An ECG Monitoring System for Prediction of Cardiac Anomalies using Support Vector Machine Classification

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Abstract – Cardiovascular disease is the leading global cause of death. A normal heart rate is 60-100 beats per minute. However, heart rate higher than 76 beats per minute when in resting may be linked to a higher risk of a heart attack. It is very difficult for a doctor to read an ECG report with bare eyes. At times, there is a high chance to miss out any abnormality in the ECG report as the change in the ECG wave shape is hardly noticeable.
This paper gives cardiac anomaly prediction and monitoring ECG signal using the raspberry pi. We used an ECG module Ad8232 interfaced with Arduino board which communicates with raspberry Pi for sending the real-time sensor data to the server using WiFi technology to predict the possibility of heart disease. The disease prediction is performed by using Support Vector Machine classifier and for maintaining the security about personal health-related data we are using an encryption scheme. Hereby providing real-time values, of ECG signal we achieved 95% accuracy in disease prediction.

Keywords— Cardiac Anomalies Detection, Machine Learning, Real time Parameter, ECG monitoring, Support Vector Machine (SVM), Encryption.

I. INTRODUCTION

In the health care industry, the medical staff interacts with a large amount of patient data daily. Health IoT applications will help in controlling and monitoring chronic diseases with reduced cost and make the care process more suitable and efficient. The medical information of the patients has hidden patterns which is essential for data analysis in the prediction of Anomalies related to the heart. Heart disease is a leading cause of death worldwide from the past 15 years [3].

Heart disease Diagnosis is based on a patient's Electrocardiogram (ECG) [9] [12] [16] test. The continuous recording of an electrocardiogram (ECG) by a wearable sensor provides a realistic view of a patient's heart condition by tracking such factors as high blood pressure, stress, anxiety, diabetes, and depression [8]; during normal daily routines, we can predict the heart disease.

By using sensor we can sense the real-time ECG values. Firstly, evaluating the real-time ECG values and the other parameter related to heart disease in the trained dataset and by applying data mining technique i.e. Support vector machine [1] [7] prediction of the disease can be done. The ECG uses electrodes which have to be placed on the body of the patient from which the heart pulse is recorded in the form of electrical activity. This signal depolarizes for every heartbeat reflected over the electrical activity on the skin [15]. So by measuring the electrical pulse, we find any deep change in the ECG signal which is one of the main attributes in measuring heart disease.

Till now various systems are implemented for predicting the heart abnormalities. Dimitra Azariadi et al. implement an IoT-based embedded platform in [1] for ECG analysis and classification for heartbeat diagnosis. The proposed system is suitable for 24-hour continuous monitoring of the patient using a Discrete Wavelet Transform (DWT) for the ECG analysis and a Support Vector Machine (SVM) [7] classifier.
Tim Turner and Rob Stocker et. al. [2] achieved 97.4 % accuracy in Heart Disease diagnosis using k-Nearest Neighbors [7].
Again cardiac disease detecting using data mining technique is given by Abdul Aziz. The decision tree model [4] [3]7] is used for disease classification including factors like age, blood sugar, and blood pressure.
Fuzzy rule-based clinical decision support system (CDSS) for the diagnosis of heart disease [6] is explained by P.K. Anooj. Here the fuzzy system is constructed by the weighted fuzzy rules and chosen attributes.
W.T.Cheng and K.L. Chan et al. [17] discovered the method of Hidden Markov Model (HMM) in classifying arrhythmia. The system provides a fast and reliable method of QRS detection algorithm based on a one-pole filter which is simple to implement and insensitive to low noise levels.

II. PROPOSED SYSTEM

The proposed system enhances and expands the predictability for getting accuracy in prediction by using real-time parameter. The system divided into two main parts hardware part like Arduino, Raspberry Pi and the ECG module AD8232 [9] for measuring the electrical activity of the heart over some time using electrodes placed on the skin. It detects the tiny electrical changes on the skin that arise from the heart muscle.

