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MF-RN: MANAGED FEATURE RECURRENT NETWORK FOR HEART DISEASE PREDICTION

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Abstract
Cardiovascular disease or CVD is among the leading causes of death around the globe in which the blood vessels of the heart that supply myocardium gets affected causing different heart related diseases like including vascular, ischemic, and hypertensive. In today's typical modern society, fatalities from cardiovascular disease have become one of the biggest challenges with around one person dying from heart disease every minute. However, identifying and predicting the onset of disease at early stages is a difficult task. Therefore, an effective deep learning-based Bi-LSTM approach is proposed in this paper for detecting CVDs. The main objective of the proposed approach is to reduce the complexity and to increase the classification accuracy of the system. To accomplish this task, information is collected from the dataset available on UCI ML repository. This data is then processed and normalized so that unnecessary and redundant data is removed from it. Moreover, in order to make the dataset more informative and useful, an Infinite Feature selection technique is implemented wherein only the critical and useful features are selected from the available set of features. For classifying the data, a bidirectional LSTM (Bi-LSTM) classifier is used. The effectiveness of the suggested approach is validated in the MATLAB software and later on compared with traditional CNN, KNN and NB models in terms of various dependency factors that demonstrate its efficacy.
Keywords: Deep learning, RNN, Heart disease, data mining, biomedical applications, etc.

1. INTRODUCTION

Heart is one of the vital organs that supplies the oxygenated blood to all the body parts through regular contraction and dilations of cardiac muscles. however, the functioning of the heart is affected by various cardio vascular diseases (CVDs). The term "cardio" refers to the heart and "vascular" refers to all the veins present in the body [1]. Noncommunicable illnesses, primarily cardiovascular diseases (CVDs), diabetes, malignancies, and respiratory illnesses, comprise the majority of fatalities and have become a serious public health problem in almost all nations. Amongst all the non-communicable diseases, cardiovascular diseases (CVDs); such as ischemic heart disease (IHD), strokes, hypertension, peripheral arterial disease, rheumatic heart disease, congenital heart disease, and cardiac arrest are the common causes of death. According to a survey conducted by the World Health Organization (WHO), it is estimated that around 10 million people are affected with heart disease and have died as a result of it. The fatality rate caused by the CVDs is increasing rapidly with figures showing that it was 17 million in the year 2002 and is expected to reach 23 million in the year 2030 [2]. The whole death rate due to CVDs in USA in the year 2010 was 235.5/100000, which means that after every 40 seconds there occurs a death because of CVD. The CVDs are very costly in terms of money. In the year 2010, the direct and indirect expenses of CVD totaled roughly 315.4 billion dollars, up more than 10% from 2007 [3]. In developing countries like India, Pakistan, Bangladesh the burden of the heart disease is increasing continuously at initial phases [4] while as in developed countries like UK, it is decreasing in the later stages.

Generally, CVDs are characterized by clogged blood vessels which may result in a cardiac arrest, chest pain because of the inadequate blood supply to the heart and cause strokes. In addition to this, there are many other sorts of heart problems, like those that damage the muscles, valves of heart or change the heart beating pattern etc. [5]. CVDs include heart and blood vessel diseases that include a wide range of issues, majority of which are associated to a procedure known as atherosclerosis. Atherosclerosis is a condition that occurs when a substance called plaque builds up on the surface of arteries and progresses continuously. This builds up results in hardening the arteries hence, making it even more difficult for blood to flow. The condition where the blood clots and may also result trigger a heart attack, is referred to as a myocardial infarction or stroke. Generally, heart diseases are found to affect individuals in the later stages of life i.e. 30-44 age, however, according to the famous cardiologist, majority of the people develop the CVD when they are just 35 years.

