International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

Study of ECG Analysis based Cardiac Disease Prediction using Deep Learning Techniques

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Submitted: 06/05/2023 **Revised**: 14/07/2023 **Accepted**: 05/08/2023

Abstract: A quarter percent of mortality rates over the world is due to cardiovascular diseases which is 32% over the world population such that approximately 17.9 million. One of such CVD is arrhythmia disease. Faster prediction of heart disease may reduce the chances of death rates. This necessities us to predict the CVD using advanced techniques like deep learning and machine learning.This study presents the various types of deep learning methods for the prediction of CVD. In deep learning, convolutional neutral network is considered to be the best technique which results in 94.2% in training as well as testing accuracy. Deep learning structures its algorithm to make Artificial neutral network that predicts intelligent decisions from dataset. ECG is a good specification used for the detection of cardio disease. Deep learning is the most commonly used method because for its accurate prediction, better sensitivity, specificity and highest prediction performance. CNN, Auto encoder and LSTM methods are found to give good accuracy results than other deep learning techniques.

Keywords: *Cardiovascular disease, Deep learning, Electrocardiogram, Neural networks*

1. Introduction

Cardiovascular diseases (CVDs) refer to the irregularities in the heart beat or assortment of disarray of structural problems and blood clots. Cardiovascular disease (CVDs) contributes an major role in the mortality rate of today's world. As estimated in 2019, CVDs have caused the a major 17.9 million lives each year, which represent 32% lethal rates globally and out of these 85% are due to cardiac arrest and stroke [14]. This clearly states that this is no longer an individual's issue but a reality that the world nations have to face, because one third of the worlds mortality due to heart disease occur low and middle income countries[13]. People living in under developed and developing countries often they do not afford any primary healthcare programs for earlier prediction and medication for CVDs. As a result, population in these countries reduced due to that people die at younger age. The solution to the cardiovascular disease to cardiovascular disease depletion depends on the inclusion of cardiovascular disease management inventions [13]. The WHO states that "Patients with cardiovascular disease should have access to appropriate technology and medications" [13]. To lessen the avoidable NCD burden, the member states in WHO agreed on global mechanisms in 2013 including a "Global action plan for the prevention and control of NCDs 2013 – 2020". The main goal of this global action plan is to avoid the count of premature deaths by 25% in 2025 to nine voluntary global targets. Some of the target focussing on preventing and controlling CVD, Target 6: To lessen the global currency of increased BP 25% between 2010 and 2005.Target 8: Minimum 50% of permitted people should sustain drug therapy and counselling to prevent cardiac arrest and strokes by 2025. Besides, Target 9: defines 80% availability of the affordable basic technologies and essential drugs including generics, essential to cure major NCDs in both public and private facilities. To achieve this target, considerable amount of investment and widening of health systems are [13]. There goes a saying, Prevention is better than cure and the prevention of CVD start from screening of man's heart rhythms. The electrical impulses can be measured and recorded using an ECG to display the robustness of the electrical impulses as they move through the heart, also the speed of the heart beats and rhythm of the heart beats. A doctor uses an ECG to investigate the indication of injury to heart damage. Irregular heart beat rhythms known as arrhythmias. The consequences of electrolyte irregularities or drugs on the heart electrical system [15]. Irin Sherly et al., [32] proposed ensemble-based prediction for issues related to heart using gradient boosting algorithm. They used four different datasets from various hospitals with 14 features and shown gradient boosting can perform well in all the four datasets.

2. Related Works

2.1. History of ECG

William Einthoven, the inventor of string electrocardiogram was born in the Dutch east Indies. He completed his

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medicine in Utrecht, Holland and was also awarded the Nobel Prize for Physiology and medicine in the year 1924. After that moment invention, the development of electrocardiography started to gain increase in the Netherlands [16]. And now ECG became a ubiquitous tool in clinical medicine. In beginning machine learning algorithm ware increasingly utilized for CVD prediction. ECG provides a picture for the physiological and structural wellbeing of the heart by detailing the diagnostic clues. Although it provides standardized recordings, it was able to employ only manual patterns and did not result in a way that better than a human interpretation that comes with experience. However deep learning techniques in ECG results in human life interpretation.

Of course, it captures more than human minds through its multilayer AI networks resulting in precise readings which in turn saves the lives of many people at earlier stages. As it is a matter of fact, for better understanding and promotion of the use of ECG, we represent a systematic review on Biological scenario, Dataset, Pre Processing, Data Extraction, Classification of diseases, Table, Conclusion.

