Android Based Sleep Apnea Monitor

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CONTENTS

- Introduction
- Existing System
- Objective
- Literature Review
- Block Diagram
- Work Done
- Results
- Conclusion
- References

INTRODUCTION[3]

- Sleep Apnea is the abnormal pauses in breathing during sleep.
- 2 classes
  - Central Sleep Apnea(CSA).
  - Obstructive Sleep Apnea(OSA)
- Symptoms - snoring, pauses in breathing during sleep, choking or gasping for air following breathing , daytime sleepiness , headaches, dryness of throat , lack of concentration ability, urination at night, depression and irritability, and obesity

EXISTING SYSTEM

- EXISTING SYSTEM[4]
  - Polysomnography(PSG)
- Thorough and reliable test.
- 100 % Accuracy.
- Full night sleep under doctors and nurses supervision.
- Breath air flow, respiratory movement, oxygen saturation, EEG, EMG, EOG, and ECG, as well as body position.

DRAWBACKS

- Also has its problems
  1. Have to stay in hospital for one night.
  2. Have to be hooked up to a no: of electrodes.
  3. A Doctor has to stay with the patient through out the night.
  4. Uncomfortable.
  5. It is an expensive process.
  6. Many sleep centers worldwide are currently operating at full capacity.

OBJECTIVE

- Android Based Sleep Apnea Detection.
  - Detection of QRS complex from ECG signal
  - Detection of R-R interval from the ECG signal
  - Calculation Of Heart Rate.
  - Extraction of Features.
  - Detection of Sleep Apnea Episodes.
  - Classification based on severity.

LITERATURE REVIEW

- PSG as a golden standard.
- ECG and Photoplethysmography signal for detecting Sleep Apnea.
- However, PPG does not provide any details about the severity of Sleep Apnea.
- EDR and RR-interval.
- Cyclic variation of heart rate (CVHR).

QRS COMPLEX DETECTION[5][14]

- Different QRS detection algorithms include:

1. Template Matching Techniques

2. Differentiation Based Method

3. Pan Tompkins Algorithm

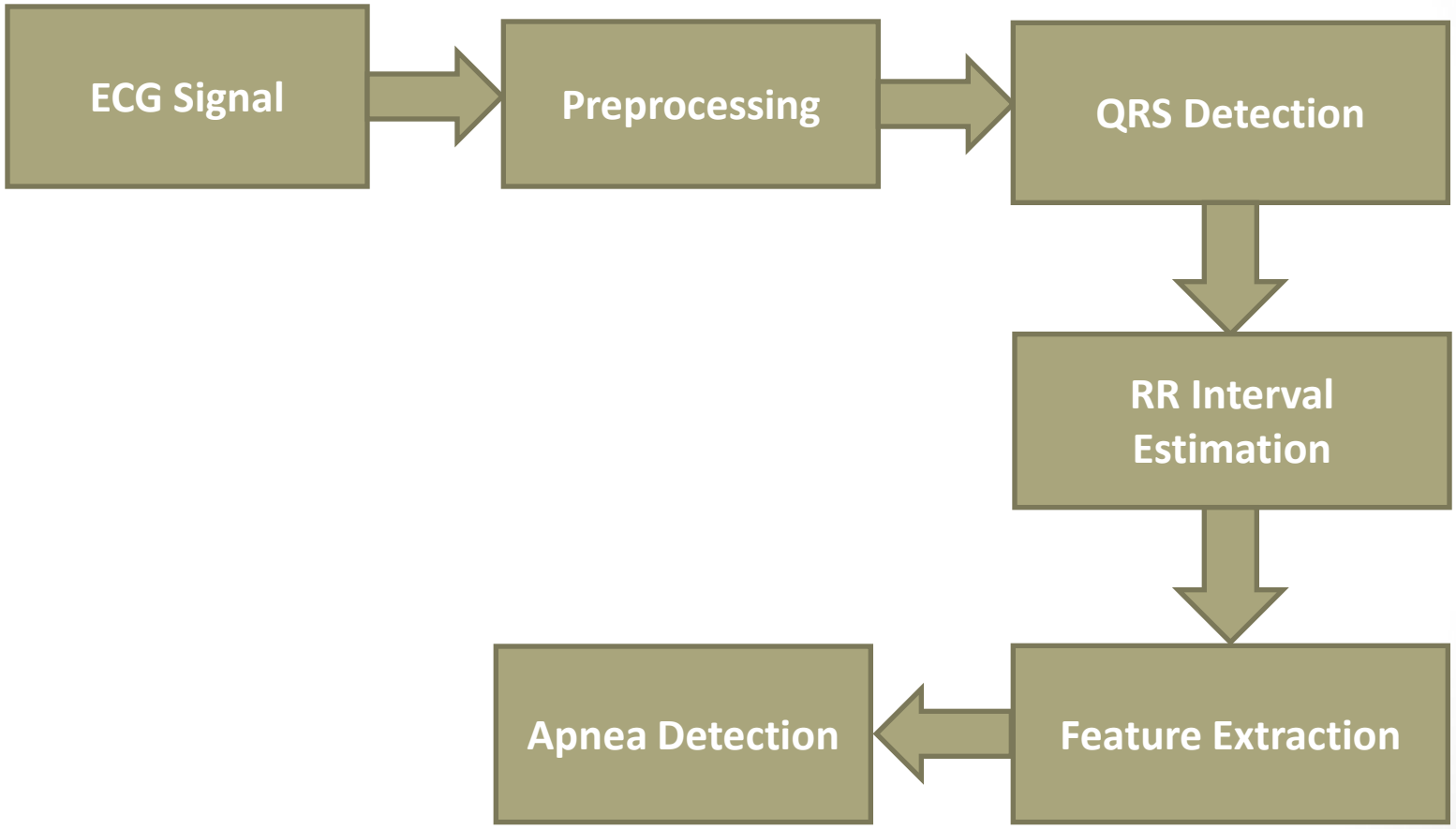
FEATURE EXTRACTED[3]

- RR-interval.
- Heart Rate.
- Epoch Length.
- The NN50 measure (variant 1), defined as the number of pairs of adjacent RR intervals where the first RR interval exceeds the second RR interval by more than 50 ms.
- The NN50 measure (variant 2), defined as the number of pairs of adjacent RR intervals where the second RR interval exceeds the first RR interval by more than 50 ms.

