ANALYSIS OF ABNORMALITY IN HEART RHYTHM USING MACHINE LEARNING APPROACH

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ABSTRACT

The human body contains a vital organ name is Heart. As any machine helps in the proper distribution of any product, our heart distributes pure blood to various parts of our body. Due to the proper flow of blood, we are able to maintain a healthy life. However, problems start if some abnormality arises in the functioning of the heart vessels. One common heart disease is arrhythmia (also called dysrhythmia), which is an abnormal heartbeat. In case of arrhythmia, the heart fails to beat at regular intervals. Sometimes, the beats are either too fast or too slow or just irregular when you are at rest or just not beating in a regular pattern. Anthemia may at times be harmless, but if left untreated for long may at times become fatal. So, to maintain a normal and healthy life, detection of anthemia at an early stage is very vital to prevent cardiac-related problems. ***This paper discusses several machine learning techniques along with their performance in diagnosing arrhythmia with the help of an electrocardiogram.***

Keywords – *Arrhythmia (dysrhythmia), D.T., SVM, ML*

1. INTRODUCTION –

The modern world is a world full of uncertainty and challenges. We are human beings; every day is fitting for our existence. Stress and strain are becoming synonymous with our daily life. To establish our identity, we unknowingly invite some diseases within our body, which, in turn, results in life hazards for us. The most common among them is heart disease – to be more precise, anthemia. A patient who has asthma has problems with insufficient blood flow within their body. Here the heart fails in proper distribution of blood to various parts of our body. As a result extra amount of blood either accumulates in the walls of the heart or in organs like the lungs or feet, which at times can lead to several health – hazards **[1]**.

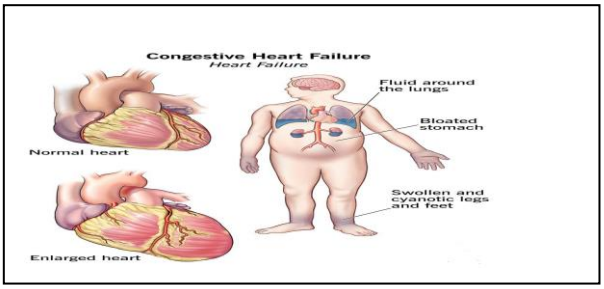

Figure: Shows the congestive heart failure symptom

Types of congestive heart failure: *Heart blockage can happen at any part of the organ most rare among them is high output heart failure. Other failures related to the heart include: - a) failure on the left side and b) failure on the right* side. High-output cardiac failure is both a rare and critical type of heart disease. The report suggests that this type of heart disease is becoming more prevalent nowadays due to changes in lifestyle. Researchers have found that only the USA has reported a case study of six million people who are suffering from this disease. To detect high output cardiac failure is a tough job. Patients suffering from this type of heart-related problem primarily have no symptoms or mild symptoms, but at times, it becomes so critical that immediate hospitalization becomes necessary. Symptoms like difficulty in breathing, chest pain, irregular heartbeat, feeling uneasy, etc., are some common reasons behind heart blockage [2].

Several factors are responsible for congestive heart disease. Most common among them are 1) blockage in the coronary artery, 2) presence of cardiomyopathy (genetic or viral), 3) congenital heart diseases (presence from the time of birth), 4) irregular high B.P., 5) obesity(if BMI is more than 30, 9), 6) smoking, 7) consumption of alcohol, 8) intake of medicine meant for cancer, kidney diseases and most vital among them is the diseases of the heart(arrhythmia).

A person affected with anthemia suffers irregular heartbeats. It generally affects the lower chamber or the ventricles of the heart, which obstructs the heart as it fails to pump enough blood to the body. A heart suffering from anthemia does not always show any sign. However, some common symptoms are: 1) a very rapid or very slow heartbeat beat, 2) Chest pain, 3) anxiety, 4) dizziness, 5) abnormal sweating, 6) feeling of tiredness, 7) fainting or a semi concuss filling etc.