1.1 TYPES OF CVDS

Basically, CVD is not a single disease and comprises

a set of other heart related diseases that affect the functioning of heart. CVD is a word which comprises a set of disorders that affect heart health, as previously stated. There are several types of cardiac diseases which are pretty common nowadays, which include, CHD, Angina, stroke etc. Coronary heart disease (CHD) is a type of heart disease in which the plague accumulates on the surface of arteries which supplies heart muscle or myocardium. Many of these atheromatous plaques could burst after years of growth thus, reducing the blood flow to the heart muscle and forming blood clots. This disease remains the major cause of unexpected death. While as, Angina is a type of pain that is linked with highly severe CHD that typically manifests as a feeling of chest pressure along with the pain in arms and jaws and other discomforts. It is basically a cramp in heart muscles. Another commonly occurring type of CVD is stroke, which is basically a type of acute neurological damage in which the flow of blood doesn't reach to the brain, due to an arterial blockage or brain hemorrhage. The brain doesn't receive any oxygen supply from the blood when the arteries are blocked, therefore they become necrotic which affects the functioning of the brain. If a stroke is not identified and treated swiftly, it can result in irreversible neurological damage or can even cause death [6-7].
In addition to the above-mentioned heart disease, various other heart related diseases are also found that include tumors related to heart and brain, abnormalities in muscles or cardiomyopathy, heart valve illness and cardiac lining disorders etc.

1.2 PROMINENT RISK FACTORS AND SYMPTOMS IN CVD

Heart disease can be caused by various factors, some of the most common and prevalent factors are age, drugs, alcohol consumption, sex, not being physically active, weight, unhygienic and unhealthy diet, diabetes, high blood pressure, stress, genetic history, cholesterol etc. In addition to this, various social and environmental factors like, poverty, illiteracy, air and noise pollution, inadequate sleep etc. also contribute to the heart diseases. Although each risk factor's specific influence differs by community or ethnic background, however, the cumulative impact of such factors associated is quite constant. Most of these factors associated are unchangeable, including such age, sex, or family history/genetic susceptibility; nevertheless, other key heart disease factors can be altered by changing the lifestyle, society and pharmacological therapy. Obese people are more likely to develop atherosclerosis in their arteries [8].
Some of commonly observed symptoms of CVDs that must not be ignored are; discomfort in chest, nausea, indigestion, heart burn or stomach pain, pain in arms, Dizziness or lightheaded, pain in throat or jaw, fatigue, snoring, swelling in legs, feet, ankles and irregular heartbeats. The more these symptoms are present the more is the probability of having heart disease [9]. Since the mortality rate caused by CVDs is exceptionally high, therefore, it is necessary to develop a method that can identify and detect the CVDs at earliest stages, so that the human loss can be avoided. In this context, Artificial intelligence-based methods (ML and DL) are providing effective results.

1.3 ROLE OF AI IN DETECTING CARDIO VASCULAR DISEASES (CVDS)

AI is destined to serve as the progressively substantial role in medical field due to the increasing developments in computer power, training algorithms and accessibility to massive datasets that are supplied from health departments and smart wearable trackers. The AI industry in healthcare coverage is growing at a 40% annual rate and is anticipated to rise $6.6 billion by the end of 2022.
Traditional invasive-based techniques for predicting heart diseases were centered on a patient history, physical lab tests, and a doctor's research of relevant symptoms. Angiography is regarded one of the most precise techniques for detecting heart abnormalities among the traditional procedures. However, this technique does have some disadvantages like, high cost, a variety of adverse effects and a high level of technological knowledge. Traditional approaches frequently result in erroneous diagnoses and take longer owing to human error. Furthermore, it is a very expensive and computationally intensive technique to disease diagnosis that takes time to assess.
AI seems to be well to automate processes, manage massive datasets, and give an extra layer of decision - making to prevent errors. According to Frost & Sullivan., AI has the potential to enhance the patient's health by 30% to 40% while lowering cost for treatment up to 50%. Although AI algorithms are still in their initial phases of use but they are improving rapidly in fields including radiology, pathology, ophthalmology, and cardiology [10]. Machine learning (ML), deep learning (DL), and cognitive computing are examples of artificial intelligence (AI) approaches that can help with identification and treatment of CVD. Therefore, increasing the quality and the efficacy of the of heart disease detection systems [11]. Some of the common and mostly used methods for detecting diseases are; Support Vector Machine (SVM),

K-nearest Neighbor (KNN), Artificial Neural Network (ANN), Naïve Bayes (NB), Decision Tree (DT) and so on. Recently, a huge number of experts tried to develop an effective heart disease detection model by using various ML based algorithms that can detect CVDs effectively. But each developed model had some limitations that degrade its performance.

