



Analyzing Tachycardia, Bradycardia and Transmitting ECG Data Using MATLAB

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Abstract: In wireless sensor network, particularly in health care applications, processing of ECG signals is the difficult task because of complex waveforms and noise involved. MATLAB is one of the powerful tools that can be used for processing the ECG signals. In this paper we have used this tool to process the ECG signals acquired from an online ECG database. As lot of information is contained in the ECG signal that describes the heart functionality, we have focused only on "Tachycardia" and "Bradycardia" to make decisions using support vector machine (SVM). For demonstration, we have presented the processing of two patients' ECG and found the maximum accuracy of 94% while making decisions. Further, we have used Dijkstra's Algorithm to send the processed ECG data from a wireless node to a remote location using a shortest path. A simulation of shortest path is also demonstrated that any WSN based applications can use for efficiently transmitting the data.

Keywords: Bradycardia; Dijkstra's Algorithm; Health Care; Heart Rate Variability; MATLAB; Tachycardia; Wireless Sensor Network

I. Introduction

Electrocardiogram (ECG) is a technique of measuring and understanding the functionality of a human heart. Output of the ECG machine is a complex waveform which only a doctor can understand. Therefore, after getting ECG report, the patient has to visit doctor's place for the treatment. Many of the countries are suffering from cardiovascular diseases (CVDs). A quote was identified in a population bulletin stating that "Projections to 2030 indicate that more than 60 countries will have at least 2 million people age 65 or older" [1]. Considering the old age, doctors always advise older to get their health check on regularly basis. The health check involves vital body parameters like blood testing, blood pressure, sugar etc. ECG is another one of the vital parameters used by doctors for knowing the functionality of human heart and cardiovascular diseases. Figure 1 shows a projected mortality trend from 2008 to 2030 published by "World Health Organization in collaboration with the World Heart Federation and the World Stroke Organization" where it is shown that CVD, as encircled in blue, is one of the major chunks for causing deaths globally [2]. Probability of heart-attack increases by the age. Therefore, elders (particularly old age people) are always advised by doctors to go through the ECG test to know how their heart is functioning so that the doctor can give preventive treatment to the patient based on the measured ECG parameters.

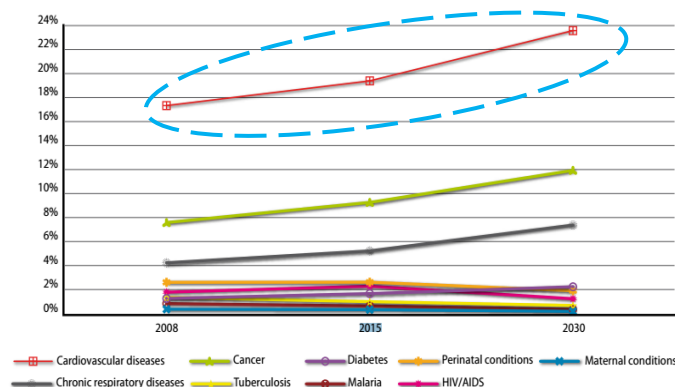


Figure 1 Projected trends of various causes of death including CVD

Therefore, in case of a larger patients' queue in a hospital, it is quite difficult for the doctor(s) to analyze the ECG reports of all the patients. This manual process of analyzing the ECG reports is time consuming and quite tiring for doctors. There exists lot of methods for analyzing and processing the ECG signals [3-7]. Objective of

any WSN based applications used in ECG monitoring is to employ light weight sensors with processing and communication unit. Figure 2 shows a WSN based fundamental arrangement of measuring the ECG signal and transmitting the processed ECG signal to a remote doctor for diagnosing purpose. The arrangement comprises three basic components (Sensors, Processor, and Communication) described below in light of ECG processing [8, 9]:

- (a) *Electrodes:* These are the sensors which are mounted on the human skin for sensing the bioelectric potential generated by heart muscles as explained in the next section of this paper.
- (b) *Processing Unit:* After acquiring the measured electric potential from the electrodes, electric potential is further amplified and processed and converted into a recordable form that a doctor can read for diagnosing purposes. The signal can be recorded on an ECG paper or can be stored in a storage medium.
- (c) *Communication Unit:* After processing the signal, the processed information can be sent to a remote location via Wi-Fi or cellular protocols. This enables the doctors or health service providers to receive patient's ECG data for medical recommendations.