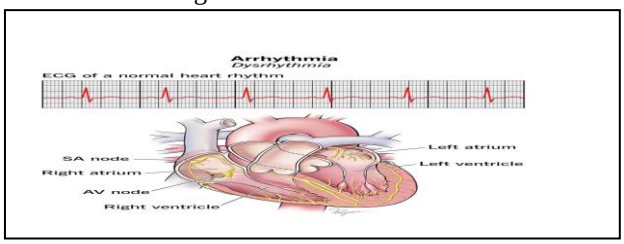

Figure 2: Common Normal Heart Rhythm

Arthemia: A heart that pumps blood to the arteries from the veins and to different parts of our body. However, when a person is suffering from asthenia, the body fails to receive proper circulation of blood to the body; as a result of insufficient flow of blood, the normal functioning of the heart and various other body parts gets affected. According to research, there are five types of arthemia. They include 1)

atrial fibrillation (AFib}, which is a very crucial and common type of arrhythmia. Reports suggest that the majority of people are affected by this type of arrhythmia throughout the world. In the USA, millions of people are affected by this type of arrhythmia. 2) atrial flutter: any problem caused by the electrical system of the heart that is a short circuit in the heart results in partial flatter [**3**]. It is a type of heart rhyme disorder of the heart. A severe type of partial flatter may result in stroke and may even cause death or permanent immobility of the body. 3) Super ventricular tachycardia (SVT): Tachycardia results in rapid movement of heartbeat (on an average of 100 to 120 beats per minute). The main difference between tachycardia and SVT is that the former begins in the ventricles and is called tachycardia. In contrast, SVT begins from the above and is called superventricular tachycardia (SVT).

4) Ventricular tachycardia: When the heartbeat of a person reduces to less than 50 bpm, it is called ventricular tachycardia. Patients suffering from ischemic heart disease are prone to this type of ventricular tachycardia. Symptoms include palpitations, shortness of breath, cardiac failure, syncope, etc.

5) Ventricular fibrillation: - It is another type of arthemia. This results in irregular heart rhythms. Fibrillation is a muscular stretching that causes individual muscle fibre to function irregularly -without proper coordination.

6) Brady cardia: - another irregular or abnormal heartbeat where the beats are less than 60 bpm. The symptoms include feeling cold, tiredness, uneasy-filling, etc. Treatment like change in lifestyle and proper medication can improve the symptoms of Bradycardia. To find out the type of arthymia a person is suffering from, various tests are recommended. Most common among them are discussed below [**4**].

For the detection of arrhythmia, it is important to find an irregular heartbeat during an examination by taking a pulse and listening to the rhythm of the heart. Listening to the heart rhythm with a stethoscope and checking the pulse rate can give an initial indication regarding the abnormality of the heart, but for more deeper investigation electrocardiogram test is more necessary.

- **Electrocardiogram (EKG or ECG):** It is the most common test for persons with heart problems. It helps to find out the electrical signal of the heart. It monitors the condition of the heart and finds out if any irregularities are occurring in the heart. This is the most common and painless test, primarily recommended by doctors. The graph paper that is delivered by the machine, after detecting the condition of the heart, helps the doctor to have a vivid picture of the condition of the patient and the stability of his heart.
- **Echocardiogram (echo):** An echocardiogram is another method applied by the medical practitioner to detect the status of the organ. Through echo the polarization activity of the heart gets checked. Echo is also a pain less procedure and is helpful to detect the condition of the patient and his heart.

Blood Tests: - sometimes blood tests are also recommended by the doctors, to detect the abnormalities of the heart. Blood test helps to find the level of sodium, potassium, thyroid, cholesterol level, etc., present in the blood, as there also responsible for silently causing arrhythmia in the heart [5].

Detection of abnormality using ML approach:

As discussed earlier, ECG is a device that detects arrhythmia through an electrical signal that gets generated in the patient's heart. These temporary electrodes help to monitor the activities of the heart. The readings/ signals are then converted to the computer screen, whose information is then diagnosed by the doctors. This is a painless procedure, and reports get diagnosed and delivered on the same day or the following day. There are three kinds of ECG tests like

a) Holter Monitor: A portable type of electrocardiogram, which can record electrical activities of the heart for 24 to 48 hours, is called a Holter monitor. It is a type of machine which was continuous, even if one is away from the doctor's chambers. It is the simplest and fastest method to detect any abnormalities present in the heart. It helps to find out the reasons behind a) irregular heart palpitation, b) arrhythmia c) unexplained dizziness. It also helps to detect ischemic and heart blockages; it also provides accurate systolic and diastolic readings, along with heart rate, mean arterial pressure, B.P. and pulse pressure. However, in spite of several advantages, one major disadvantage of the Holter monitor is that patients might not experience any symptoms of cardiac problems during the monitoring periods [6].

b) Event Monitor: Another method used to record heart electrical activities is through a portable device called an event monitor. Its activities are more or less like ECG, but this device can record events for a longer duration of time. It can be worn during normal activities, even while sleeping. An event monitor is a small monitoring device and only starts recording or functioning when if symptom arises.