2.2. Biological Scenario

2.2.1. CVD Overview

Cardiovascular disease is one of the conditions that affects blood vessels or heart. The risk factors of CVD may include high BP, inactivity, diabetes and being overweight. It is also known as heart disease. Blockage which prevents the blood from running to the heart or brain causes active task called cardiac arrest and stroke [4]. Heart disease mainly caused due to the building up of cholesterol deposits on the interior walls of the blood vessels [4][34][36].

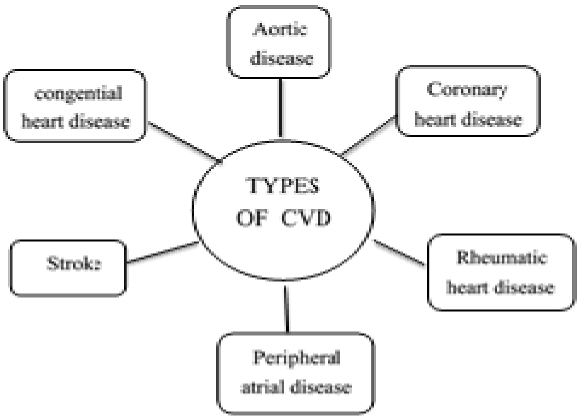

Fig.1: Types of Cardiovascular diseases

2.2.2. Cost rate of CVD by WHO

CVD cost will rise to $749 billion by 2035 expected by researchers.A heart attack hospitalization costs a medium of $54,384 and bypass surgery can cost of $84,891 to $1,77,546. To recover attributes from the signal. For the research of heart attack heart disease, National Institute of health spent more than $1.4 billion in the year 2019.

2.2.3. ECG Signal

Test which predicts and measures the electrical activity of heart is called electrocardiogram. A graph records data in signal form which represents the electrical signal travelling through the heart. The number of wavesforms in ECG are P wave, QRS wave and T wave.The P waves denotes the electrical atrial depolarization the QRS complex denotes the ventricular depolarization and T waves represeant the ventricular repolarization. The point P on the ECG wave is the highest peak. The activation of the left and right ventricles with maximum QRS complex is depicted by QRS wave over to QRS wave, the T wave is followed. Initiations of the atria, repolarization of the ventricles and simulation of the ventricles are connected with these impressions[3]. Irin Sherly et al., [31] proposed ECG signal quality improvement using different types of filters.

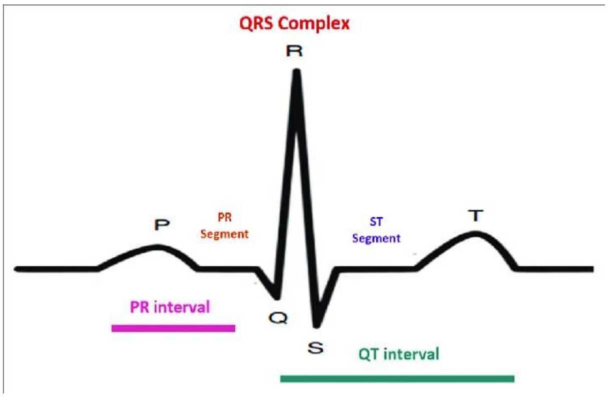

Fıg 2: ECG Signal [25]

2.2.4. ECG Diagnosis Framework

By keeping the electrodes on the chest, electrical impulses can be measured and detected from arms and legs [3[37]]. These electrodes are attacted with an ECG machine through wires made up of lead.Therefore it is clearly known,that the electricity won't pass into the body. The sequence PQRST waves collected by machine is translated into graphical representation then it should be printed on a paper. The doctor can interpret the printed data to find the abnormalities of the heartbeats such as pulse rate, rhythm of Heart, Electrical heart Axi, The PR intervals, The QRS complex, Repolarization, The R/S ratio. The following are the steps to interpret an ECG:

Step 1: Collect the details of the patient and store it in a database.

Step 2: To make the process easier pre processing the data is used.

Step 3: Data extraction is to retrieve the data from the ECG data set.

Step 4: Classify the type of disease using DL techniques.

Step 5: Predict the disease based on arrhythmia type.

3. Dataset Description

For the analytic and prediction purpose grouping of data pieces can be considered as a single unit is called dataset. The two accurate dataset used are MIT-BIH arrhythmia dataset and the PTB diagnostic ECG database used for heart disease prediction [5]. To develop a deep neural network, the cardinality of samples in both the datasets is fair enough. Whether the normal case or may be affected arrhythmia, the ECG shapes of the heartbeat corresponding to the signals are different in each cases. With each segment corresponding to heartbeat by signals or segmented to heartbeat, these signals are segmented and preprocessed using preprocessing techniques.