APNEA-HYPOPNEA INDEX[3]

- Index used to indicate the severity of sleep apnea.
- It is represented by the number of apnea and Hypopnea events per hour of sleep.
- The AHI is calculated by dividing the number of apnea events by the number of hours of sleep.
- AHI values are categorized as:
  - Normal: 0-4
  - Mild Sleep Apnea: 5-14
  - Moderate Sleep Apnea: 15-29
  - Severe Sleep Apnea: 30 or more

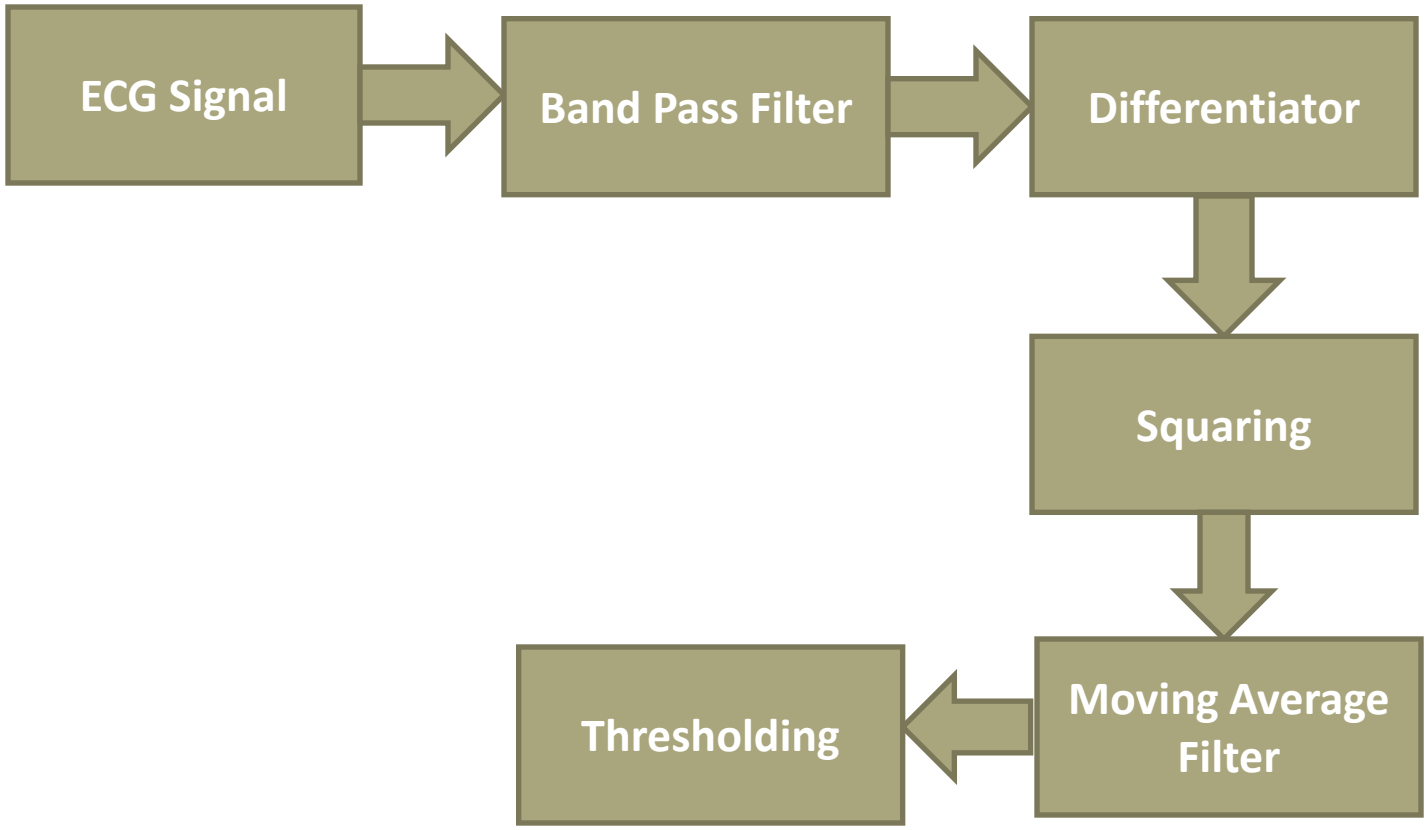
BLOCK DIAGRAM[4]



ECG SIGNAL

- The Physionet data base is used as the input to the system.
- The data consist of 70 records, divided into a learning set of 35 records and a test set of 35 records, all of which may be downloaded.
- Recordings vary in length from slightly less than 7 hours to nearly 10 hours each.

PAN TOMPKINS ALGORITHM[5]



LOW PASS FILTER[5]

- Reduce Power-line noise because it suppress the high frequency noise.
- Mainly due to difference in electrode impedances and stray currents through patient and cables.
- Power line noise in the range of 60 Hz.
- Second Order Low Pass Filter
- Cut Off 15 Hz.

$$H(z) = \frac{(1-z^{-6})^2}{(1-z^{-1})^2}$$

HIGH PASS FILTER[5]

- Reduce Baseline Wander.
- Noise include Breathing Noise, Loose sensor contacts, Body Movements, Perspiration etc.
- Lies in the range of 0.5 Hz.
- A High Pass Filter of Cutoff 5 Hz is used.

$$H(z) = \frac{-1+32z^{-6}+z^{-32}}{1+z^{-1}}$$

DERIVATIVE[5]

- The Differentiation is standard technique for finding the high slopes that normally distinguish the QRS complex from other ECG peaks.

$$H(z)=\frac{1}{8T}(-z^{-2}-2z^{-1}+2z^{1}+z^{2})$$

SQUARING[5]

- That is all signal samples are squared point-by-point.
- This operation makes all data points in the processed signal positive, and it amplifies the output of the derivative process nonlinearly.
- It emphasizes the higher frequencies in the ECG signal, which are mainly due to the QRS complex and restricts false positive caused by T waves.