c) Pacemaker: it is a device used for stimulating the heart chamber to regulate its contraction. It senses electrical pulses to understand the heartbeat at normal rhythm and rate. It also helps the heart chamber beat in normal sync for effective pumping of blood in our body. Persons who have Vardy cardia and fainting symptoms are in urgent need of a pacemaker. If pacemakers are not inserted properly one may have the chances of developing infections around the wires of the pacemaker, which at times can be fatal. After inserting the pacemaker's person can easily lead a normal life of 5 to 15 years at an easy [7]. An EKG reads that signal and monitors its impact on the heart as it contracts and relaxes during each heartbeat. The ECG signal contains the P-wave, QRS and T-wave, which use onset, offset and peak points, which are known as the fiducial points. Applying these and a set of known conditions helps to generate a data set, then apply several machine learning algorithms that help to identify various abnormality conditions. For example, a simplified ML algorithm can be used to detect abnormality conditions of the heart from an ECG report **Algo.with Description: -**

a. Identify the principal **fiducial points** on a generated ECG report.

b. Compute the statically calculated variance in the generated **R—R gap** by applying a certain threshold value.

c. Identify abnormal activity – with the help of **P waves**

- ✓ No regular atrial activity was identified.
- ✓ Any irregular abnormality activity reported. ?
- ✓ High-frequency abnormality waves are present?

Using the above algorithmic approach, the results are generated to detect the abnormality of the heart and reported accordingly [**8, 9**].

RELATED WORK

Different researchers apply distinct ML approaches to solve heart disorder-related predictions using ECG signals using classification models. **Table - 2** below describes related work, different ML methods, classifiers used, and inferences taken from the paper in tabular form.

TABLE 2: **DESCRIBES RELATED WORK, DIFFERENT ML METHODS, CLASSIFIER USED, AND INFERENCE**

Related work	**Method**	**Classifier used**	**Inference**
ECG, ML and time series analysis [**10**]	Time series and meta-analysis of algorithms	ALL ML algorithms	Performance of ML for ECG classification
ML for ECG risk and treatment [**11**]	Patients with occlusion myocardial infarction (OMI)	ML with classifier	R.F. model shows good results.
configuration of electrodes affects the result [**12**]	Developing algorithms to detect electrode misplacement	R.F., N.N. and D.T.	Better education regarding ECG acquisition.
AI-enabled ECG [**13**]	Adoption of the AI-enabled ECG	AI methods	Better Diagnosis
AI-Enabled Electrocardiogram Analysis for Disease Diagnosis [**14**]	A.I. using ECG data accompanied by modern wearable biosensor	A.I. with ML for classification	Health monitoring and early diagnosis.
ECG reflects electrical activity and checks the condition of the cardiac cycle [**15**]	AI-enabled ECG analysis	A.I. methods	adoption of AI-enabled ECG
ECG approach used for identifying CVD problems.[**16**]	Detecting ECG anomalies using DL models.	DL, NN	ECG and arrhythmia classification.
ECG analysis and classification for CVD [17]	ECG analysis for classification	CNN, DL, ML, LSTM	classification accuracy is 99.13%
Automated diagnosis of CVD diseases [18]	ECG data analysis	CNN, SVM	A system that helps for the patient's autonomy
Interpretable ML techniques for CVD [19]	Identify and characterize ECG signals.	ML, DL	Progress for ECG signal identification
Machine Learning for Detecting Atrial Fibrillation from ECGs [20]	Meta-analysis of diagnostic accuracy	ML, DL, CNN	ML is effective for detecting A.F. from ECGs
ML-based disease classification techniques. [21]	Optimized framework named WbGAS for prediction.	ML, CNN, DL	comparing the outcomes of different ML-based approaches
Arrhythmia can modify the heart's rhythms and its potential impact [22]	MMPA to identify A.F. in brief ECG data.	SVM, A.F.	For ECG recordings, HRV is effective and reliable for A.F. identification
Classifying patients using ML to build a	Building DSS for prediction	SVM, Grid search	The proposed DSS is the

DSS [23]			same as the standard ECG
An intelligent hybrid classification model for data classification [24]	Hybrid model for handling class imbalance	Adaboost, Bagging, R.F., K-NN and SVM	building intelligent and accurate IoT-enabled healthcare systems

METHODOLOGY

The techniques of separation of a data set into classes by the use of classification techniques are highly used in the medical field. Actual separation of both different types of data is performed. The starting step in the procedure is finding the class for available data points, several names that include target, output, etc. Different mathematical theories, such as L.P., D.T., and N.N. involved in categorization. Coronary disease detection can be done through categorization steps because it has two parts, that is, one has CVD or not.