In this paper, an improved heart disease detection method based on DL will be proposed for handling the large datasets effectively. Along with this, the computational and training time will also be reduced in the proposed model. Some of the recently proposed are discussed in the next section of this paper.

2. LITERATURE SURVEY

Over the years, a significant number of methods have been proposed in this discipline. Many studies and experiments on cardiovascular disease data sets were qualitative exploratory by using various methodologies and classifiers. Some of them are defined here, Jamal Salahaldeen Majeed Alneamy et al. [12], proposed a hybrid TLBO (teaching learning-based optimization) method and FWNN (fuzzy wavelet neural network) for detecting cardiac diseases. In order to improve efficiency of FWNN, the TLBO method was applied. the performance of the proposed model is analyzed in terms of MSE and execution time and an accuracy rate of 90.29%. Mehmood, Awais et al. [13], proposed a method named as, CardioHelp, which anticipates the risk of having heart diseases with the help of CNN (convolutional neural networks). This method was focused on secular data modeling by using CNN for anticipation at its initial stage. The accuracy of the proposed model achieved an accuracy of 97%. Oliver, Sheryl et al. [14], the authors proposed RLNNC (Regressive Learning-Based Neural Network Classifier) in order to enhance the accuracy and processing time of detection. The techniques that are based on RLNNC have proven to be highly accurate and efficient than traditional techniques. Tan, L et al. [15], presented a deep learning-based 5G-enabled concurrent cardiovascular monitoring system for COVID-19 patients. To obtain ECG data, the Flink data stream processing framework has been used. Finally, a model of CNN and long active memory networks to forecast the COVID-19 patient's cardiovascular health automatically has been developed that enhanced heart disease prediction precision to 99.29%. R. Chitra and Dr.V. Seenivasagam, [16], a Supervised Learning Algorithm is suggested for early heart disease prediction utilizing the patient's medical information, and the results are compared to those of the well-known supervised classifier SVM (Support Vector Machine). The results suggest that the CNN classifier can more accurately estimate the chance of patients having heart disease. Ashir Javeed et al. [17], presented a feature selection strategy that utilize a FWAFE (floating window with variable size for feature exclusion) for improving heart risk prediction accuracy. In addition to this, a DNN (deep neural networks) and ANN (artificial neural networks) were used as classification frameworks. FWAFE-ANN and FWAFE-DNN were two types of hybrid diagnostic systems proposed in this study. Bayu Adhi Tama et al. [18], new CHD detection method that was based on gradient boosting machine, random forest, and extreme gradient boosting was proposed. Moreover, a particle swarm based on optimization feature selection was used for selecting features. Srivastava, Keshav & Choubey, Dilip, [19], a novel technique for determining disease has been presented using the Cleveland Heart Disease Dataset through combining the processing power of multiple ML and data mining algorithms, and results obtained showed that K-Nearest Neighbors has the greatest accuracy of 87% of all the algorithms. S. Ambekar and R. Phalnikar, [20], proposed heart disease prediction model that was based on KNN and NB algorithms. Along with this, unique disease risk prediction technique based on convolutional neural networks was deployed. The results demonstrated that the CNN-UDRP method has a predictive performance of above 65%. Amin Ul Haq et al. [21], proposed a heart disease prediction system based on ML methods. Moreover, three feature selection methodologies, seven popular machine learning techniques, performance evaluation metrics like Matthews' correlation coefficient, specificity, classification accuracy, sensitivity and execution time and the cross-validation method were used to evaluate the performance of each models. Shankar, VirenViraj et al. [22], a ML based heart disease prediction method is proposed in which Convolutional neural network (CNN) was used to predict the disease. The suggested model achieved a precision rate of 80 to 85%.