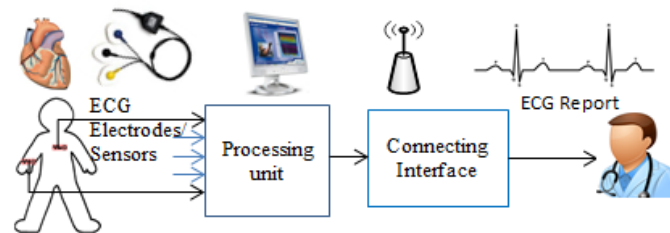


Figure 2 Components used in measuring and transmitting ECG signal

Due to advancements in the sensor technology, it is easy to replace the mesh of wires connecting the ECG electrodes/sensors with a processing unit [10-11]. As a result, wireless ECG sensors play an important role in many fields and acts as a backbone of any WSN based application. Particularly, in medical field, these sensors play the role of eyes and ears with the help of which doctors can feel how the human heart is functioning and can provide treatment well in advance in case of abnormality. For simulation or analyzing real-time ECG signals, MATLAB and LABVIEW are the two commonly used tools mostly preferred by the researchers. Lot of research has happen around ECG signal processing for identifying vital parameters like detecting Ischemia, Emotions, Sleep Apnea [6, 12-13]. To focus and differentiate from the current work, we have used MATLAB to analyze ECG signals for determining “Tachycardia” and “Bradycardia” in the ECG signal. The following sections of the paper describe how the electric pulses (ECG signals) are generated by the human heart. The paper further addresses processing of acquired ECG signal in MATLAB and applying SVM for making decisions. The last section of the paper demonstrates the ECG data transmission using a shortest path followed by the conclusion.

II. ECG Signal – Waveform Analysis

For analyzing an ECG signal, it is very important to understand the activities performed by the heart. The heart of the human is divided into four cavities: two “Atria” cavities called as input section located in upper side and two “Ventricle” cavities called as output section located in the lower side. Right atria receive the blood from body and pump into the right ventricle from where the blood is pumped through the lungs to make it oxygenated. The oxygenated blood is feed to left atria from where it is feed to left ventricle which is further pumped into arteries for circulating the blood in the body. Therefore, in such a pumping arrangement of heart, ventricle cavities play a major role. However, both the ventricle and atria cavities must operate in synchronized fashion for operating the heart functionality properly. The pumping of the heart happens due to generation of action potential as described below.

Human body is composed of living tissues/cells that acts as a power station (pump to flow blood) of the body because they are responsible for generating electrical signals of microvolts. Such cells, in a relaxing state, have a negative charge along the inner surface of its membrane and a positive charge along the outer surface. Cells in this state are called as polarized cells. Whenever the cells are stimulated or excited, the outer side of the cell membrane becomes momentarily negative with respect to inner surface. Cells in this state are called as depolarized cells. The process of polarization and depolarization as shown in Figure 3 makes the cells as tiny batteries for producing bioelectric potentials which are associated with heart activity. Similar bioelectric potentials/signals are also introduced by brain activity and muscle activity.

The wave of excitation when propagated in the muscle/cells causes the contraction which in turn produces an electric voltage called as action potentials because they are generated by action of the muscles. The generated

electric signal is measured with the help of electrodes mounted on the human body which are further amplified and recorded on a paper or stored in a memory device for further processing. The recorded data is called as the Electrocardiogram (ECG OR EKG) of the heart muscles and is represented by a waveform called P QRS T as shown in Figure 4. As both the ventricle and atria cavities operate in synchronization, the polarization/depolarization produces the waves P QRS T whose description and timing operations are described in Table 1 and Table 2 respectively.