A) Support Vector Machines (SVM): SVM is used for ramification techniques for data. A non linear mapping technique is used for converting the data into a higher dimension for training. To differentiate the points for the input variables of a hyperplane for classes ranging from 0 to 1. A 2D plane helps to show this as a line, and it is predicted that each point can be completely separated from its original line. The coordinating distance from the hyperplane through the adjacent data is called the margin. The line that has the most lag margin is helpful for distinguishing two classes using an optimal hyperplane. The points of this hyperplane are known as support vectors, as the name suggests; they help to define or support the structure of the hyperplane. In general, optimization techniques are used to calculate the value of the parameters which helps in the maximization of the margin level. Depending on the several kernels, the hyperplane can be decided. Kernels are different types like linear, polynomial, radial, and sigmoid. The hyperplane is used to separate the locations in the available variable space that contains their class, either 0 or 1. Margin denotes the distance between the hyperplane and adjacent data coordinates. Optimal hyperplane denotes the line that has the largest margin that can distinguish between the two classes. These points are called support vectors, as they define or support the hyperplane. The SVM is widely considered due to its efficiency in pattern classification techniques. Kim et al. [**25**] proved that the SVM in the classification for prognostic prediction. The brief mathematical description based on the SVM model is described below for the calculation. CVD with the convention of linear divisibility for training samples, we have

$$S = \{(x_1, y_1), (x_2, y_2), \ldots\ldots\ldots\ldots (x_n, y_n)\} \quad \text{-------- (1)}$$

Where $x_i \in (|R|)$, such that the design matrix X belongs to the d dimensional response space, and the response variable, CVD, is represented by , which has a binary class in the vector Y with $y_i \in (0, 1)$ in the study. The appropriate discriminating equation is given by

$$f(x) = sign\{(z, x) + \beta\}] \quad \text{---------- (2)}$$

Similarly, Z represents the vector that determines the coordination of the hyperplane (discriminating plane), and so Z, X, and β are offsets. There are infinite numbers of possible hyperplanes that are efficiently classified by the training data, which can be applied to the validation dataset. The optimal classifier shows that similar optimal generalized hyperplanes are nearer or even away from each cluster of objects. The input set of coordinates is considered optimally separated by the hyperplane.

B) Random Forest (R.F.): This ML algorithms that uses concepts of Bagging or Bootstraping aggregation. To estimate a value from a data sample, use the mean bootstrap, which is are powerful statistical approach. Lots of samples of data are taken, and the respective mean is calculated; after that, all of the mean values are averaged to give a real mean value. In bagging, the sampling method is used, but instead of estimating the mean of every data sample, decision trees are generally used. Here, several samples of the training data are considered and models are generated for every data sample.

C) Simple Logistic Regression: In the binary classification method, the values are identified in two classes. Both LR and linear regression aim to calculate the coefficient values for every input variable correctly. The logistic function acts as a non-linear function, which helps to transform any range of values from 0 to 1. In logistic regression, the prediction made is mainly used for the purpose of predicting the probability of a data instance that consists of either class 0 or class 1. It is necessary for solving problems where rationality is mostly preferred for any particular prediction. A better work from L.R. can be expected when attributes are not related to output variables. It uses the sigmoid function for classification, like

$$P = \frac{1}{1 + e^{-x}} \quad \text{---------- (3)}$$

In this case, the L.R. coefficients for each example are given as $x_1, x_2, x_3, x_4, \ldots\ldots\ldots\ldots\ldots x_n$ will be $b_0, b_1, b_2, b_3, \ldots\ldots\ldots\ldots\ldots b_n$ during the training phase. Here, the stochastic gradient is used to calculate and update values like

$$y = b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + \cdots \ldots \ldots . b_nx_n \text{ --- (4)}$$

Again

$$b = b + 1 * (y - p) * (1 - p) * p * x \quad \text{------- (5)}$$

Here, y is represented as the output value for each training phase. L.R. depends on the actual representation of the data.

D) Decision Tree: In practical approaches, D**.T.** is the most important predictive modelling and classification method. D.T. algorithm can help to detect different ways by splitting the data sets based on numerous situations. A responsive point value is treated as an actual set of values for any classification tree for a tree method-based model. The purpose of the D.T. is to solve decision-making problems that can be helpful in making building models more challenging. The steps for the decision tree are as follows

a) it divides the data set into two sub-data.
b) the total trainig data is considered as a root for an initial stage.
c) continuous values need to be classified before any model building. However, in the case of *categorical values*, preferences are given for detecting feature attributes.
d) in the case of any established subset, each subset includes data that are useful for predicting future attributes.
e) At last, repetition of steps-(a) to steps(d) continues unless we get a perfect leave.