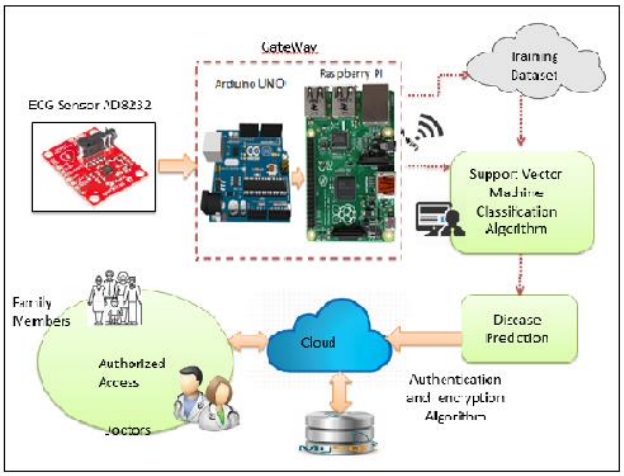

Figure 1. System Structural Design

Figure 1 shows the structural design of the proposed system. The AD 8232 sensor module can sense the real-time signal values from the patient's body. The ECG signals are extremely noisy this particular module extract, amplify, and filter small biosignals and remove noise so that identifying the peak values form the signal is easy. The LED light on the module gives regular movements rhythmically in a heartbeat. Combination of the Arduino converts the analog signal to digital and raspberry pi transfer it over the internet. By applying the support vector machine algorithm on the real-time sensor data and previous trained data set we can predict heart disease. This data is stored in the cloud to provide privacy i.e. the information used only by an authorized person such as family members or the doctors. By using the encryption algorithm data can be stored on the cloud.
The proposed system helps to detect two types of arrhythmia i.e. Bradycardia and Tachycardia [18].

A. Bradycardia

In Bradycardia the heart rate is slower than normal. The normal heart rate for adults is 60 and 100 times a minute. In the case of bradycardia, the heart beats for fewer than 60 times a minute.
In heart doesn't pump enough oxygen-rich blood to the body so it can cause a serious problem. However, bradycardia doesn't cause symptoms or complications in some people for them it not as that serious. Particularly healthy young adults and trained athletes. For them, bradycardia isn't considered a health problem
Symptoms:

- Dizziness or lightheadedness
- Fatigue
- Shortness of breath
- Chest pains
- Confusion or memory problems
- Easily tiring during physical activity

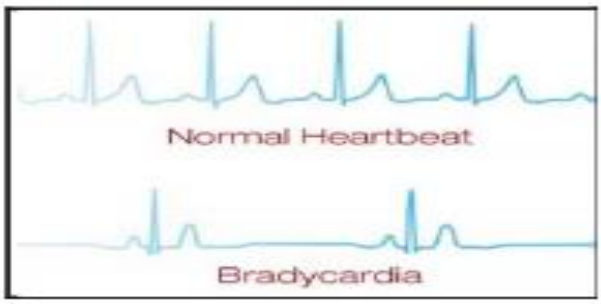

Figure 2. Bradycardia

B. Tachycardia

Tachycardia is a common type of heart rhythm arrhythmia in which the heart beats faster than normal while at rest. In the case of Tachycardia, the heart beats for more than 100 times per minute. When the electrical signals in the organ's upper chambers fails, it accelerates heart rate. It beats so fast that it can't fill with blood before it contracts. That reduces blood flow to the rest of your body. In Tachycardia the electrical signals quicken the heart rate, which is usually about 60 to 100 beats a minute at rest.

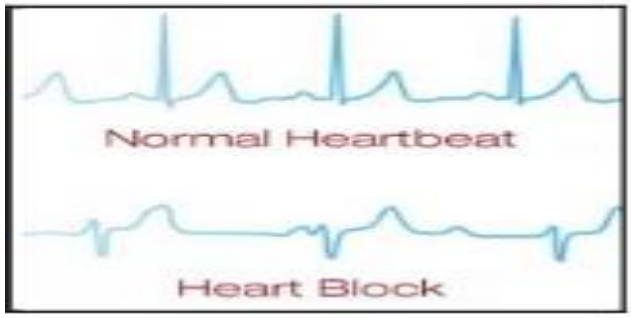

Figure 3. Tachycardia

The tachycardia is dangerous and can disturb normal heart function and lead to serious complications. In tachycardia the heart rate is increased up to 400 bpm that can cause:

- Heart failure
- Stroke
- Sudden cardiac arrest or death

In normal paints heart beats 60bpm = 1bit/second

In tachycardia heart beats 400bpm i.e. 1 bit /0.15second

Symptoms:

Tachycardia can cause the following tachycardia-related signs and symptoms

- Shortness of breath
- Lightheadedness
- Rapid pulse rate
- Heart shivers — a racing, uncomfortable or irregular heartbeat or a sensation of "flopping" in the chest
- Chest pain
- Fainting (syncope)

III.ALGORITHM USED

A. Support Vector Machine Algorithm

- SVM is a powerful classifier that is able to distinguish two classes. SVM classifies the test image in to the class with highest distance up to the neighboring point in the training.
- SVM training algorithm built a model that predict whether the test image fall into this class or another.
- SVM necessitate a vast training data to decide a decision boundary and computing cost is very high although we are using single pose (frontal) detection.
- The SVM is a learning algorithm for classification which attempt to discover the finest distinguishing hyper plane which minimize the error for unseen patterns.