To conduct, compare and validate their new prediction methods on arrhythmia, researchers can use standard ECG database[1] called MIT- BIH arrhythmia database. This provides standard investigation material for the detection of heart arrhythmia which is available publicly[MIT]. To finish the MIT- BIH arrhythmia dataset, 5 years are needed[7]. Del Mar Avionics model 445 two-channel reel - to-reel[RTR] story Holter recorders was used to made the ECG recordings and DMA model 606 playback unit was used to recreate the signals for digitization[6].

The long-term ECG's which also available to researchers without mentioning this collection, the database wouldn't be complete 1)AHA Database Evaluation of Ventricular Arrhythmia detector[8] and the European ST-T database[9].

3.1. MIT-BIH Sound Pressure Test Dataset

In ambulatory ECG recordings,Twelve half-hour ECG recording and 3 half-recordings of sound were made used as physical active voluntees[6].The MIT- BIH arrhythmia database contains P- wave annotations for 12 signals[7].

Fig 3: MIT- BIH arrhythmia database [26]

3.2. PTB diagnostic ECG database

PTB stands for the Physikalisch- technische Bundesanstalt, the compilation of digitized ECG's for research algorithmic bench marking has been provided by the national metrology institute of Germany. PTB publica is the publications database of the ptb Braunschweig and Berlin. The main part of the record begins with the year 1999[12]. Physionet bank produces databases which was conducted for the detection system test. The ECG database collected from this direction test from 52 healthy patients and 148 diagnosis ML patient has a result sensitivity level is 73% [11].

Table 1: Result of MI and Healthy persons [11]

TYPE	NO OF SUBJECTS	NO OF RECORDS
Healthycontrol	52	82
MI	148	369

4. Methods

4.1. Data Preprocessing

Raw data is transformed into an understandable format is called data preprocessing. It consists of enormous repetition as well as uprooted heartbeats and obvious sound and faults, later it will not be used in preprocessing. Preprocessing improves classification accuracy and execution time by extracting only clinically relevant markers. This markers measures the cardiac electrical cycle.

The P waves occur when the arteries contract during the arterial depolarization at the time of the sequence of waves in ECG, whereas the QRS complex occurs when the ventricles contract during ventricular depolarization at its end is the J point. To eliminate the high-low frequencies noises and the other disturbance, the ECG signals were preprocessed using filtering algorithm. The baseline wander absorbed by ECG signal is the low frequency noise [23]. To overcome this noise, 0.5 Hz was used as cutoff frequency. Amplified sinus noise occurs at a frequency of 50Hz. Four algorithms were developed to detect the QRS speak detectors. The four algorithms were developed by Behar [16] Zhang [17] pan and Tompkins and difford [16]. To extract the features, QRS peaks are essential. QRS peak detectors are two best techniques to evaluate the signal quality indexing [18].

The duration of the QRS complex and P & T waves of relevant and clinical markers are recovered by filtering the raw ECG waveforms in processing.

4.2. Data Extraction

A kind of data gathered or recovered from a variety of sources is data extraction.Here, the features are extracted from the ECG signal by detecting P,Q,R,S and T waves. Denoising technique is one of the practices to expose the QRS complex. First, dissimilar frequency components can be obtained by segmenting and then QRS complex can be extracted. To detect the QRS accurately, cubic spline wavelet is proposed[20]. Different types of diseases and abnormalities can be represented using different features QRS complex is used to extract because it has a sharp biphasic or triphasic wave of 1mv amplitude and duration 80-100ms[21].

ECG features can be categorised as statistical, wavelet based and morphological [22]. In Pan and Tompkins algorithm, first the interference of ECG is filtered out using band pass filter. Then this filtered signal is categorized basedon slope, amplitude and width to accurately detect, QRS complex[1].