In the case of D.T. classification, it started with recording from the root level, where values get compared with root features for succeeding record characterization. In this comparison, the equivalent values of the coming node get successfully analyzed.

E) Approach of K-NN: KNN is another supervised ML approach used for both regression and classification. For categorization techniques, the use of k labels is allowed, and for the regression, the returned value is the mean of k labels. KNN is the basic technique used for classification where earlier knowledge of data is missing. Manhattan distance is used as a distance metric for distance units for calculating the nearest data points. Knn gives better results when data is large and noisy [**26**].

RESULTS AND DISCUSSION

The proposed method uses a collected ECG data set of patients suffering from arrhythmia diseases, and using ML algorithms; there is a need to classify the ECG signal for abnormality or normality. The collected input signals are analyzed by using different filter methods like low pass and high pass filters to check the level of noise present in the signal. Detecting the peak present in the QRS area and extracting the important characteristics for the ECG signal helps to detect the presence of arrhythmia diseases. The below figure shows the difference between normal and abnormal heart rhythm from the ECG signal.

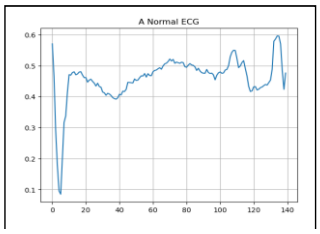

Figure 1: Normal ECG

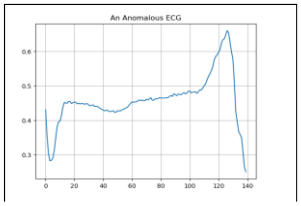

Figure 2: Anomalous ECG

Model Training: This phase uses a dataset consisting of (4045 and 10505) where 4045 are normal ECG records, and there are 10505 records for abnormal ECG signals. The split of the data set into training and testing with a random state is 1.

Here, 70% and 30% splitting ratios are used. During training checked the corresponding loss also. Below, figure 3 discusses the corresponding statistics of the model training loss and corresponding validation loss. [27] .

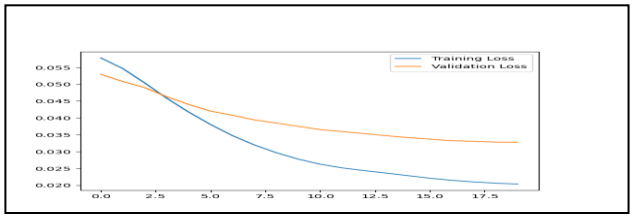

Figure 3: Model Training

During the model construction, checked for the input, reconstruction of signals and corresponding error level. These are shown in below figures 4 and 5 with training loss details.

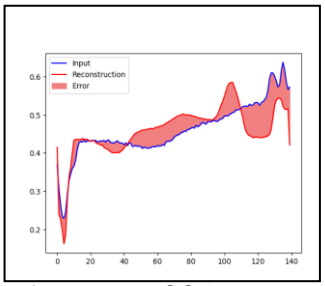

Figure 4: Model Construction

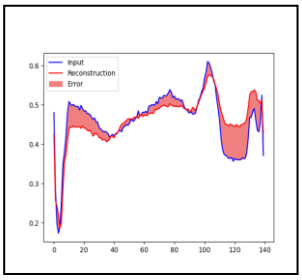

Figure 5: Model Loss

Next, we show the graph for training loss and test loss in Figures 6 and 7

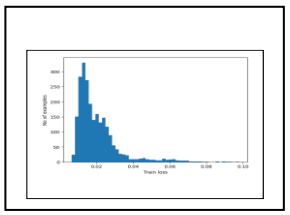

Figure 6: Training Loss

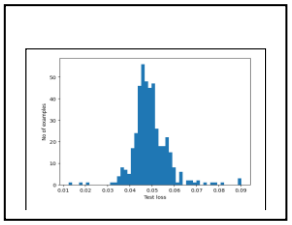

Figure 7: Test Loss

The developed model shows the following statistics, which are used for the classification of abnormality in the heart rhythms which are Accuracy = `0.94`, Precision = `0.992243`, Recall = `0.90892854`

Applying several machine learning algorithms to classify the abnormal and normal ECG signals that are shown in table 3 below.