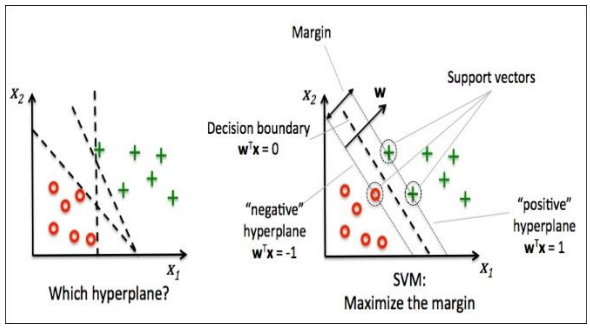

Figure 4. Distinguishing Hyper Plane to Minimize the Error

- The data which cannot be distinguished the input is mapped to high-dimensional attribute space where they can be separated by a hyper plane. This projection is well performed by means of kernels.

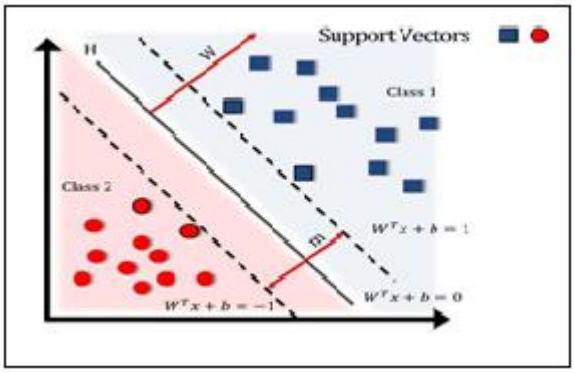

Figure 5 Separating Hyper Plane by Equation

- If training set of samples and the equivalent resultant values {-1, 1}. So SVM intend to get the best separating hyper plane specified by the equation WTx+b that make use of the distance between the two classes as shown in above figure.

B. AES (Advanced Encryption Standard)

AES is a modification of Rijndael that has a permanent block size of 128 bits, and a key size of 128, 192, or 256 bits. The Advanced Encryption Standard (AES) algorithm is one of the block cipher encryption algorithm. This is used for encryption and decryption of text. AES works by repeating the same defined steps multiple times.

IV. IMPLEMENTATION DETAILS

Accurate and exact prediction of heart disease mainly depends on Electrocardiogram (ECG) data. An ECG signal can trace the various physiological and abnormal conditions of the heart. According to the P, Q, R, S, and T [9] changes, the system may predict if the user potentially suffering from heart disease or not.

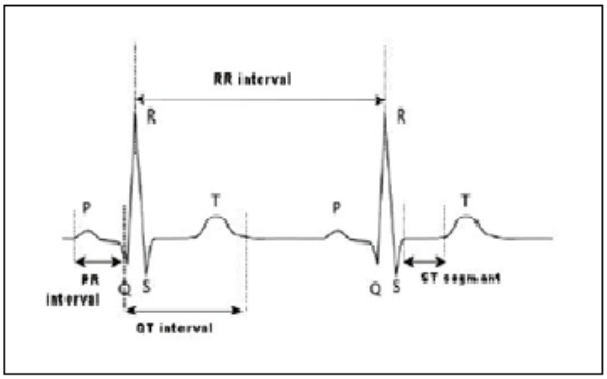

Figure 6. ECG Signal Intervals

The recording of an ECG on standard paper allows the time taken for the various phases of electrical depolarization to be measured, usually in milliseconds. There is a recognized normal range for such 'intervals':

- PR interval: Normal range 120 – 200 ms (3 – 5 small squares on ECG paper).
- QRS duration: Normal range up to 120 ms (3 small squares on ECG paper).
- R-R interval: 1 second
- Q-T interval : 0.36-044 sec
- R-wave : 1 millivolt
- P-wave duration: 0.06-011 <0.25 sec
- T-wave duration : 0.16 <0.5 sec

A. Data Set Used

According to the P, Q, R, S and T value changes, the system predicts if the user potentially suffering from heart disease or not. We used the dataset from

https://www.kaggle.com/shayanfazeli/heartbeat

And the actual ECG sensor data by placing the sensor at the positions as shown in figure 7. We have tested the data with 10000 records to get an accurate prediction.