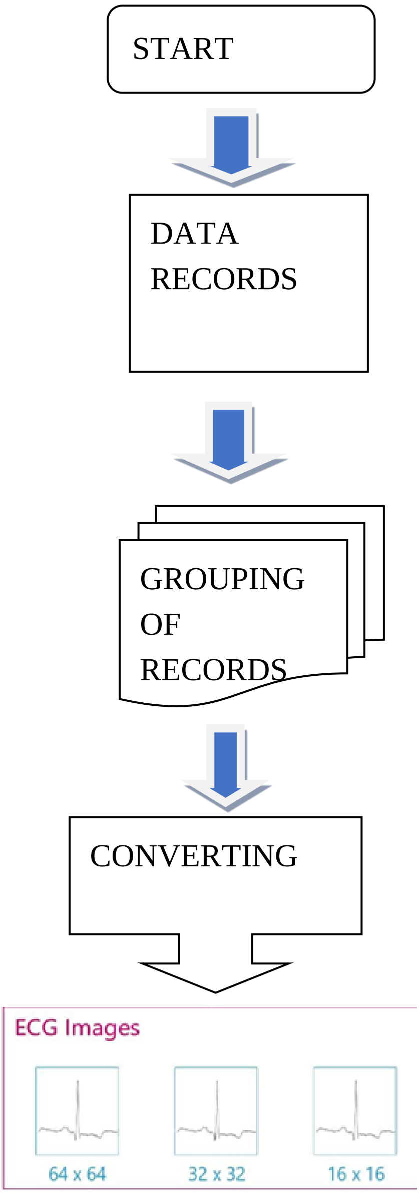

Fig 4: Steps in Preprocessing

First extracted feature is QRS complex based on other morphological features. The mean ,range and variance , standard deviation, Shannon entropyetc of ECG signals are called statistical features[1]. At last, the wavelet is used to decompose the ECGsignal into a number of segments with multiple resolutions[1].

5. Classification Of Diseases

CVD is the class of diseases which can be detected using deep learning techniques. Deep learning is alike to the human brain which make use of innovation concern. Deep learning or deep neutral network(DNN) isthe subset of ML. The main motive of a neural network is to get inputs, then to perform calculations and to produce output in the classification of ECG signals. The CVD diseases can be predicted using various deep learning systems such as Convolutional neural network[CNN], Recurrent neural network[RNN], Auto encoders, Deep Belief Networks[DBN], Long short term memory networks[LSTM].

5.1. Convolutional neural network

Detection of CVD diseases can be carried out by deep learning techniques. Deep learning techniques work just like a human brain.

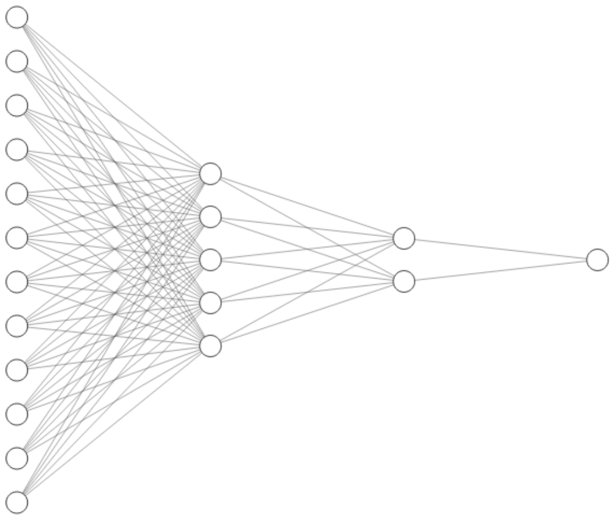

Fig 5: Strucure of CNN with various layers

The characteristics are obtained from the above first three layers whereas the fourth layer involves in charge of classification. The accuracy of this structured data using CNNmodel goes up to 85-88%. CNN works on single input single output fashion. The sensitivity and specificity are 98.33% and 98.35%.

5.2. Recurrent Neural Network

A variant of artificial neural network which makes useof a series of time input is called Recurrent neuralnetwork. The data at an instant is given to the network whereby we get the output which is the addition ofvalues in the memory. The accuracy of RNN method is 98.4%.

5.3. Auto encoders

Auto encoder is a type of ANN which is used toprovide proficiency in efficient coding of unlabeled data. Classification of CVD based on missing dataimputations and sleep breathing helps auto encoder reach the stage of the art. Framingham and Cleveland heart disease, the accuracy of the result was found to 97.3% and 96.1%.

5.4. Deep belief network

Deep belief network addresses the issues with classic neural network. This is a hybrid generative graph model. The top 2 layers have no direction whereas lower layer has directed links [31]. It is a learning model using a training set. Features extracted from ECG are sent to the deep belief network to address the issues. First it initiates the parameter and it enters into training data using CD algorithm it satisfices rare and at last it tunes the network parameter.

5.5. Long short-term memory network

It's a variant of artificial Recurrent neural network that has the ability to grasp the order dependence in sequence prediction problems. Three gates are available in the LSTM are disregard gate, in-gate, out-gate. The accuracy rate of LSTM for prediction of CVD is found to be 95.32 %.

