Bradycardia Detection and Prediction

Using ECG for Heart Beat Detection

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Abstract— **In this project, we have made an Smart Android application, that collects the ECG signal from the user and uses the data collected to detect the heart rate from the ECG signal detected. By constantly monitoring the heart rate, we ensure the users health and can possibly prevent various arrhythmia events. In our implementation, we attempt to detect and predict Bradycardia instants in the application**

Keywords—Bradycardia, ECG – Peak Detection, Detection and Prediction

I. Introduction

In this age of technology, with personal wearables being a thing of normality, the horizon for medical application broadens and a real time health assistant is no more of a pipe dream. With medical emergencies such as heart attack and stroke, it seems only better that a real time monitor that can predict possible future events of Bradycardia (slow heart rate related heart attacks) should be implemented.

ECG Signal Structure: The ECG signal is the recording of the electrical activity of the heart over a period of time using electrodes placed on the skin. ECG signal is a periodic signal of unique structure as shown in figure below. ECG Signal consists of P, Q, R, S waves that consistently repeat periodically and thus can be used to calculate heart rate by measuring the time period between consecutive P/Q/R/S waves. Best way to detect heart rate from the ECG Signal is to look for periodic instants of R-Peaks to calculate the heart rate.

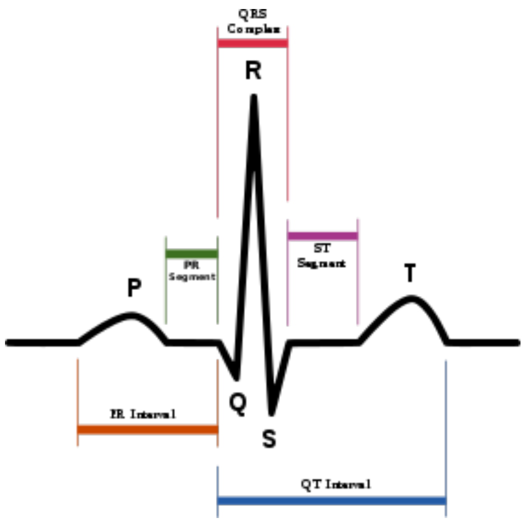
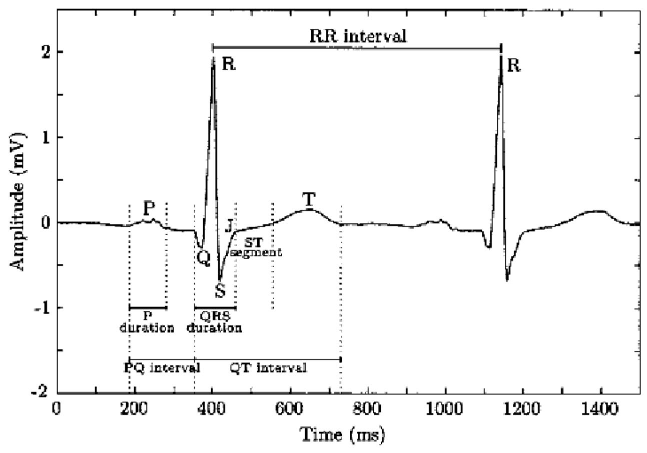


Fig: ECG Signal General Structure



II. IMPLEMENTATION PROCESS

A. Data Collection

In order to successfully attempt to develop an accurate prediction method we need an accurate sampling on the data for significant duration. To this end the whole team was wearing the sensors collected from IMPACT Lab for a duration of 8 hours per individual. This collected data was available to us in .EDF File.