MOVING AVERAGE FILTER[5]

- The slope of R wave alone is not a guaranteed way to detect a QRS event.
- Many abnormal QRS complexes that have large amplitudes and long durations might not be detected using information about of slope of R wave only.
- Thus for detecting QRS event more information has to be extracted.

THRESHOLDING[5]

- In this the output of the moving window integrator need to be compared with a certain threshold value.
- QRS complexes are detected in regions where the filtered signal rises above the threshold.
- A lower threshold is used if no QRS is detected in a certain time interval.

R-R INTERVAL & HEART RATE

- The R-R interval is the time between 2 consecutive R peaks.
- $$RR\ INTERVAL = \frac{1}{SAMPLING_{RATE}} * PEAK\ SAMPLE\ DIFFERENCE$$
- Heart Rate is the speed of the heartbeat measured by the number of heartbeats per unit of time.

$$HR = \frac{60}{R-R\ Interval}$$

REQUIREMENT ANALYSIS

- GNU Octave
- Physionet Sleep Apnea Database.
- Android SDK
  - Eclipse and ADT plugin.
  - Android SDK Tools
  - The latest Android platform.
- Device with a minimum android version of Gingerbread (2.3–2.3.7)

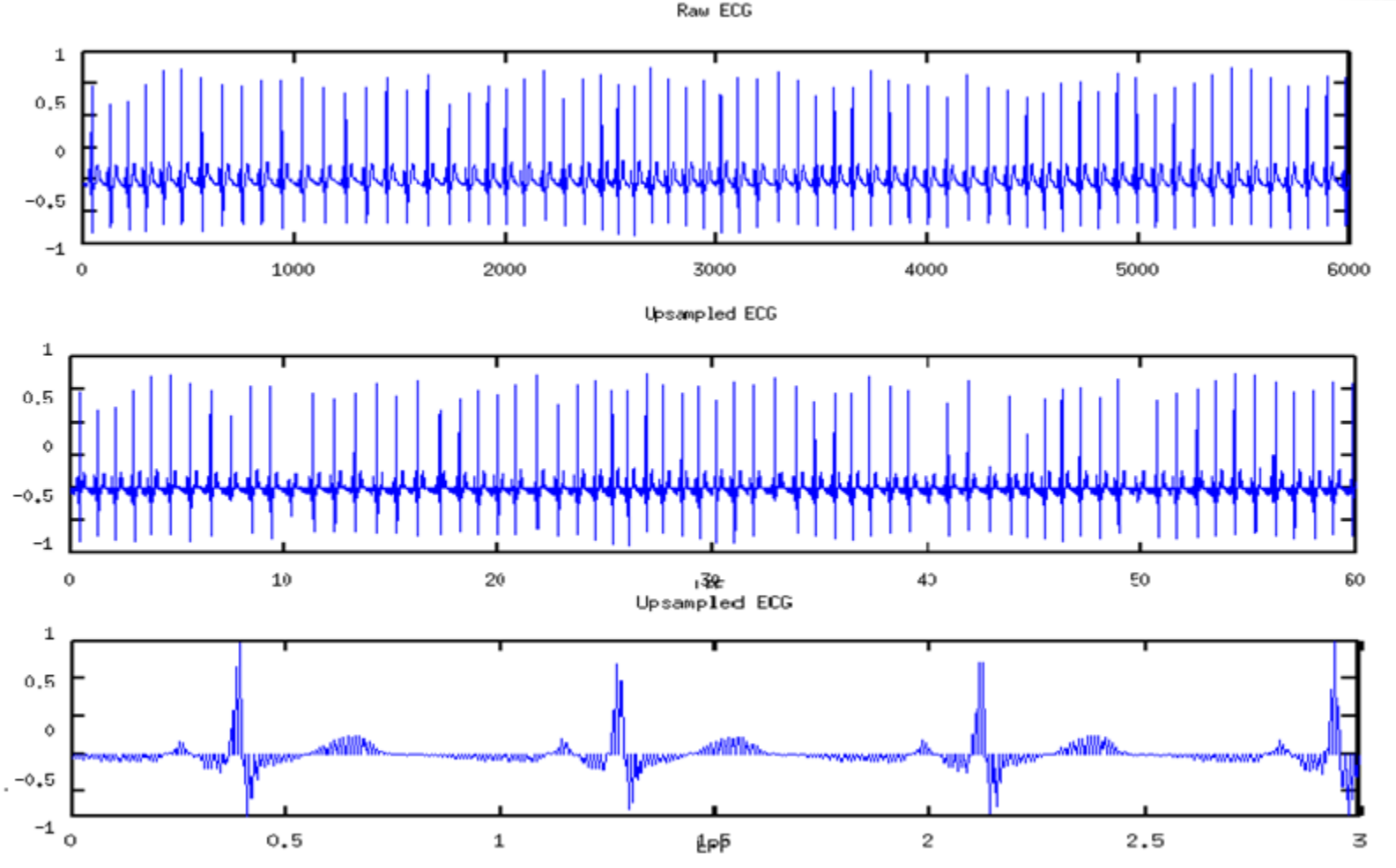
RADXA ROCK

- ARM Cortex-A9 quad core @ 1.6Ghz
- 2GB DDR3 @ 800Mhz
- 8 GB Nand Flash
- Mali400-mp4@533Mhz, OpenGL ES 2.0
- 150Mbps 802.11b/g/n with antenna.