5.6. Merits and Demerits of deep learning techniques

The merits of using deep learning techniques includes: It provides vigorous solution for core such as picture categorized, picture decomposition, lingua filtering, vocal identifications and Eugenic [30][33]. It requires less domain knowledge to solve the problem with the given dataset [30]. Deep learning method provides clinical support to make several efficient decisions. It helps in maintaining accurate data. Using deep learning in the health care, surgeries are performed by robots. It helps in detecting illness and analysis of results. Research and development technology uses deep learning methods in manufacturing and managing medicines. It consumes the doctor's work in analyzing and predicting the diseases as it classifies the diseases efficiently.

The demerits of deep learning algorithms include [2]. It is only apt for larger amount dataset not for smaller dataset. Data learning has CPU OR GPU'S deployed on software so it is not a real time solution. Increasing the layers of DNN techniques may results in loss of function. It mainly depends on ECG features to declare the results not on patient's physical state. This method is used only for limited classification of diseases [6 types of arrhythmia diseases], to generate some other complicated types it needs large resources.

6. Results And Discussion

At last with the help of various methods in deep learning, particular type of disease the patient affected can be identified easily. As how fast we are predicting the disease, many more death rates can be reduced. Then the doctor treats the patient accordingly a type of disease. Artificial Intelligence makes a history in the health care sciences. The Deep learning method from artificial intelligence helps in identifying and preventing the disease and also contributes a part in decision -making which benefits in reducing the mortality rates. Among several techniques in deep learning, the Convolutional neural network is considered to be the best in predicting the cardiovascular diseases with the help of ECG signal. This method is proven to be the efficient tool since it classifies different methods of arrhythmia [2].

7. Conclusion

This paper presented a study of various deep learning techniques used to predict the CVD. From MIT-BIH arrhythmia dataset and PTB, ECG data is obtained. Dataset is preprocessed, parameters are extracted and classified based on arrhythmia type. During feature extraction phase, features are extracted. QRS peaks play a vital role in disease prediction using ECG. To evaluate the signal quality, QRS detectors are used. Statistical features such as mean, variance, Shannon entropy of ECG signals are found. DCT and DWT procedures are used to decompose the waves of ECG into number of segments. From the ECG signals the P,Q,R,S and T waves are extracted during characteristics extraction. Denoising techniques are used to detect QRS complex. In order to detect QRS complex correctly, spline wavelet technique is used. ECG signals are filtered using band pass filter. The techniques like Long short term memory networks [LSTM], Deep Belief Network [DBN], Auto encoders, Convolutional neural network [CNN], Recurrent neural network [RNN] are used for classification of cardiovascular diseases from the extracted features. Accuracy of CNN model goes up to 85-88%. RNN method got an accuracy of 98.4%. Auto encoder also produces an accuracy of 97%. The accuracy rate of LSTM for prediction of CVD is about 95 %. From the study, CNN, Auto encoder and LSTM methods are found to give good accuracy results to classify the disease type faster. In future, ECG images can be combined with clinical data to provide good accuracy results.

Table 2: Performance Evaluation of classification algorithms

REFERENCE	ALGORITHM CLASSIFICATION	DATA SOURCE	PERFORMANCE
Zahra Ebrahmi et al	GRU/LSTM,CNN and LSTM	ECG arrhythmia	AF-100% (SVEB)-99.8% (VEB)-99.7%
Y Chen et al	XG Boost	Risk after total knee Arthroplasty by deep vein thrombosis	Accuracy is 0.832[95%-CI:0.748-0.916]
A.N Ardan	Fuzzy InferenceSystem	Myocardial infraction prediction technique	Sensitivity level of 73%
J. P. Kelwade et al.	Artificial NeuralNetwork	MIT-BIH arrhythmiaDataset	Accuracy-97%
VSR Kumari	Multilayer Perceptron	MIT-BIH arrhythmiaDataset	Accuracy 95% Precision: 95.1% Recall: 95.1%
C. Karande	Neural network using genetic algorithm	Prediction of Heart Attack	Accuracy 94.3 -96.4%
Sulochana wadhawani	Neural Networks, R-R Detection method	MIT-BIH Atrial Fibrillation database	Accuracy is 85%
Vicent J. Ribas Ripoli et al.	CNN, DL, Hybrid CNNLSTM.	MIT-BIH Atrial Fibrillation database	Accuracy 89.8%
Vicent J. Ribas Ripoli et al.	Deep Neural Network	Cardiology service hospital clinic, Barcelona	Accuracy-85.52% Sensitivity-91.76 Specificity-78.27%

Author contributions

Prabu Sankar N: Conceptualization, Methodology

Ramaprabha Jayaram: Software, Field study

Irin Sherly S: Data curation, Writing-Original draft preparation,

Gnanaprakasam C: Visualization, Investigation

Vinston Raja R: Writing-Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

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