From the literature survey conducted, it is observed that over the years, a significant number of methods have been proposed by various researchers in order to detect the heart diseases at early stages, to decrease mortality rate. Moreover, it was also analyzed that most of the scholars used deep learning (DL) based methods in their work as such systems are able to handle large datasets quite effectively. Although, the models were providing good results in detecting CVDs, but still there were some drawbacks in these systems that deteriorated their overall

performance. One of the major drawbacks in such systems was that the classifiers used by researchers were not recommend for sequential and were not compatible with the changes formed in data due to noise and other factors which in turn affected the accuracy of the system. In addition to this, not much work has been done on reducing the dimensionality of the datasets which makes detecting CVDs a time consuming and complicated procedure. Keeping these things in mind, a new and improved heart disease detection model must be proposed which not only improves the accuracy but also reduces the complexity and processing time of the detection system.

3. PROPOSED WORK

In order to overcome the limitations of the conventional heart disease detection approaches, a novel and enhanced heart disease detection method is proposed in this work, that is based on advanced variant of Recurrent Neural Network (RNN), named as Bidirectional Long Short-Term memory (Bi-LSTM). As previously noted, that the processing and intricacy of the detection technique can be substantially decreased by reducing the dimensionality of the database employed. Also, the classification performance of the detection system can further be increased by employing a more efficient and suitable classifier for sequential data. Considering these findings, the major focusing area of current approach relies on the feature selection and classification phase. For this, an infinite feature selection technique is implemented along with the Bi-LSTM classifier in the proposed work.

In this research, a publicly available dataset is selected from the UCI ML repository which contains the data about number of patients, whose brief description is given in the methodology section of this paper. However, the data attained form the dataset is in the raw form and contain lot of empty cells, NAN values and redundant data that must be eliminated to produce effective results. For this the data is processed and normalized before more advanced techniques like feature selection and classification techniques are applied to it. Furthermore, in order to reduce the dimensionality and complexity of the dataset, an infinite feature selection (IFS) techniques is applied to it, which helps in selecting only those features that are important and crucial for CVD detection. The IFS calculate the correlation and standard deviation of the features based on their weight. The primary reason for using infinite feature selection in proposed method is that it reduces computational complexity while selecting features and position them intuitively by assessing their weights for a specific trait. In addition to this, a Bi-LSTM classifier is used in proposed model. the main motive for using the Bi-LSTM is that it delivers effective results for sequence classifications problems. Furthermore, Bi-LSTM recalls every bit of information (past and future) across time which makes it appropriate and suitable for time-series predictions. Another important purpose of implementing the BI-LSTM in this research is that it simultaneously trains two LSTM models on the input pattern. This can provide additional information to the network, allowing it to comprehend the issue more quickly and comprehensively. Therefore, by integrating and implementing IFS and Bi-LSTM in the proposed work, a highly efficient and accurate heart disease detection model is proposed. The detailed description of how the proposed model works is given in the following section.

3.1 METHODOLOGY

In order to attain the desired results in the proposed model, it undergoes through a series of steps, as shown in figure 1.1. Each step is explained in brief below;