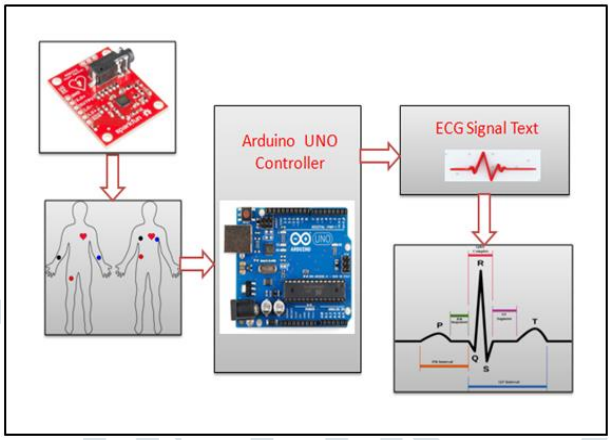

Figure 7. Dataset Preprocessing (1)

By applying classification algorithm on the extracted

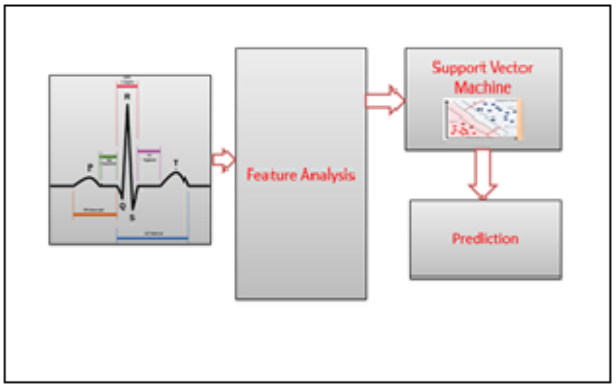

Figure 8. Decision Making (2)

Features of ECG signals and trained data set, abnormalities of ECG signals of the particular individual system takes the decision about the heart disease.

B. Experimental Set Up

The experimental set up is as shown in figure 4.7. It includes Raspberry Pi and Arduino based system that records the ECG signal of the individual and send it to the server. There is serial communication between raspberry pi and Arduino microcontroller.

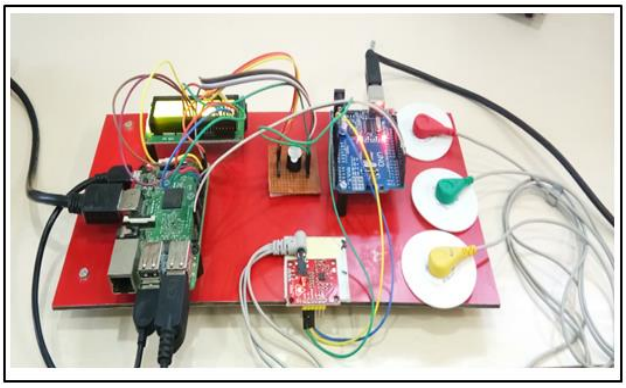

Figure 9. Experimental Setup

By connecting the sensor AD8232 as shown in figure 10 we can get the actual values of heartbeats of the patients. These values are sending to the server with the help of raspberry pi and on the server-side, a file is generated with these ECG records with the current date .txt. This file values are testing data for SVM which will then predict the abnormalities.

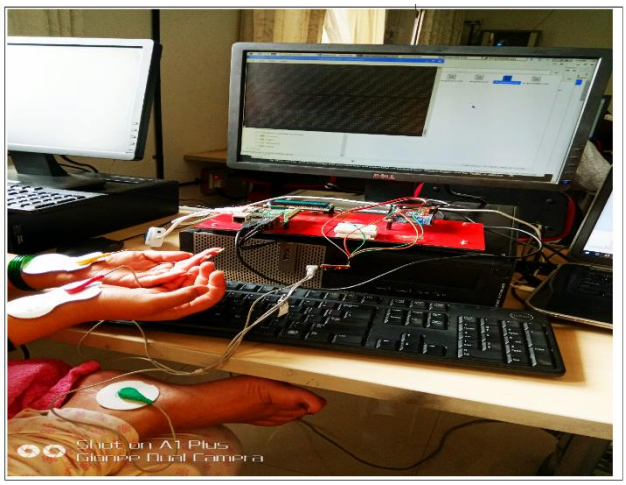

Figure 10. Actual ECG Values of the Patient

The system can detect the abnormal wave by detecting the first level of the heart block. If the ECG gives the values of P-R interval over 200 ms or less than 120ms then it is abnormal wave.