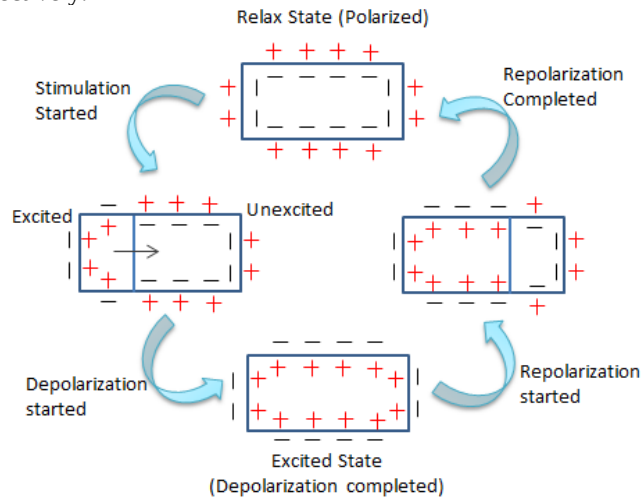


Figure 3 Electrical activity (contraction in a cell): Polarization and Depolarization of a Cell

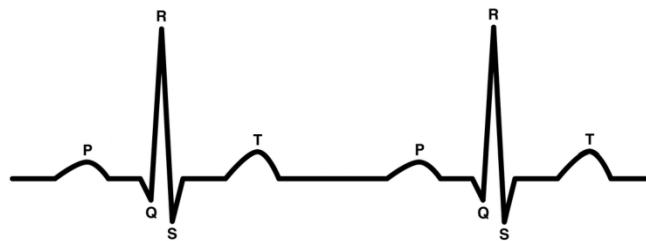


Figure 4 Standard ECG Waveform

Table 1. P-QRS-T Waveform Description

Waveform	Description
"P"	This wave is generated due to depolarization of Atria muscle.
"QRS"	This wave is generated due to repolarization of Atria and depolarization of Ventricles.
"T"	This wave is generated due to repolarization of Ventricle muscle.

Table 2. P-QRS-T Waveform Timing Significance

Waveform Duration	Description
"P" duration (<80 ms)	Abnormal "P" wave indicates Atrial Hypertrophy. Absent "P" wave indicates atrial fibrillation, severe hyperkalemia.
P-R duration (120ms-200ms)	Long P-R interval indicates blockage of atrioventricular.
QRS duration (80ms -100 ms)	Wide QRS waveform indicates blockage of left/right bundle branch, or ventricular fibrillation, or hyperkalemia.
QT duration (<440 ms)	Long QT interval indicates myocarditis, or stroke, or hypocalcemia, or hypokalemia, or hypomagnesemia. While short QT interval indicates hypercalcemia, or hypermagnesemia, or graves' disease.
"T" duration (160 ms)	A tall "T" waveform indicates left bundle branch block, or stroke, or ventricular hypertrophy. While a small waveform is produced due to anxiety, left ventricular hypertrophy, or drinking hot/cold liquid.

III. Processing & Analyzing Raw ECG Signal For Decision Making

For processing, analyzing, and transmitting ECG signal, we have chosen MATLAB to simulate the client and remote platform. ECG signal readings obtained from the ECG electrodes are stored in a text file which is being

taken as an input for processing the signal. Figure 5 shows the detailed flowchart for processing the ECG signal and Figure 6 shows the graphical representation of ECG signal processing for each step. We have considered an ECG data set of 100 people and for visualization purpose; we have displayed only ECG signals of two patients. Functionality of processing the ECG signal is divided into following five steps:

Step 1: We have used an online ECG database site “Physionet” [14] and Biopac MP45 [15] to acquire data values in voltage form which is stored in the text files. This text file is taken as an input to the Matlab for further processing in step2.

Step 2: The acquired ECG data comprises lot of noise because of power line interference. To remove the noise, a notch filter is applied to remove 50 Hz tone on the acquired signal and converted the time domain ECG signal into frequency domain. Wavelet decomposition is used to decompose the converted frequency domain ECG signal into a 10Hz signal and further a smoothing filter is applied to remove the glitches.