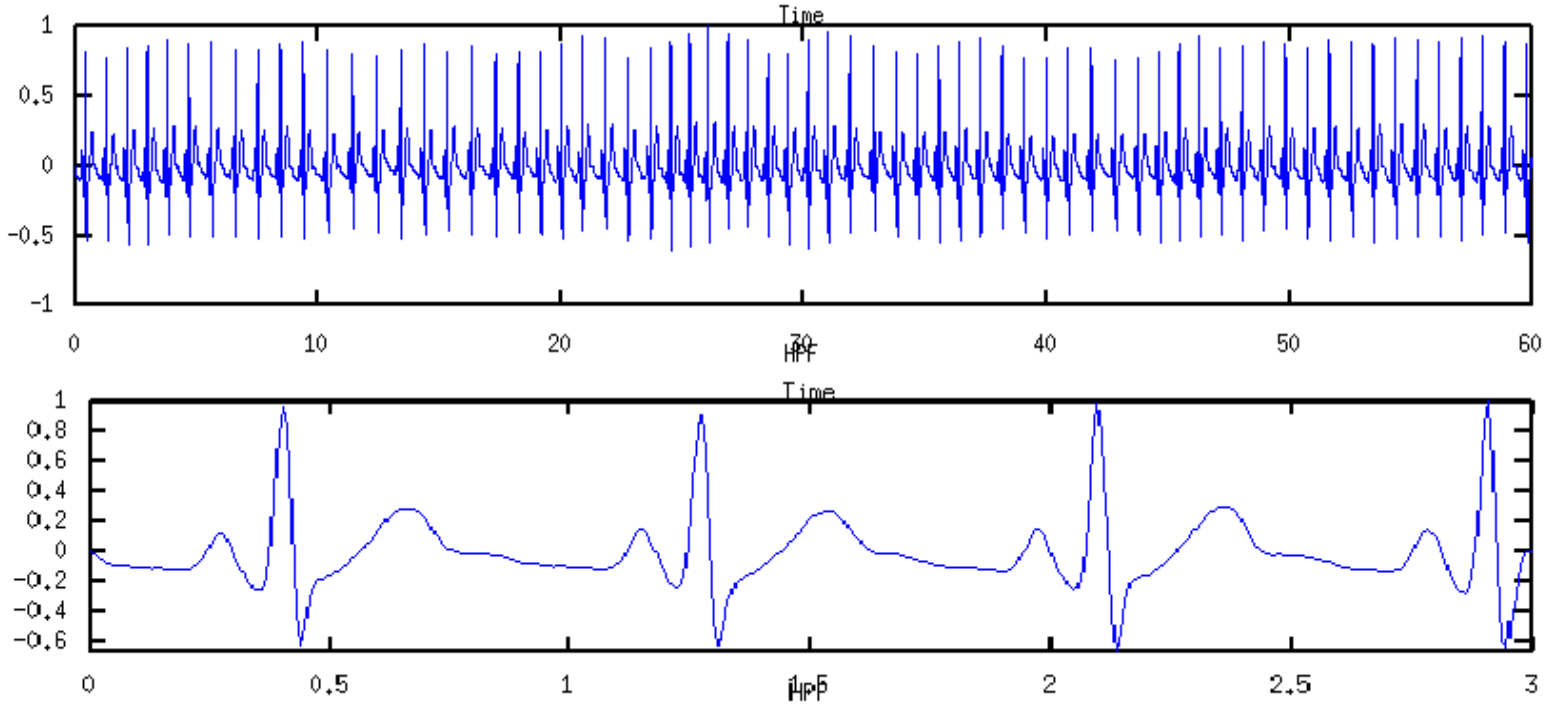
WORK DONE

- The sleep Apnea ECG data was obtained from Physionet Sleep Apnea ECG database.
- The database was up-sampled/down-sampled to a sampling frequency of 200 samples per second.
- The Pan Tompkins algorithm was applied on the database and the following were detected:
  - QRS Peak
  - R-R interval
  - Heart Rate
- The different Features were extracted.
- Apnea was classified in an Android based Platform.