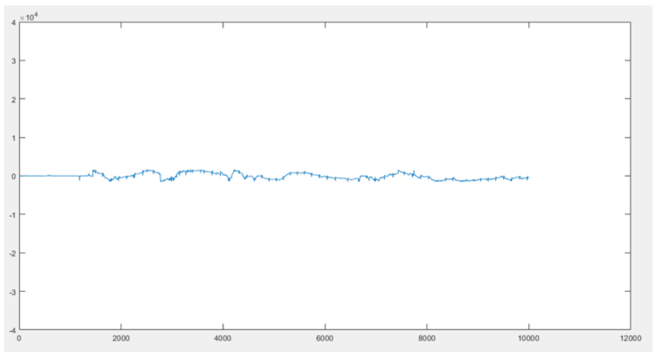


Fig: Collected ECG Signal for 8hrs data (Baseline Error Visible)

B. Preprocessing

As can be seen in Fig2, the collected data has various errors such as Inaccurate Baseline, High Frequency Noise and Inaccurate ECG Amplitude.

In order to resolve these issues we implemented the preprocessing algorithm in the MATLAB which read the

.EDF files containing the collected information about the ECG Signal from 4 people.

After much search, we found that the best way to properly preprocess the collected information is to use an implementation of Chebychev Bandpass filter for High Frequency noise cancellation and Baseline accuracy.

Chebychev Filter: are analog or digital filters that have steeper roll-off and more passband ripple or stopband ripple than Butterworth filters. Also, it is said that they have a smoother response in the passband but a more irregular response in the stopband

For our processing application, we used the Following tuning parameters in the MATLAB Code.

Passband: 2/Fn to 10/Fn

Stopband 1/Fn to 2/Fn and 10/Fn to 99/Fn

Where the Fn is the Nyquist Frequency which is half of the sampling frequency.

Having processed this data, statically on MATLAB, we use this cleaned data for Heart Rate Detection and Prediction algorithm on MATLAB as well as Android Application.

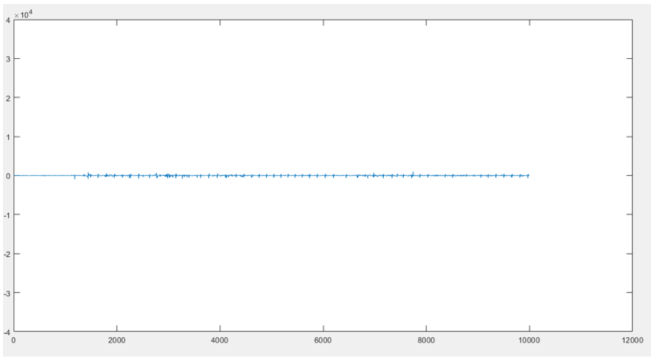


Fig3: Processed ECG Signal (Min HF Noise and Baseline Errors)

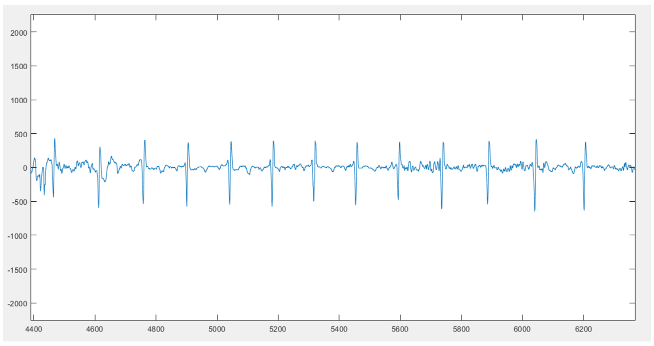


Fig4: Processed ECG Signal - Zoomed of Fig 3

C. *Detection of Heart Rate*

Once we have the processed data, we were able to use this data for our Smart Android application.

Looking into ways to detect the Heart Rate, we found multiple algorithms such as R-Peak Algorithm, Pan-Tompkins Algorithm. Exploring their implementation and accuracy, we finally used a receding window implementation of the R-Peak Detection algorithm.

The way a tradition R-Peak algorithm works to detect R-Peaks of ECG Signal is that it averages out max values of the ECG Signal provided to it and then calculates threshold value for the R-Peak in the collected signal

Challenges: Issues with this approach are that the collected data has ***baseline error and high frequency noises*** and varying amplitude ranges which get distorted over very large time period signals. Thus, directly applying the R-Peak algorithm to 8 hours data collected didn't yield the desired results as seen in Fig6.