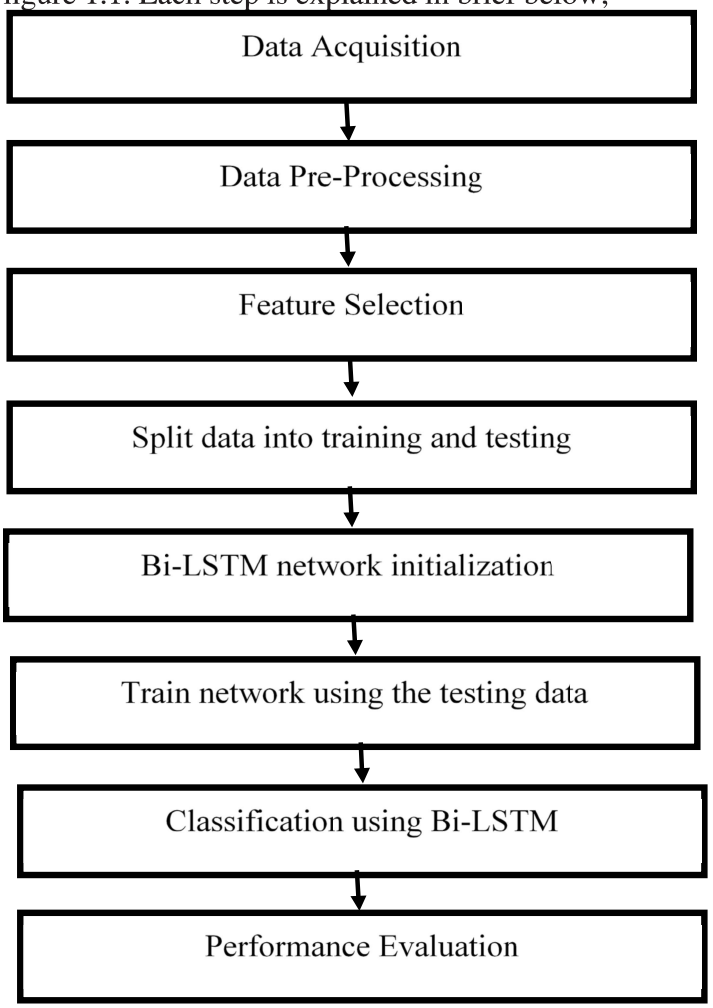

Fig.1.1Work flow of the proposed Bi-LSTM model

Data collection: The first phase opted in the proposed model is to collect necessary information about CVD

from the currently available datasets, upon which more advanced approaches like pre-processing, feature selection etc. are applied. Here, data is taken from the UCI ML repository in which a total of 303 samples are present and each sample have 14 attributes (like Age, sex, fbs, trestbps, thal etc.). Table 1.1 shows the sample of the dataset used in the proposed work.

Data Pre-Processing: In the next phase of the proposed model, the raw data acquired must be pre-processed. The necessity for data processing originates from the presence of unneeded, inappropriate, NAN and missing values in the datasets that must be eliminated in order to attain high accuracy results.

TABLE 1.1SAMPLE DATASET

age	sex	-	thal	num
63	1	-	6	0
67	1	-	3	2
67	1	-	7	1
37	1	-	3	0
41	0	-	3	0
56	1	-	3	0
62	0	-	3	3
57	0	-	3	0
63	1	-	7	2
53	1	-	7	1
57	1	-	6	0
56	0	-	3	0

Feature selection: once the data is processed, features are selected from it. For this, an infinite feature selection (IFS) is implemented in the proposed work which effectively selects features in the proposed model as per their weights. Here, we have selected 10 best features with highest weights and removed the remaining unwanted features which in return reduces the dimensionality of dataset. By doing so, the dimensionality of the data is reduced which in turn reduces the processing time and intricacy of the model. This data is then divided into two categories of training and testing, for training and validating the proposed model.

Network initialization: After this, the Bi-LSTM network is initialized wherein, the total number of selected features, alpha and correlation types are the attributes of IFS. Moreover, a number of Bi-LSTM parameters like, network type, hidden units, epochs, learning rate and threshold value are also defined whose values are mentioned in table 1.2.

TABLE 1.2 NETWORK INITIALIZATION PARAMETERS OF PROPOSED MODEL

Sr. No.	Attributes	Values
1	Selected Features	10
2	Alpha	0.6
3	Correlation Type	Spearman
4	Network Type	RNN (BILSTM)
5	Hidden Units	25
6	Max. Epochs	150
7	Initial Learning Rate	0.015
8	Gradient Threshold	1

Training model: Now, once the proposed model is initialized, it is trained by passing the training data to it. The proposed Bi-LSTM model starts training itself as per this data.