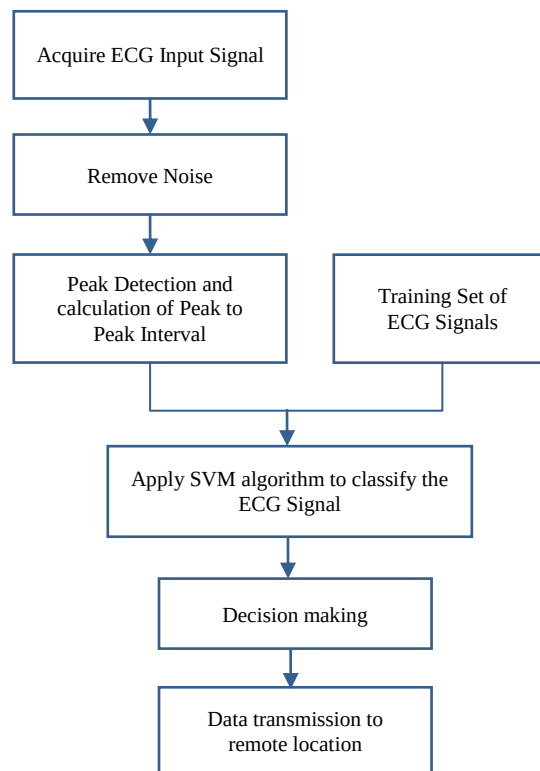


Figure 5 Flowchart of ECG signal processing

Step 3: In order to calculate the heart rate from the filtered signal, as shown in Figure 7, obtained from step 2, interval between the R-R waves need to be determined. The R-R interval plays an important role in determining the Heart Rate Variability (HRV) of the patient. HRV is also known as the variation between Beat-to-Beat intervals or sometimes also called as Normal-to-Normal beat. HRV varies from patients to patients and can also vary for an individual at a particular period of time.

The change in HRV depends on many situations like environmental conditions (like polluted air), health conditions (like obesity, diabetes etc.), psychological conditions (like depression, anxiety, stress, smoking etc.), or medication conditions. In each of such conditions, abnormality situation of Tachycardia and Bradycardia (or bradyarrhythmia) may be present in the ECG signal. Bradycardia, when the heart rate is less than 60 beats per minute, arises when the electric pulses are not transmitted from atria to the ventricles. There are various factors, like damage of heart tissues due to aging or heart attack, sleep apnea, high blood pressure, etc. that may cause the symptoms of Bradycardia. On the other hand, the Tachycardia, when the heart rate is more than 100 beats per minute, arises when the heart produces electrical pulses at a faster rate. Symptoms of Tachycardia may cause sudden death or heart attack or chest pain etc. due to generation of fast pulses. Traditional way of analyzing the ECG signal and finding HRV is very time consuming and is quite tedious in pinpointing the heart related problems.

In this paper we are using MATLAB tool for finding the mean HRV of the patient to determine whether the patient is suffering from Bradycardia or Tachycardia. To calculate the HRV, we have first identified the “R”

peaks from the filtered signal. All the identified “R” peaks are marked as red in Figure 6 (step 3). As filtered ECG signal involves peaks of P, R, and T waves, we have taken care of removing these peak values by using threshold values so that only “R” peaks are captured for calculating the duration between them.