Furthermore, as a result of measuring errors, we saw in the file that certain values are out of range uptil 4.5 which distorted the R-Peak Threshold values as a normal ECG signal is usually -1.5 to 1.5. Thus, any value in the Processed above 1.5 has been filtered out directly.

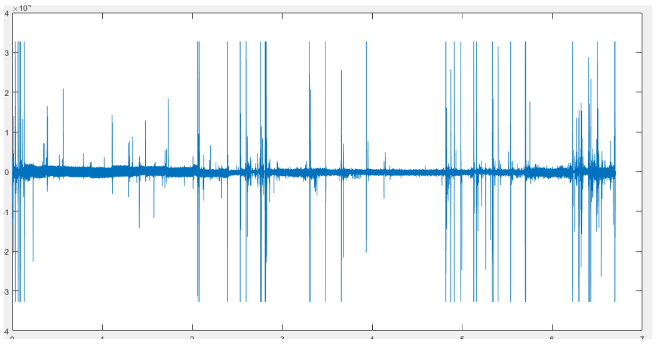


Fig5: Processed ECG Signal

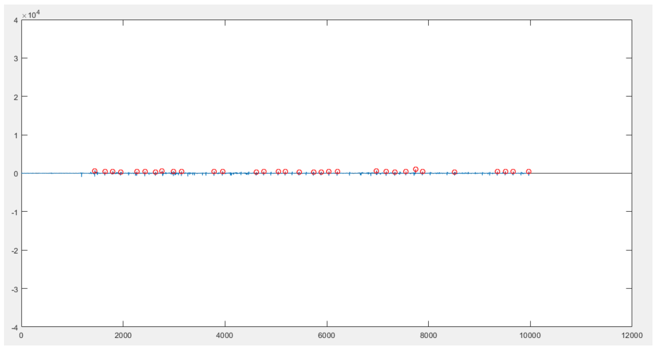


Fig 6: R-Peak Algorithm applied to 8 hour cleaned data (Red circles are detected peaks)

Solutions: A **Receding Window Detection method** has been implemented which breaks the complete data into smaller subsets of 800000 samples and applies the R-Peak Algorithm.

Benefit of doing so are two fold, R-peak Algorithm's threshold for R-Peaks are continuously evaluated and in case a certain section has erroneous measurements, rest of the detection is not implementation. 800000 is the maximum sampling limit we could set with accurate results in any one file (Fig 7). This limit would be variable from file to file of samples collected. For a real time implementation a sampling limit of 100000 works very accurately.

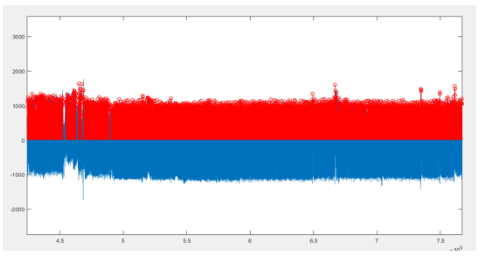
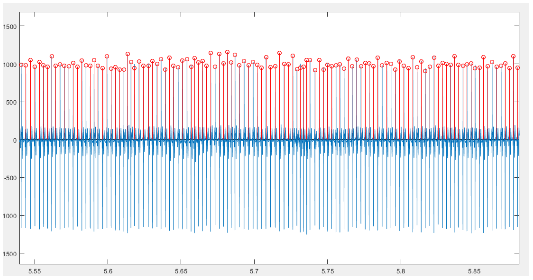



Fig7: a) The R-Peak Detection on the signal. (Red are the detected peaks)
b) Zoomed in on the Signal.