Classification: The performance of the trained Bi-LSTM model is than analyzed and assessed by passing the testing data to it. The model starts identifying and classifying diseases as per the training provided to it. On the basis of this classification, the performance is validated in number of dependency factors, discussed in the next section.

4. RESULTS AND DISCUSSION

The findings obtained after modelling the suggested Bi-LSTM framework in MATLAB software are explained in this section. The efficacy of the suggested Bi-LSTM technique is evaluated by comparing its accuracy to that of the previously proposed CNN, Naive Bayes, and KNN algorithms. Moreover, the performance of the proposed Bi-LSTM approach is also analyzed in terms of sensitivity, specificity, precision and recall.

4.1 PERFORMANCE ANALYSIS

In order to prove the effectiveness of the proposed Bi-LSTM model in terms of various performance dependency factors, we firstly analyzed its performance during the training phase. Figure 1.2 represents the training progress graph in terms of its accuracy and loss in proposed Bi-LSTM model attained during training. After analyzing the figure closely, it is observed that the accuracy curve is going upwards smoothly as the number of iterations are increasing, while as the loss curve is decreasing continuously with the increase in iterations performed. This means that the proposed Bi-LSTM model is getting trained effectively with less loss.

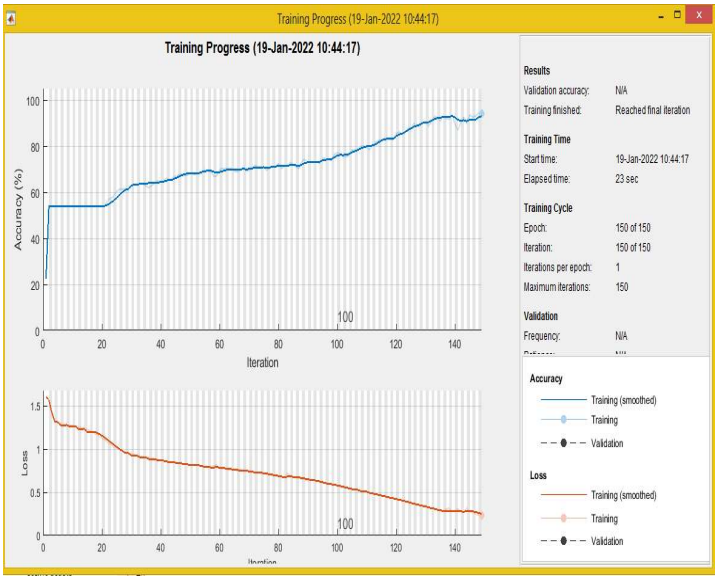

Fig.1.2Training progress of proposed Bi-LSTM model

5. CONCLUSIONS

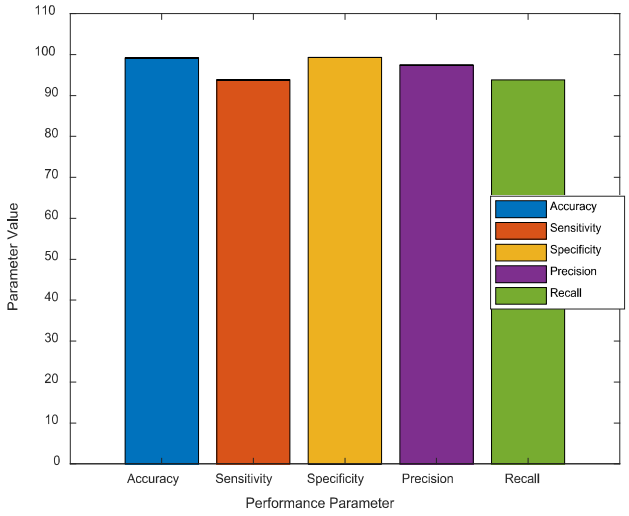

Fig.1.3 Different performance parameters in proposed Bi-LSTM model

Moreover, the effectiveness of the proposed Bi-LSTM approach is evaluated in terms of various dependency factors including, accuracy, sensitivity, specificity, precision and recall (see figure 1.3). After examining the graph, it is observed that the proposed Bi-LSTM approach achieved a value of 99.1111% for accuracy which in itself is a great number. Similarly, the value of sensitivity and specificity were also determined to be 93.778% and 99.2561% respectively. Furthermore, the efficiency was evaluated in terms of precision and recall whose values were 97.3856 % and 93.7778%. These results in itself determine the superiority of the proposed Bi-LSTM model.