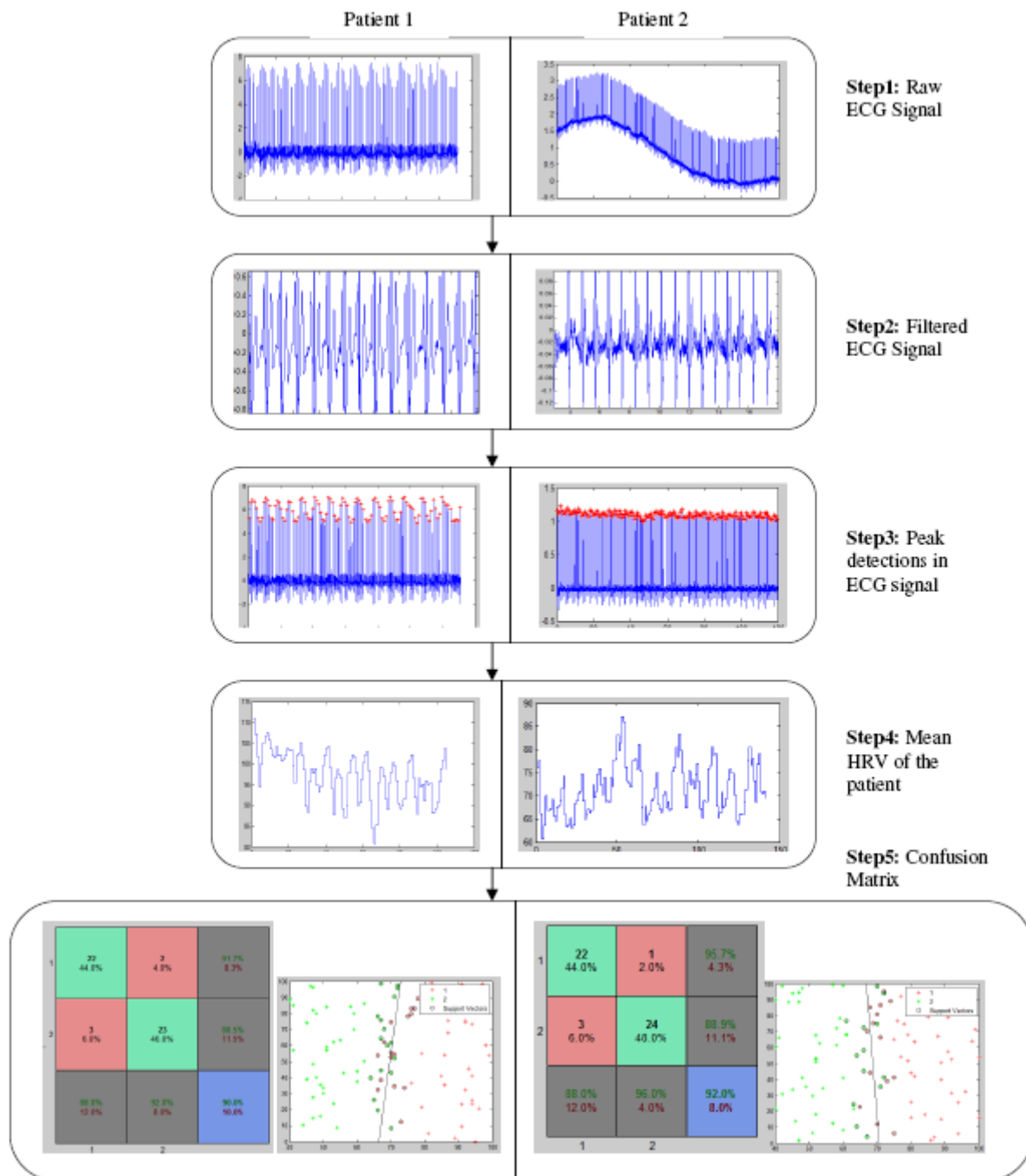


Figure 6 Graphical representation of ECG signal processing

Step 4: After calculating the “R” peaks, interval between each of the consecutive peaks, e.g. P1, P2, P3 as shown in Figure 7, need to be calculated for determining the mean heart rate of the patient. The calculated mean heart rate is shown in Figure 6 in the form of a stair wave.

Step 5: In this step, we first need to train a classifier/learning model using a set of ECG signals so that it can be used further for testing the other ECG signals for making decisions. We have used Support Vector Machine (SVM) for learning and classification of the ECG signals. SVM is a supervised learning model used to classify the data points of one class from the data points of another class. SVM finds a best hyper-plane for the separation of these two classes if the test data has exactly two classes. SVM used in this paper, as shown in

Figure 8, classifies the ECG signals into two categories: “Tachycardia” and “Bradycardia”. For classifying the ECG signals, we have trained the SVM classifier. A set of 100 different pre-processed and decomposed ECG signals are considered and divided randomly into two sets, each with 50 signals. A first set of 50 ECG signals are used to train the SVM classifier and the remaining second set of 50 ECG signals are used for the testing and making the decisions. In the training phase, out of 100 ECG signals, a sample training set of ECG values from 26 to 75 (first set) covering both the classes i.e. “Tachycardia” and “Bradycardia” are used. Class labels “1” and “2” are assigned to features, where 1 indicates “Tachycardia” and 2 indicates “Bradycardia”. After learning phase, this trained data is feed to the SVM classifier for testing the second set using the function “*svmclassify* (*svmStruct*, *testset*),” where “*svmStruct*” is a matrix of trained data wherein the rows indicate the observations (HRV) and columns indicate the features (Tachycardia/Bradycardia), and “*testset*” is the testing data for which decisions need to be made. Output of the above function comes in the form of class labels i.e. “1” or “2” which is used further for creating a confusion matrix as shown in Figure 9.