Using these detected R-Peaks, we calculate our Heart Rate as shown below.

$$Heart\ Rate = \frac{60 * Frequency\ of\ ECG\ signal}{Time\ period\ of\ R - Peaks}$$

D. Detection of Brachycardia.

In order to detect brachycardia after it has occurred, we set a threshold on the heart rate, should this go under threshold of 60 beats per min, then its annotated as Bradycardia (Fig8: Pink signal).

E. Correlation of Heart Rate and Variances in heart rate (HRV)

Using the sample data (*ekg_raw_16273.dat)*, we analysed the correlation between variance and brachycardia heart rate threshold to find if there was any way of monitoring variances and predict Brachycardia from the ECG signal collected as shown in Fig 8.

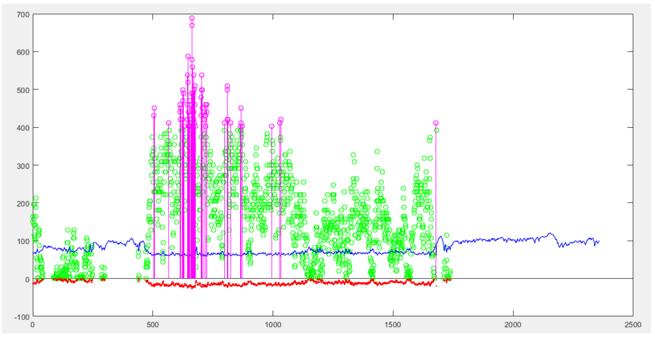


Fig8 In **Blue**: Hear Rate; **Red**: The deviation from mean heart rate of the sample tested; **Green**: Variances of Heart Rate; **Pink**: Bradycardia Instances detected

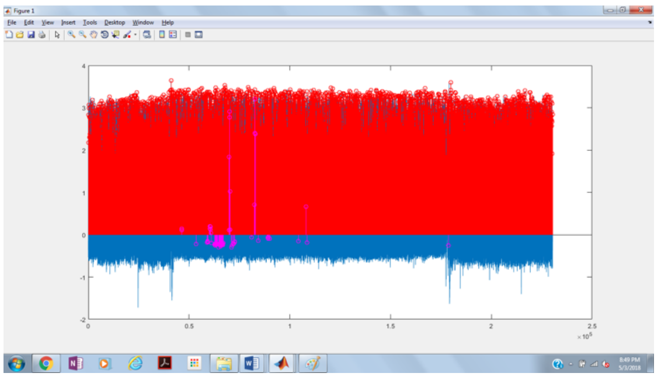


Fig9: **Pink:** Bradycardia instants overlayed with ECG

Here, The user could evaluate the performance on basis of false positive vs false negatives by simply zooming in and analysis.

<u>*Observation:*</u> In Fig8, Please note that when an actual Bradycardia is occurring it continuously denotes it as Bradycardia (continuous strip of pink at the start) vs false measurements where it is occasionally pink.

This behavior annotates pre-Bradycardia event that the variance will start increasing towards the threshold level for it. Thus, Variance could be a feature in our application.

III. IMPLEMENTATION PACKAGE EXPLANATION

A. MATLAB Implementation

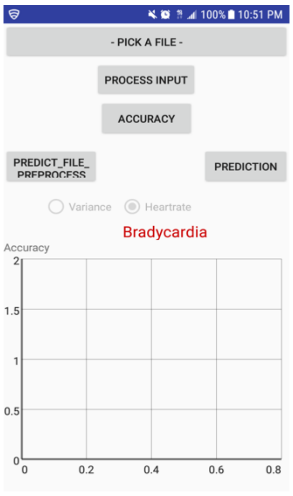
In the project package, we attach the following MATLAB Code files
Filtering.m -> Implements chebychev filter
FilteringnDetection -> Implementation of R-peak algorithm on one window
FilteringDetection-Loop -> Receding Window impelementation
Sir_Data -> Detection Code