C. Result Analysis

The accuracy of the proposed system is calculated in terms of TP, TN, FP and FN by using WEKA tool. Here we have given the .ARFF file as an input to the SVM classifier to predict the patient is abnormal or not.
The classification report of the system with the help of WEKA is shown below. Here we are considering the two classes a and b. Where class a indicates the Normal patient and class b gives an Abnormal patient.

TABLE I: Classification Report

Class	a	b		FN
a	4791	192	a= Normal	192
b	219	4798	b=Abnormal	219
FP	219	192		

From above classification report the confusion matrix of the system is shown in below table.

TABLE II: Confusion Matrix

Class	TP	TN	FN	FP
a	4791	4798	192	219
b	4798	4791	219	192

The system performance is calculated in terms of accuracy, precision and recall of the system.

- **Precision:** It is the percentage of our result which are relevant. It is calculated with the formula

Precision=TP / (TP + FP)

- **Recall:** It is the percentage of the total relevant results correctly classified by our algorithm.

Recall = TP/ (TP + FN)

- **Sensitivity = TP / (TP + FN)**

- **F-score = 2*TP / (2*TP + FP + FN)**

- Accuracy of the system is calculated using formula below.

Accuracy= TP+TN/ (TP+TN+FP+FN)

With the help of above formulas we can define the accuracy the proposed system. Here we are getting the accuracy of the proposed system for prediction of the cardiac arrhythmia for both the classes is 95.89% which is cross-verified using WEKA.

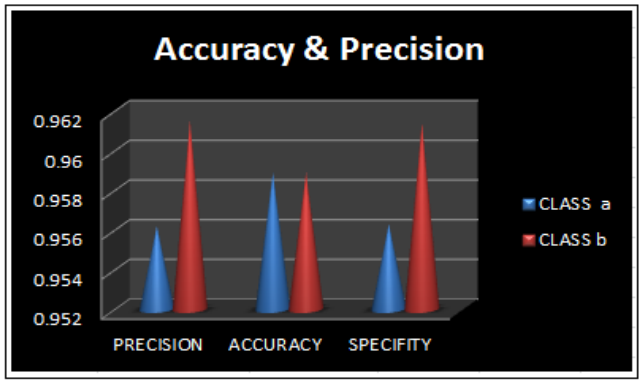

Figure 11. System Performance

Comparing the proposed system with existing algorithm like Logistic Regression,

TABLE III: Algorithm Comparison

Algorithm	Tested On	Correctly Classified Instances	InCorrectly Classified Instances	Accuracy(%)
NB Classifier	10, 000	8055	1945	0.8055
Logistic Regression	10, 000	7555	2445	0.7555
K-Nearest Neighbor algorithms	10, 000	8989	911	0.8989
Random Forest	10, 000	8255	1745	0.8255
SVM(Proposed)	10, 000	9589	411	0.9589

Naive Bayes [7], K nearest neighbor [7] [18] and random forest we find that our system gives the maximum accuracy in prediction of heart disease.

The graphical representation of the above table is shown in the below figure which clearly shows that the proposed system is more accurate than the existing one.

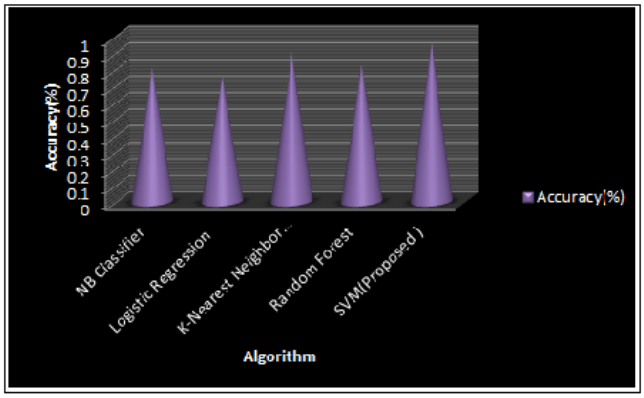

Figure 12. Algorithm Comparison

V. CONCLUSION

The cardiovascular diseases can occur due to improper functioning or sudden changes in the major parameters like extremely susceptible heartbeat value and variant. Therefore the technique for the prediction of heart disease is clarified by considering the actual parameter value of the patients like heart rate. The proposed system can help to predict the possibility of having heart disease using the support vector machine algorithm. This algorithm gives 95.89% accuracy by considering the actual ECG parameter. All patient health-related information is stored in the cloud with encryption securely.

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