In addition to this, to prove the supremacy of the proposed Bi-LSTM model over traditional CNN, NB and KNN approaches, its performance was analyzed in terms of their accuracy values, as shown in figure 1.4.

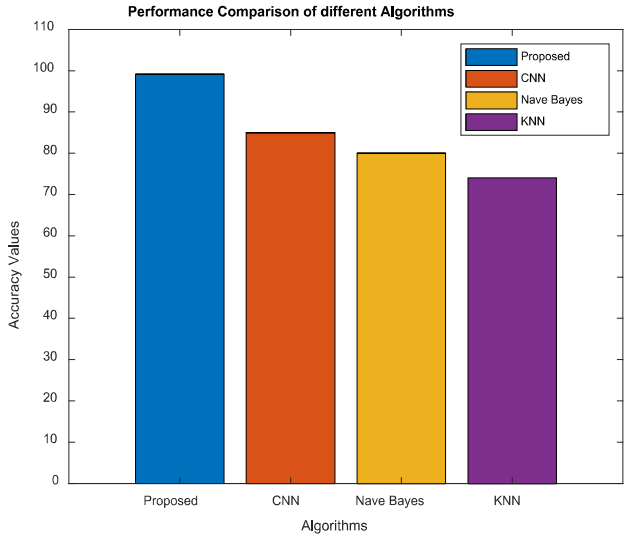

Fig.1.4 Comparison graph for accuracy

Figure 1.4 illustrates the comparison graph of the traditional heart disease detection model with the proposed Bi-LSTM model in terms of their accuracy. From the given graph, it is observed that the value of accuracy in traditional KNN, NB and CNN models were mounted at 74%, 80% and 84% respectively. On the other hand, when the performance of the proposed Bi-LSTM model is analyzed for accuracy, it came out to be 99.1111%, marking its supremacy over other models. The specific values attained in each method are recorded in tabular form and is given in table 1.3.

TABLE 1.3 Comparison Table for Accuracy

Sr No.	Algorithms	Accuracy %age
1	KNN	74
2	Nave Bayes	80
3	CNN	85
4	Proposed	99.11

After reviewing all of the figures and charts, it is clear that the suggested Bi-LSTM-based heart disease detection method is capable of accurately and precisely diagnosing CVDs.

6. CONCLUSION

In this paper, an improved and enhanced CVD detection approach that is based on Bi-LSTM model is proposed. The efficacy of the proposed Bi-LSTM model is analyzed and compared with the various state of art approaches in

MATLAB software. The simulating results were attained in terms of accuracy, sensitivity, specificity, precision and recall. Through extensive results, it is found that the value of accuracy was attained lowest in the traditional KNN model with 74%, followed by NB with 80%, followed by CNN with 85%. On the other hand, the value of accuracy rate achieved in the proposed Bi-LSTM model was significantly higher with 99.1111% value. This means that there is an improvement of around 25.11%, 19.11% and 14.11% in proposed Bi-LSTM model when compared with traditional KNN, NB and CNN models respectively. In addition to this, the performance of proposed model is also depicted in terms of sensitivity, specificity, precision and recall that came out to be 93.77%, 99.25%, 97.38% and 93.77% respectively. These values prove the efficacy and supremacy of the proposed Bi-LSTM model.

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