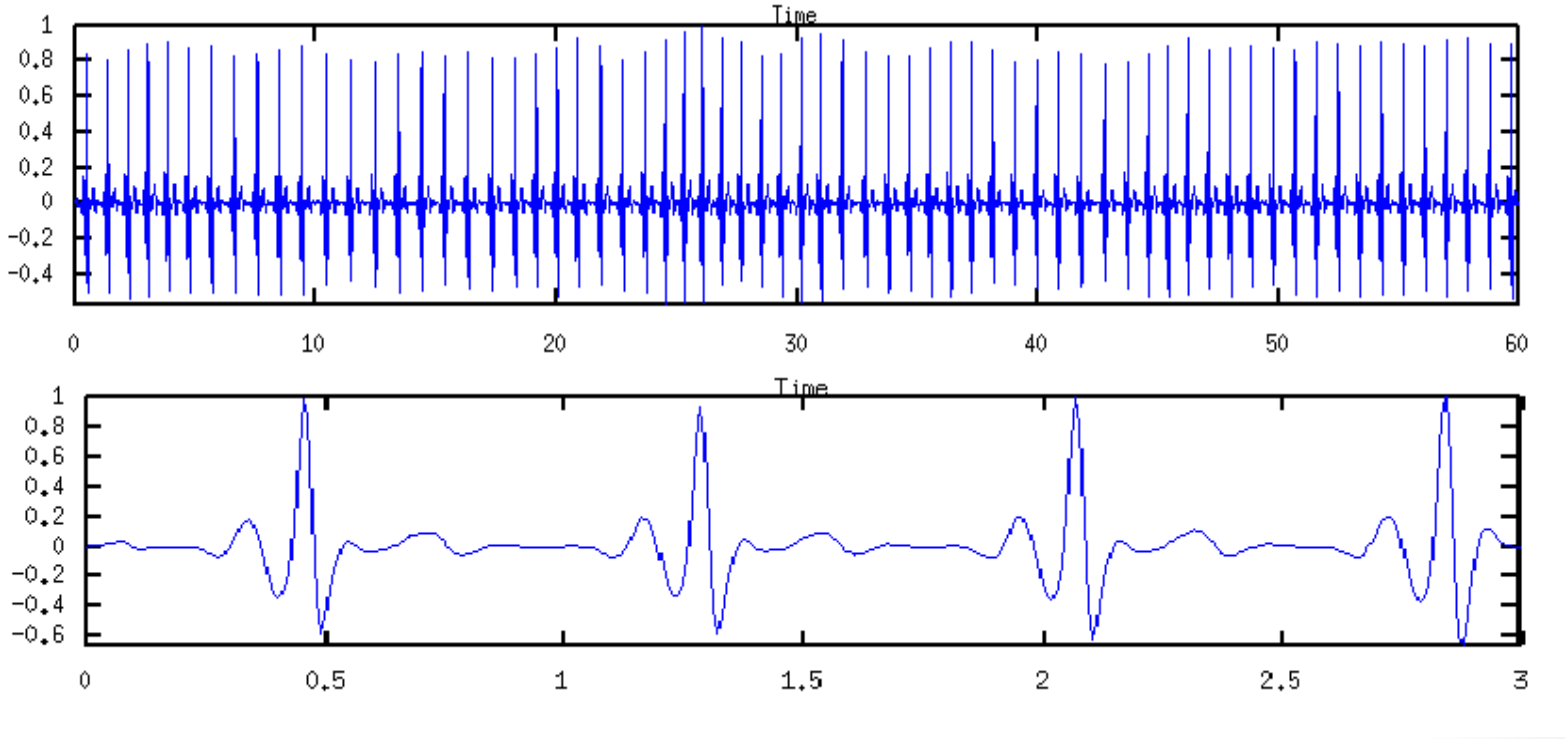
ECG Signal


Raw ECG
1
0.5
0
-0.5
-1
0
1000
2000
3000
4000
5000
6000
Upsampled ECG
1
0.5
0
-0.5
-1
0
10
20
40
50
60
Upsampled ECG
1
0.5
0
-0.5
-1
0
0.5
1
2
2.5
3