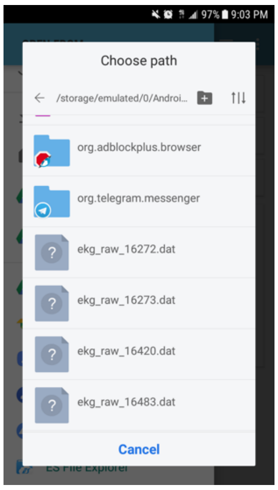
B. DESIGN AND WORKING OF APPLICATION

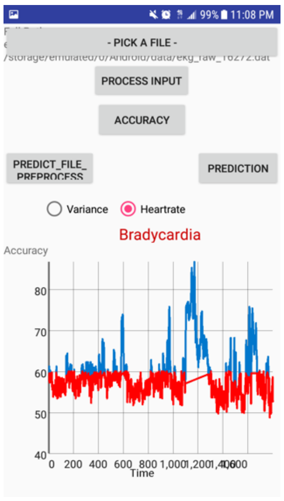
B.1. Selection of file

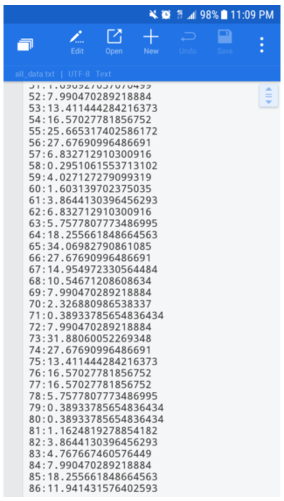
A functionality of file picker has been added to select the DAT files to be which are to be used for training the model and for the prediction process as well.

We have placed the DAT files in memory card of the device.









```
52:7.99047028921884
53:13.411444284216373
54:16.57027781856752
55:25.665317402586172
56:27.67690996486691
57:6.832712910300916
58:0.2951061553713102
59:4.027127279099319
60:1.603139702375035
61:3.8644130396456293
62:6.832712910300916
63:5.7577807773486995
64:18.255661848664563
65:34.06982790861085
66:27.67690996486691
67:14.954972330564484
68:10.54671208608634
69:7.990470289218884
70:2.326880986538337
71:0.38933785654836434
72:7.990470289218884
73:31.88060052269348
74:27.67690996486691
75:13.411444284216373
76:16.57027781856752
77:16.57027781856752
78:5.7577807773486995
79:0.38933785654836434
80:0.38933785654836434
81:1.1624819278854182
82:3.8644130396456293
83:4.767667460576449
84:7.990470289218884
85:18.255661848664563
86:11.941431576402593
```

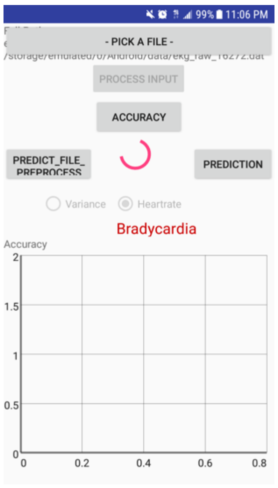
B.2. Processing the files

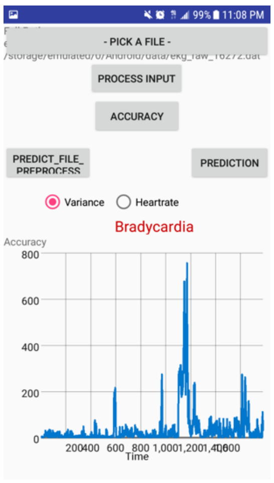
After the file has been selected, we proceed to process the input. Using the peak detection algorithm we calculate the heart rate and the variances of the input. As soon as a variance is calculated, it is appended into a text file, which is placed onto the SD card of the device.

This recorded variance is further used as a parameter for the SVM model. The graphs of HeartRate vs Time and Variance vs Time are plotted. These options can be selected using the radio buttons. Multiple toasts are launched which provide the details about system performance and the presence of Bradycardia in the file provided.