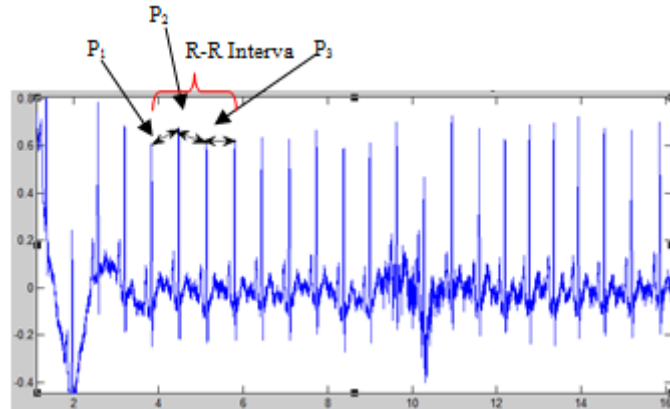


Figure 7 Real-time R-R duration of an ECG Waveform

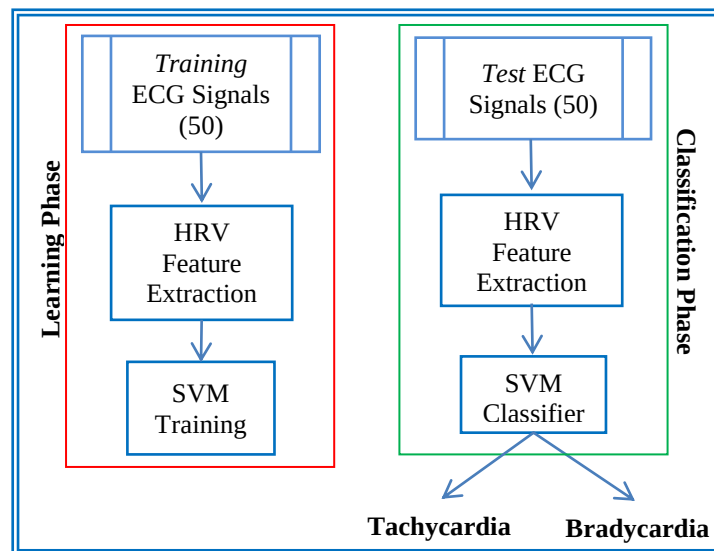


Figure 8 ECG Learning and Classification Phases

The displayed confusion matrix illustrates the actual and predicted classifications of ECG signals done by the SVM classifier. Confusion matrix as shown in Figure 9, displays the following information related to Tachycardia/Bradycardia classes/feature in the context of ECG:

- Left upper corner green box shows the correct predictions of Tachycardia labeled as 1. The box shows that 23 (46%) predictions were made correct by the classifier.
- Left lower corner red box shows the incorrect predictions of Tachycardia. The box shows that 2 (4%) predictions were made incorrect by the classifier.
- Right lower corner green box shows the correct predictions of Bradycardia labeled as 2. The box shows that 24 (48%) predictions were made correct by the classifier.
- Right upper corner red box shows the incorrect predictions of Bradycardia. The box shows that only 1 (2%) prediction was made incorrect by the classifier.