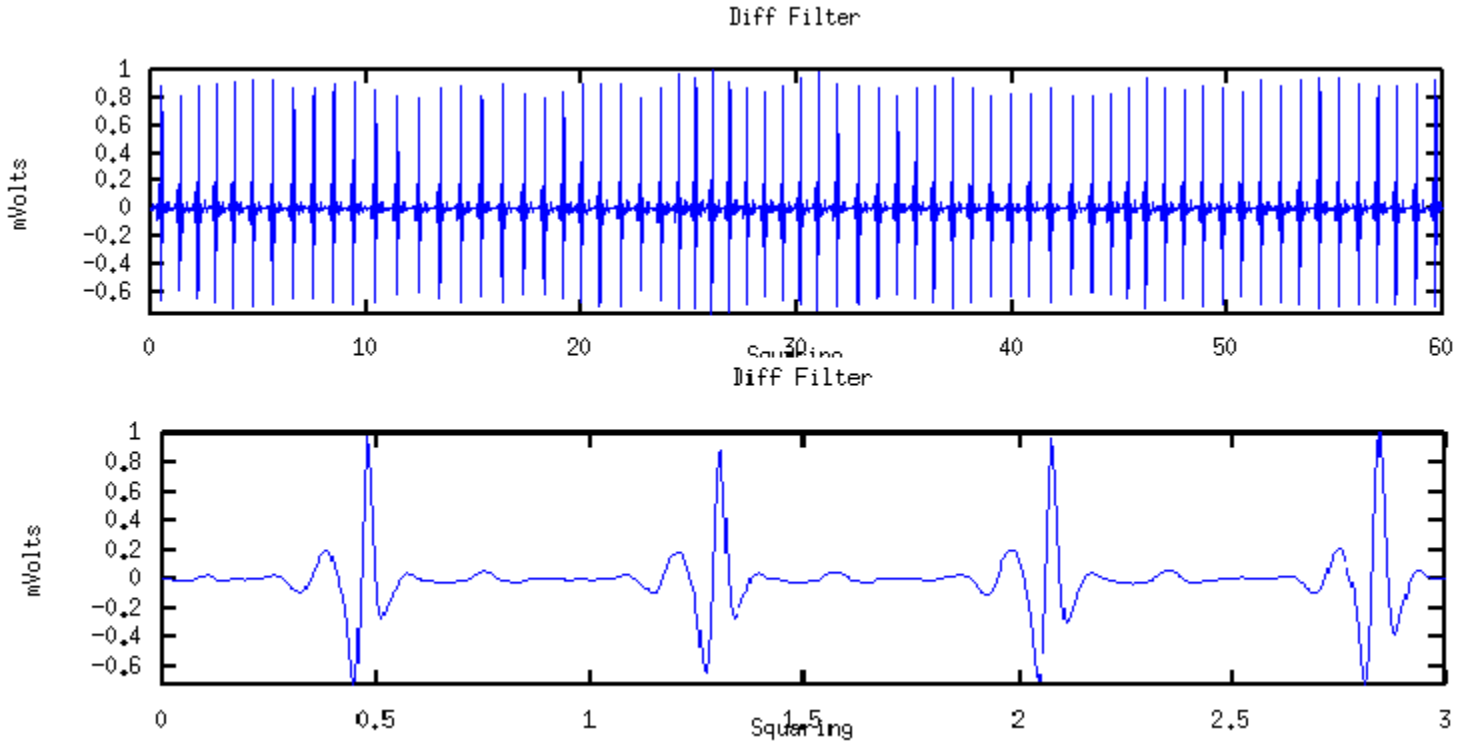
LOW PASS FILTER



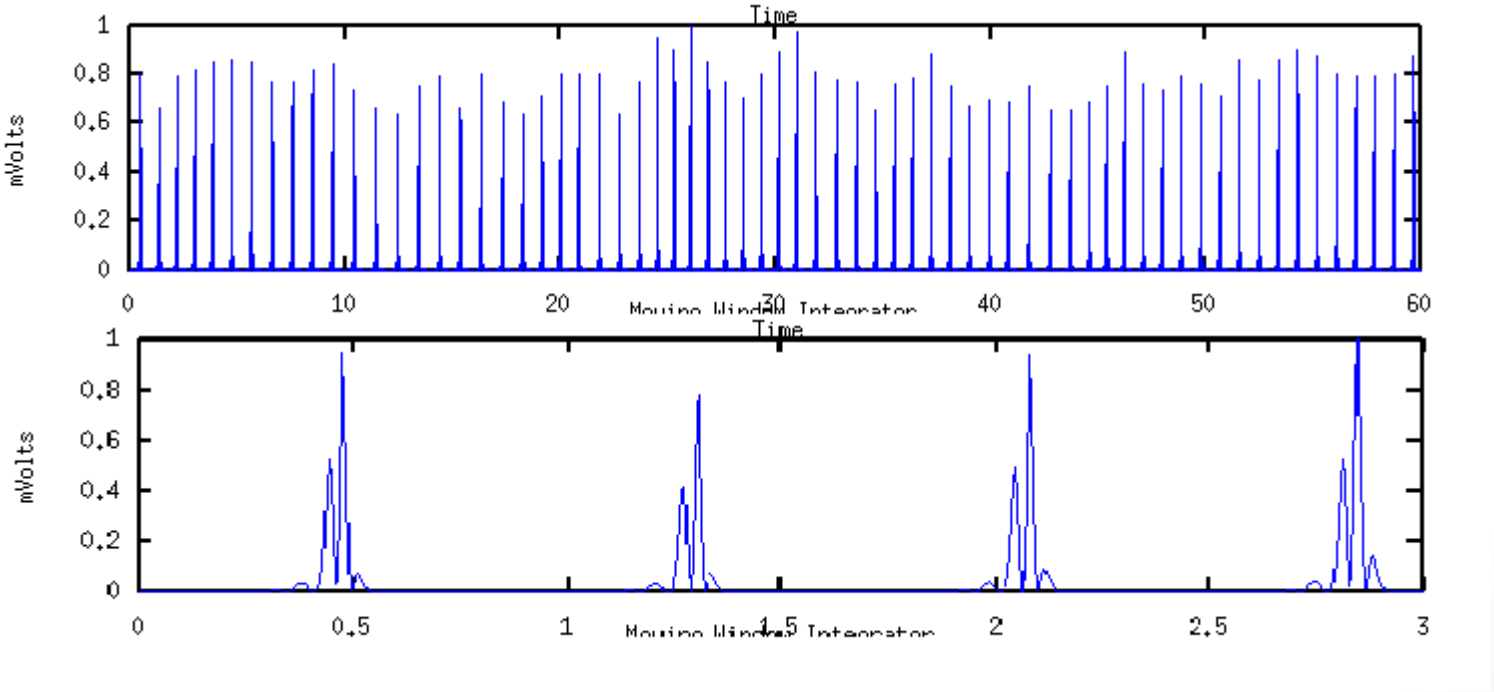
HIGH PASS FILTER



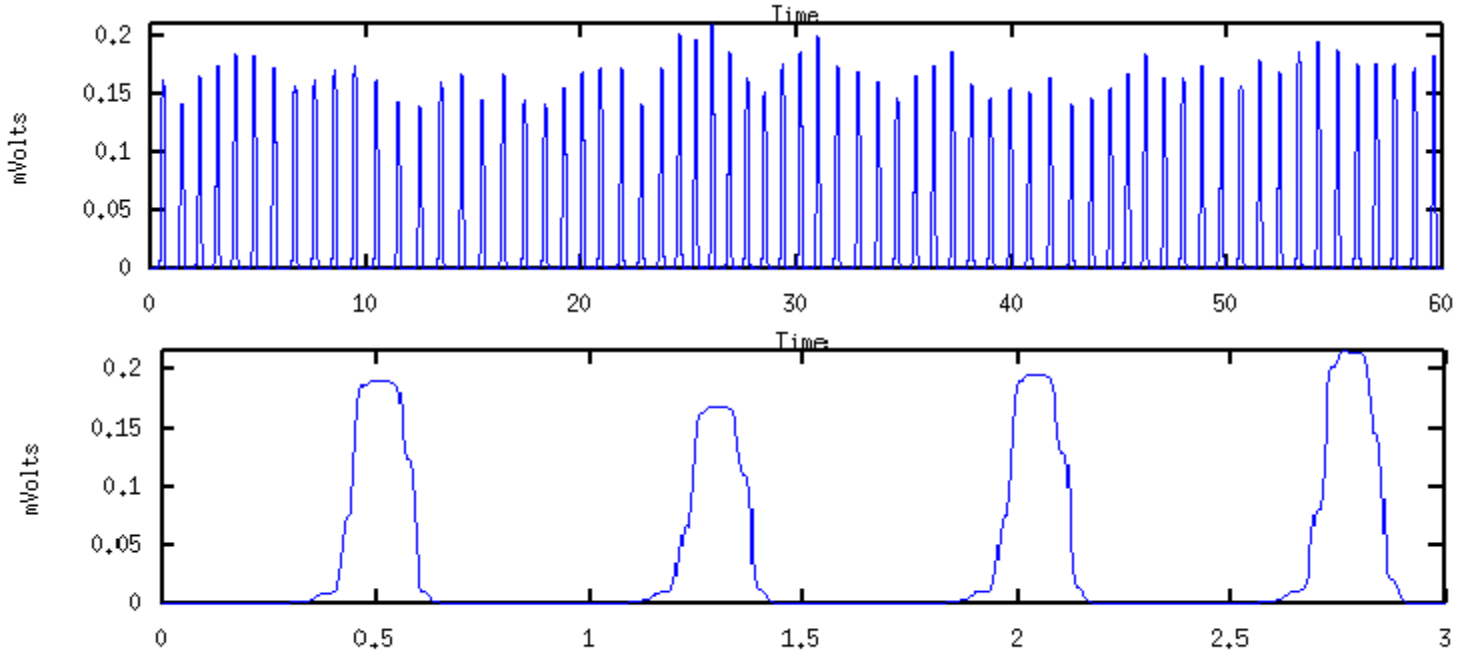
DERIVATIVE


Diff Filter
mVolts
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
0
10
20
30
40
50
60
Diff Filter
mVolts
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
0
0.5
1
1.5
2
2.5
3