The graphs are plotted using GraphView and can be zoomed in or zoomed out for inspection. The red line indicates the detected Bradycardia.

We annotated bradycardia events which were used to evaluate the performance of our algorithm. For this task we chose the threshold of heartrate as 60 beats per minute.



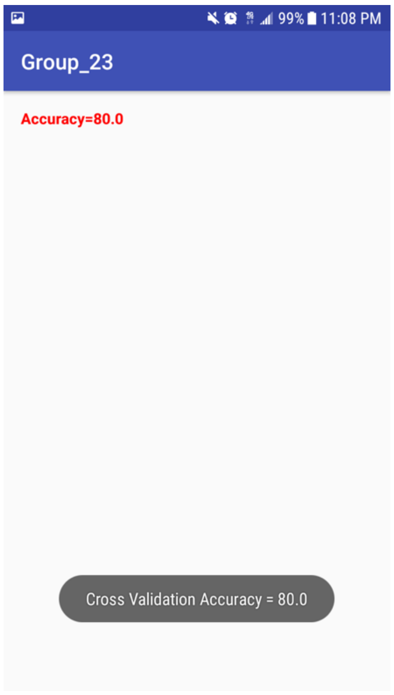


B.3. Calculating the accuracy of the model

The variances stored in the text files are given as input for training the model.

The annotated data is used for testing the model and getting the accuracy.

The k-fold cross validation is performed and the calculated accuracy of the model is displayed. The k value used for performing this operation is 3.



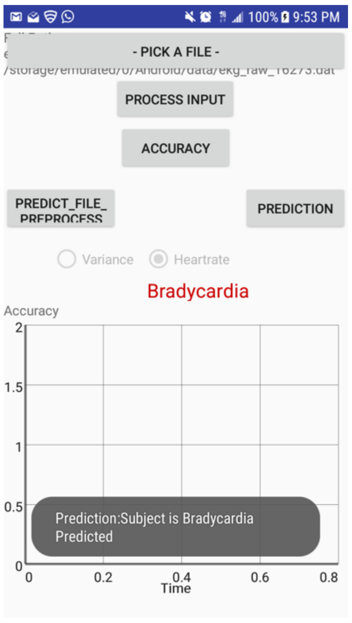
Accuracy=80.0

Cross Validation Accuracy = 80.0

B.4. Prediction

A file is again selected using a file picker which needs to be predicted. The trained SVM model predicts if the file has Bradycardia instances or not.

A toast is used to display the outcome.



Prediction:Subject is Bradycardia Predicted

IV. TASK COMPLETION EVALUATION

Data Collection		
1.1 - 1.4	Each member wear sensor and collect data	All
1.5	Read IRB and accept	All
Data Preprocessing		
2.1	Clean ECG	Sushant, Tanmay
2.2	Annotate R-Peaks	Sushant, Tanmay
2.3	Implement R-Peak Detection	Sushant, Tanmay
2.4	Derive Heart Rate	Sushant, Tanmay
2.5	Plot Variance vs time	Sushant, Tanmay
Brachycardia Detection		
3.1	Brachycardia Detection	Yash, Sushant, Tanmay
3.2	Annotate Brachycardia	Yash, Sushant, Tanmay
3.3	Evaluate performance	Yash, Sushant, Tanmay
3.4	Implement Android Application	Yash, Sushant, Tanmay
3.5	Execution Time	Yash, Sushant, Tanmay
Brachycardia Prediction		
4.1	Variance vs Time: Pre-Bradycardia event	Saurabh, Yash
4.2	Threshold Based Bradycardia prediction	Saurabh, Yash
4.3	Evaluation	Saurabh, Yash
4.4	Machine Learning Implementation	Saurabh, Yash
4.5	K-Fold cross validation	Saurabh, Yash
4.6	Evaluation	Saurabh, Yash

V. ACKNOWLEDGEMENT

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VI. REFERENCES

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