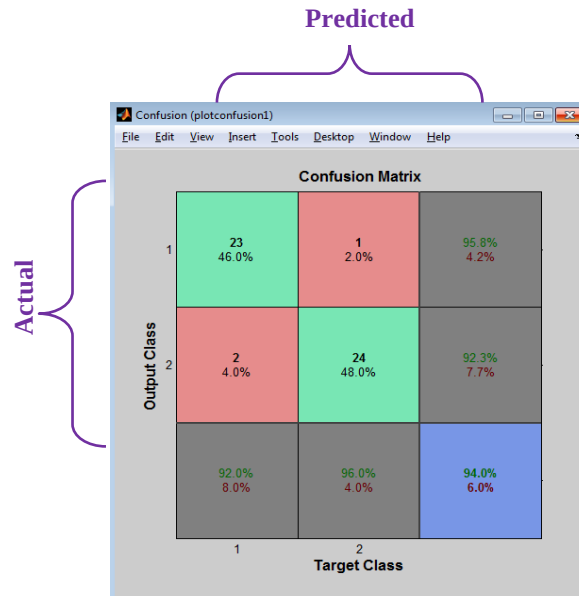


Figure 9 Confusion matrix showing decisions by SVM classifier

With the help of SVM classifier, we were able to achieve the prediction accuracy of 94% which is calculated by using the following formula:

$$Accuracy = \frac{(\text{Sum of diagonal green box values})}{(\text{Sum of red box values and green box values})}$$

IV. ECG Signal Transmission using Shortest Path

Once the ECG signal is processed and classified, it's required to transmit the ECG data from a wireless node/hospital to a remote location efficiently. Figure 10 shows the command window of MATLAB, where the code running the Dijkstra's Algorithm in the background is asking the user to enter the source hospital name and destination hospital name. For demonstration purpose, we have simulated total 15 nodes/hospitals plotted randomly. All such nodes are connected by various paths with different length. For example, we have entered source hospital as 2 and destination hospital as 5. There exist lot of paths between the source and destination nodes like $2 \rightarrow 13 \rightarrow 12 \rightarrow 11 \rightarrow 15 \rightarrow 6 \rightarrow 5$ is one of them having distance more than 105. However, the shortest path algorithm implemented in this paper displays the shortest path as shown in Figure 11, where shortest path for sending data is $2 \rightarrow 1 \rightarrow 12 \rightarrow 15 \rightarrow 6 \rightarrow 5$ having distance of 102.9294 and are encircled in red for better visibility. Therefore, once the ECG signal is processed, the data can be transmitted efficiently to a remote doctor with a suitable shortest path. With the help of ECG signal processing and shortest path implemented in this paper, a doctor can look at the processed waveforms of various patients in one go from the remote location.

```
Enter Source Hospital:2
Enter Destination Hospital:5
Source Hospital = 2
Destination Hospital = 5
distance = 102.9294
path = [2 1 12 15 6 5]
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Figure 10 Command window for finding shortest path

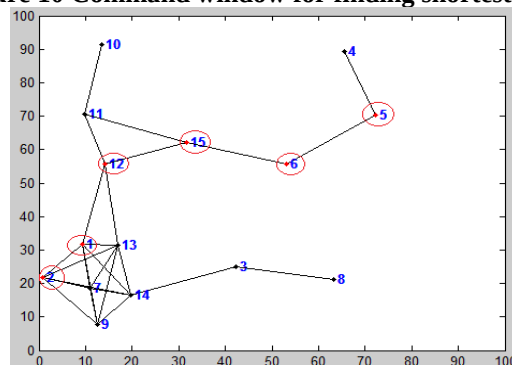


Figure 11 Shortest distance for sending ECG data

V. Conclusion

The paper described a detailed analysis on how P-QRS-T waveforms are generated by the human heart along with the significance of duration of these waveforms. We have used MATLAB tool to process the ECG signal acquired from an online ECG database. After processing the ECG signal, the paper described how SVM is used for providing the decisions related to Tachycardia and Bradycardia. It was identified that the maximum accuracy achieved with our methodology is 94% which we would like to enhance in future and hopefully, our work, after further refinement, will be able to contribute to better accuracy. Further, we have demonstrated that the processed data can be sent to a remote hospital via a shortest path. Dijkstra's Algorithm was used in calculating the shortest path. For demonstration purposes, we have processed the acquired ECG signal at the source hospital. However, the same can also be done at the remote station i.e. send the acquired raw ECG data via shortest path to a remote station for further processing and decision making. Therefore, with the help of the demonstrated work, doctors can quickly receive the ECG data and can identify the problems related to heart functionality.

VI. References

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