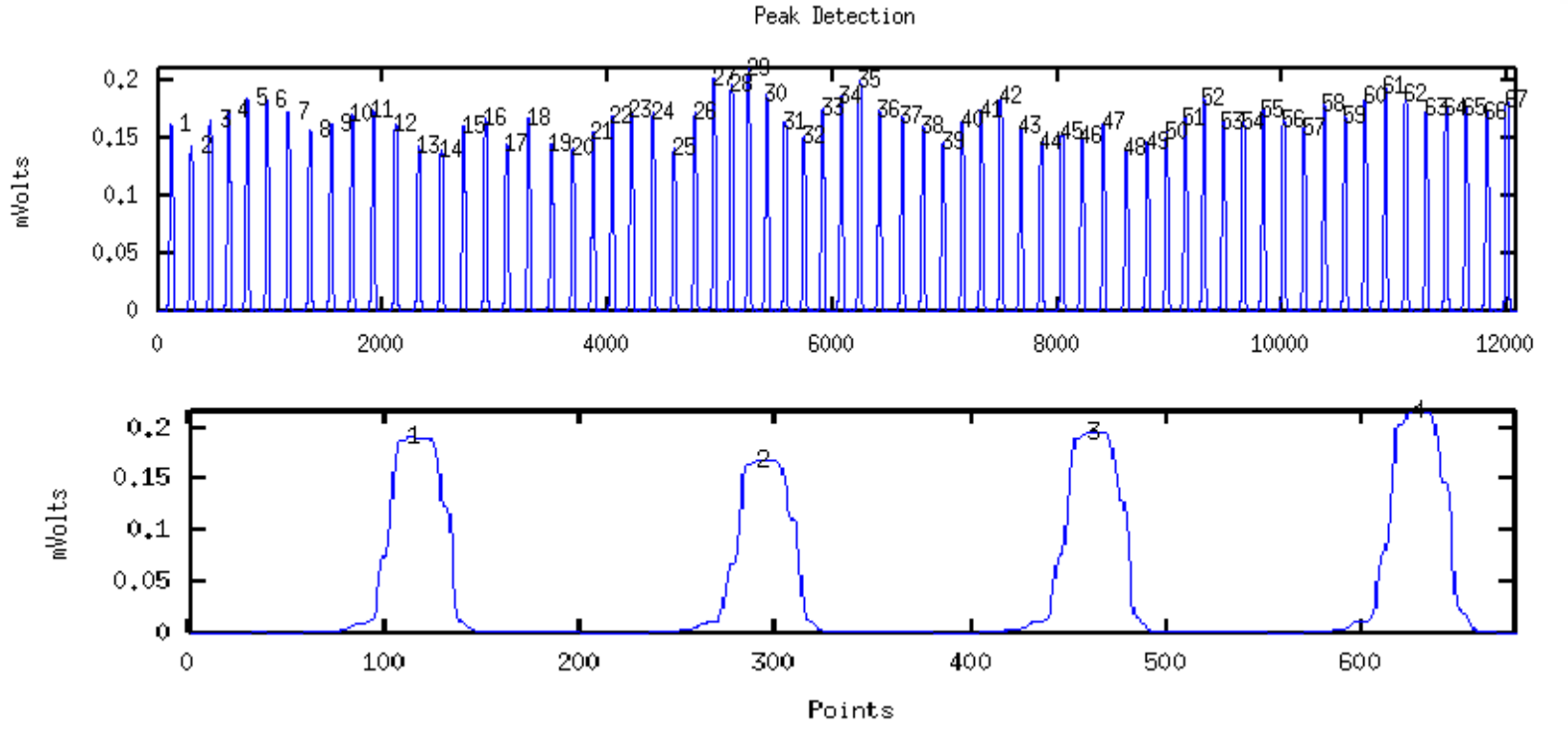
SQUARING


Time
mVolts
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
Moving Window Integrator
Time
mVolts
1
0.8
0.6
0.4
0.2
0
0
0.5
1
1.5
2
2.5
3
Moving Window Integrator