Table 3: Comparison Matrix for ML Algorithms

SL. No	Algorithm	Accuracy
1	Naive Bayes	0.6975690152451587
2	SVN	0.8030490317264112
3	Decision Tree	0.8908117016893284
4	**Random Forest**	0.9546765554182118
5	KNN	0.6464580152451587

From the above table, it is observed that the random forest algorithm gives good accuracy as compared to other machine learning algorithms.

Discussions: The acquisition of polarization working of the heart is captured by the use of an ECG signal. This paper has tried to find out various health hazards related with the heart for its irregular functioning. As heart is a major organ of our body, any mal functioning of our heart can lead to mortality. So proper treatment of our heart needs advanced technologies for proper diagnosis and for quick and healthy recovery. Polarization and depolarization of the heart are essential as it is a continuous process that is responsible for the contraction and de-contraction of the heart for the pumping of blood among several parts of the body. Without polarization and depolarization, it never happened. One cycle of an ECG consists of patterns like P, Q, R and S signals or waves. Examining the chances of several A.I. techniques for interpreting ECG signals regarding the diagnosis of a heart condition is a common activity. The difficulty of the ML algorithm model's interpretability has hindered doctors from having confidence in the diagnosis results of ML models. Each recording undergoes a preprocessing stage in order to extract the important feature vectors from the ECG signals. From 0 Hz range to 85 Hz, the power spectrum density and HRV–based characteristics are in consideration. The preprocessing activity generates a feature vector of several dimensions. Purifying the signal by avoiding the noise level is an important challenge. As the noise level increases, the performance decreases. Arterial filtration (A.F.) is an atypical electrical activity that helps to detect the abnormal activity of the heart since chambers of the heart or atria cannot pump blood normally. Atrial tachycardia is responsible for the characterization of the heart rate that is excesses of 100 beats per minute, which is the presence of an abnormality.

Moreover, early detection is essential for avoiding fatality. Predicting mortality demands analyzing the polarization and depolarization activity of the cardiovascular system is essential. The ECG signals help to show the atrial and ventricular activity of the heart with the help of polarization and depolarization. The early detection of the symptoms related to A.F. and the prognosis of A.F. activity both need the use of ML and A.I. techniques. Further identifying abnormality and correctly classifying the abnormality are the primary concerns related to capturing ECG signal analysis. Below, figure 8 shows the ECG signal abnormality detection graph for a better understanding of the abnormality [**27**].

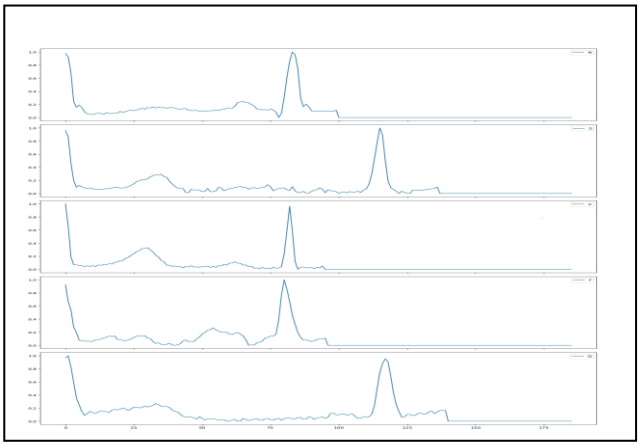

Figure 8: Abnormality Detection

CONCLUSION

Science and technologies is making a great advancement in every sphere of life including the medical field. Now a day's health hazards are also increasing at an alarming rate, especially heart related diseases. So, to cope up with the critical and complicated heart related treatments proper utilization of advanced technologies becomes necessary. Further Random Forest algorithm approach can perform better as compared to other classification techniques. Diagnosis of heart diseases from a tracing of ECG signals is complex for clinical physicians working at respective levels. These difficulties give an opportunity for the involvement of the ML techniques to analyze the ECG signals more deeply for better prediction by extracting important features. The black box nature of these ML algorithms and their respective performances helps to detect abnormality of the heart rhythm more precisely. Random forest algorithm creates different decision trees that help us to find more clarification of heart rhythms. The available heart ECG data set is preprocessed to remove noise level, then application of several ML methods, their results and complexity can easily choose the best methods. In conclusion, the respective results achieved help us better diagnose the patients with good physicians. Further new approaches should be discovered, and existing methods need to be formalized to achieve physicians ' innovation behind the use of the ML model's decision approach.

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