Network is a collection of neurons. Inputs to each of these neurons are processed through the activation functions assigned to the neurons. Any neural network has one input and one output layer. But the number of hidden layers differs for different networks depending upon the complexity of the problem to be solved. Choice of the activation function to be used depends on the problem to be solved and the type of data being used. Now for a neural network to make accurate predictions each of these neurons learn certain weights at every layer. The algorithms through which they learn the weights are called back propagation. A neural network having more than one hidden layer is generally referred to as a Deep Neural Network.

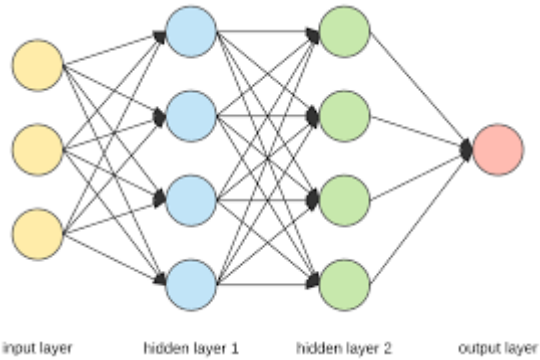

Figure 3: Neural networks and back propagation

5.2 Deep Belief Networks and Deep Boltzmann Machines

Deep Belief Networks and Deep Boltzmann Machines are deep learning models that belong in the “Boltzmann family, ” in the sense that they utilize the Restricted Boltzmann Machine (RBM) as learning module. The Restricted Boltzmann Machine (RBM) is a generative stochastic neural network. DBNs have undirected connections at the top two layers which form an RBM and directed connections to the lower layers. DBMs have undirected connections between all layers of the network. A graphic depiction of DBNs and DBMs can be found in Figure 3.

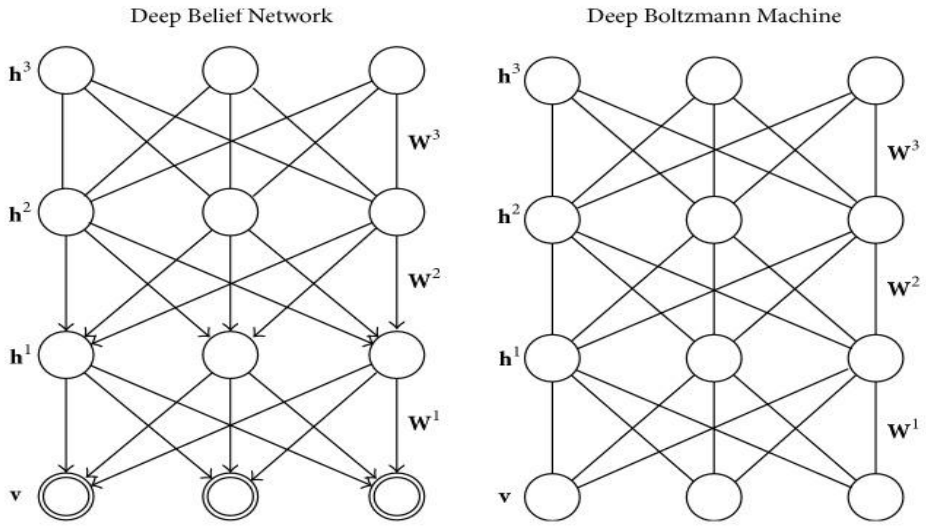

Figure 3: Deep Belief Network and Deep Boltzmann Machine

Different steps needed for heart disease prediction

In this study, Heart disease detection system is created by using the Higher Order Boltzmann Deep Belief Neural Network (HOBDBNN). IoT medical data is collected by placing sensor device on the human body. The collected information is transmitted via the gateway and stored in a cloud server. From the cloud, heart disease data is accessed and fed into three important steps:

- Heart Data Preprocessing
- Feature Extraction, and
- Heart Disease Classification.

5.3 Medical Data Pre-processing

In this step, unwanted data is eliminated by applying the Median Studentized Residual approach because it perfectly examines the relationship between the data in the data set, thereby improving the overall heart disease recognition process. Initially, Collect IoT medical data such as ECG, heart rate, blood pressure, SpO2 level, glucose level, blood fat level, chest pain, and pulse rate. Then the data is examined in terms of rows and columns, and missing values are replaced by computing the median value. After replacing the missing value, data should be normalized in the range of 0 to 1 to minimize the complexity while analyzing heart disease patterns. Normalization is performed using the multiple distributions of the data or regression analysis of the heart data.

5.4 Heart Feature Extraction

The second step in the study is to extract the various features from the IoT device-based medical data. The dataset includes the information such as heart rate, blood pressure, blood glucose level etc. To effectively obtain the status of the heart disease, it is necessary to derive the main features such as the statistical and temporal features. They are Peak amplitude, Total hormonic distortion, Heart rate, Entropy, standard deviation etc. These features are extracted from the data collected from the wearable IoT medical device. The extracted features are maintained as the determinants for predicting heart disease and changes present in the heart pattern.

5.5 Heart disease classification

The extracted features are classified using the Higher Order Boltzmann Deep Belief Neural Network (HOBDBNN) approach. The proposed method utilizes a collection of hidden layers that successfully retrieve the new incoming heart disease-related features from history. Therefore, the system demonstrates minimal complexity and misclassification. Then, the excellence of the system is analyzed using the MATLAB tool based results, and efficiency is evaluated based on sensitivity, specificity, f-measure, loss function, receiver operating characteristic (ROC) curve, and time.

5.6 Expected outcome

An integrated IoT based Heart Disease Prediction is performed using HOBDBNN approach. The proposed approach processes big data and recognizes abnormal heart patterns in least time with high accuracy. This method learns heart disease features from past analysis, and achieves efficiency by the effective manipulation of complex data.

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