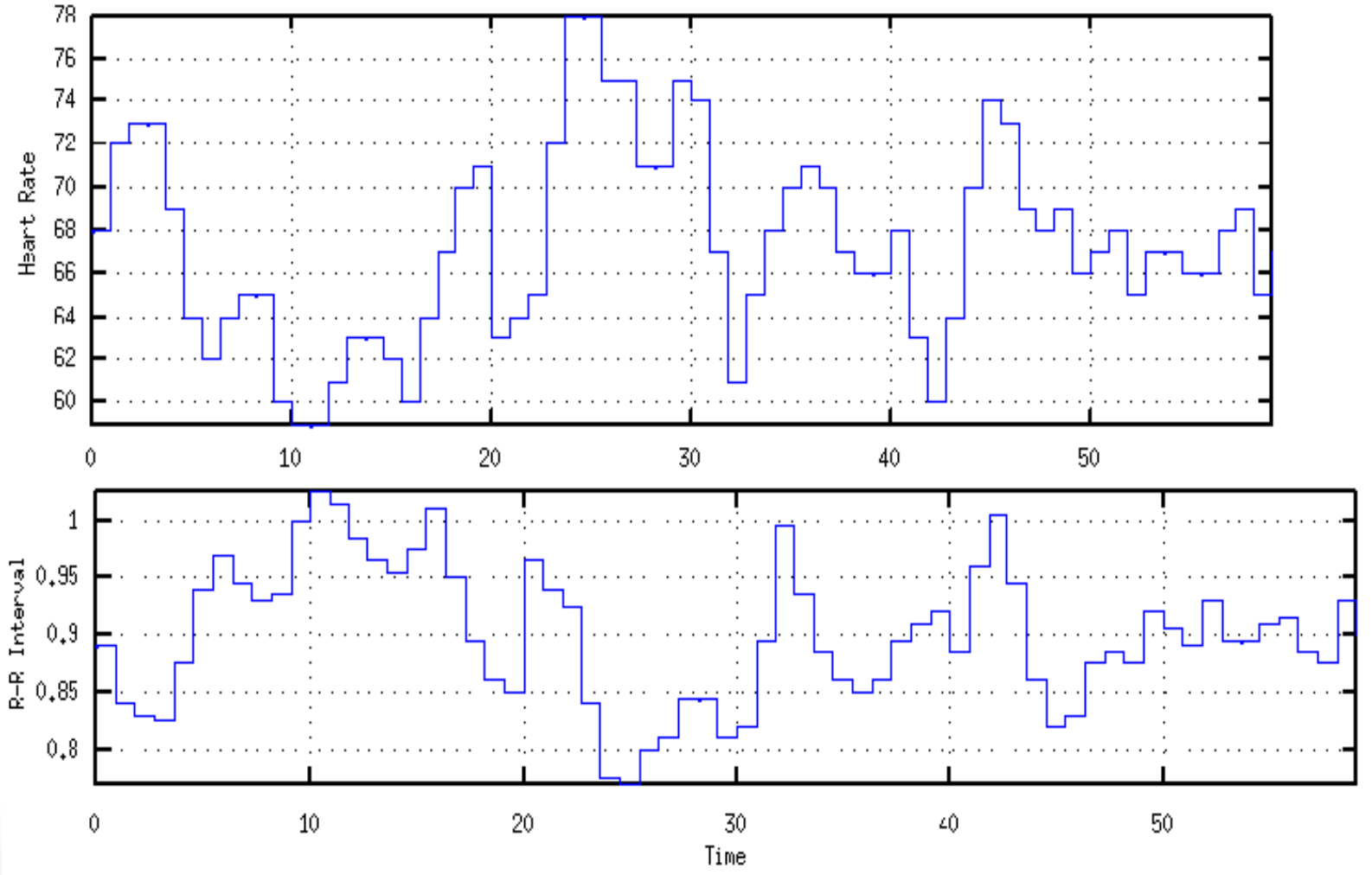
MOVING AVERAGE FILTER



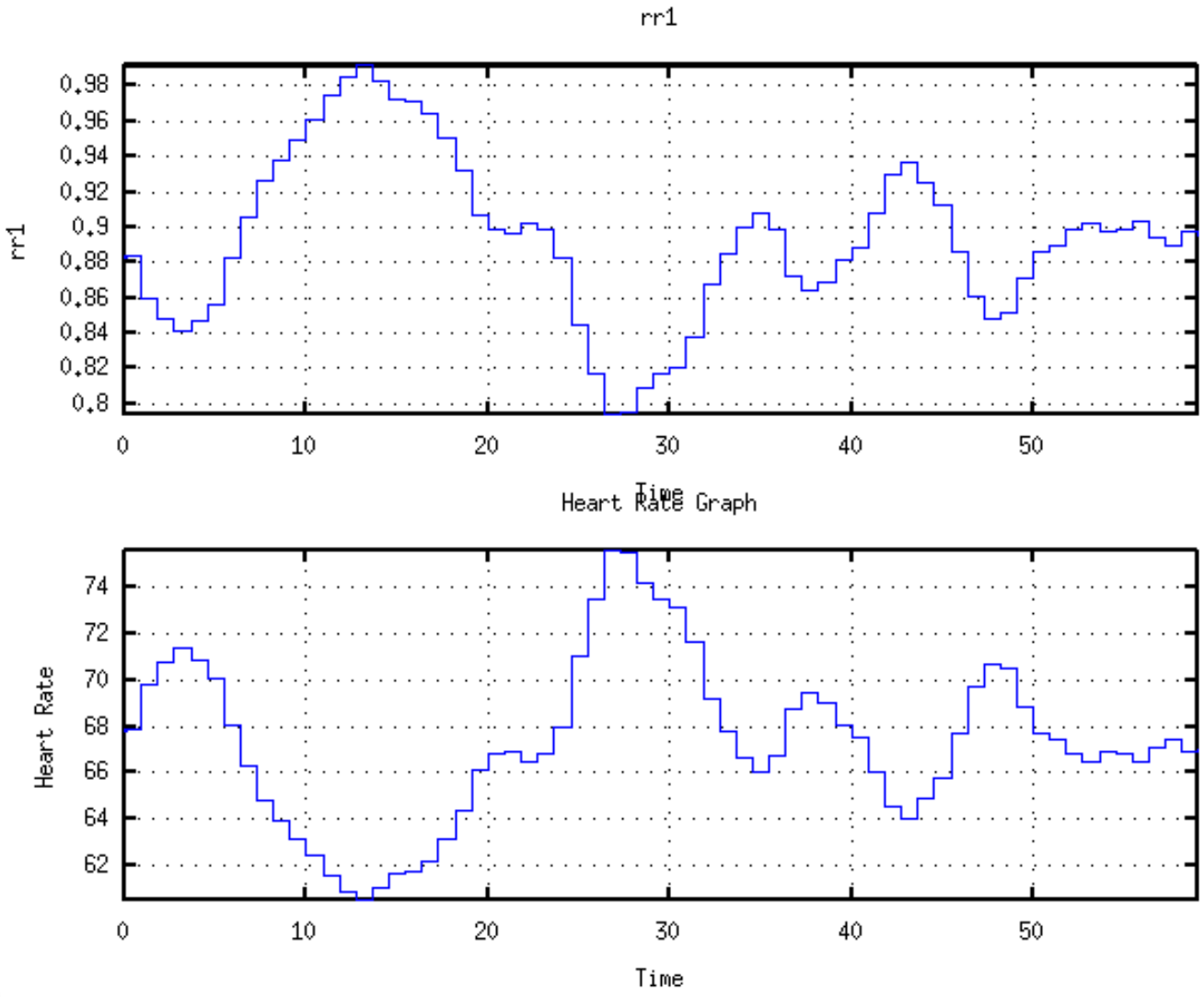
THRESHOLD


Peak Detection
mVolts
0.2
0.15
0.1
0.05
0
0
2000
4000
6000
8000
10000
12000
mVolts
0.2
0.15
0.1
0.05
0
0
100
200
300
400
500
600
Points

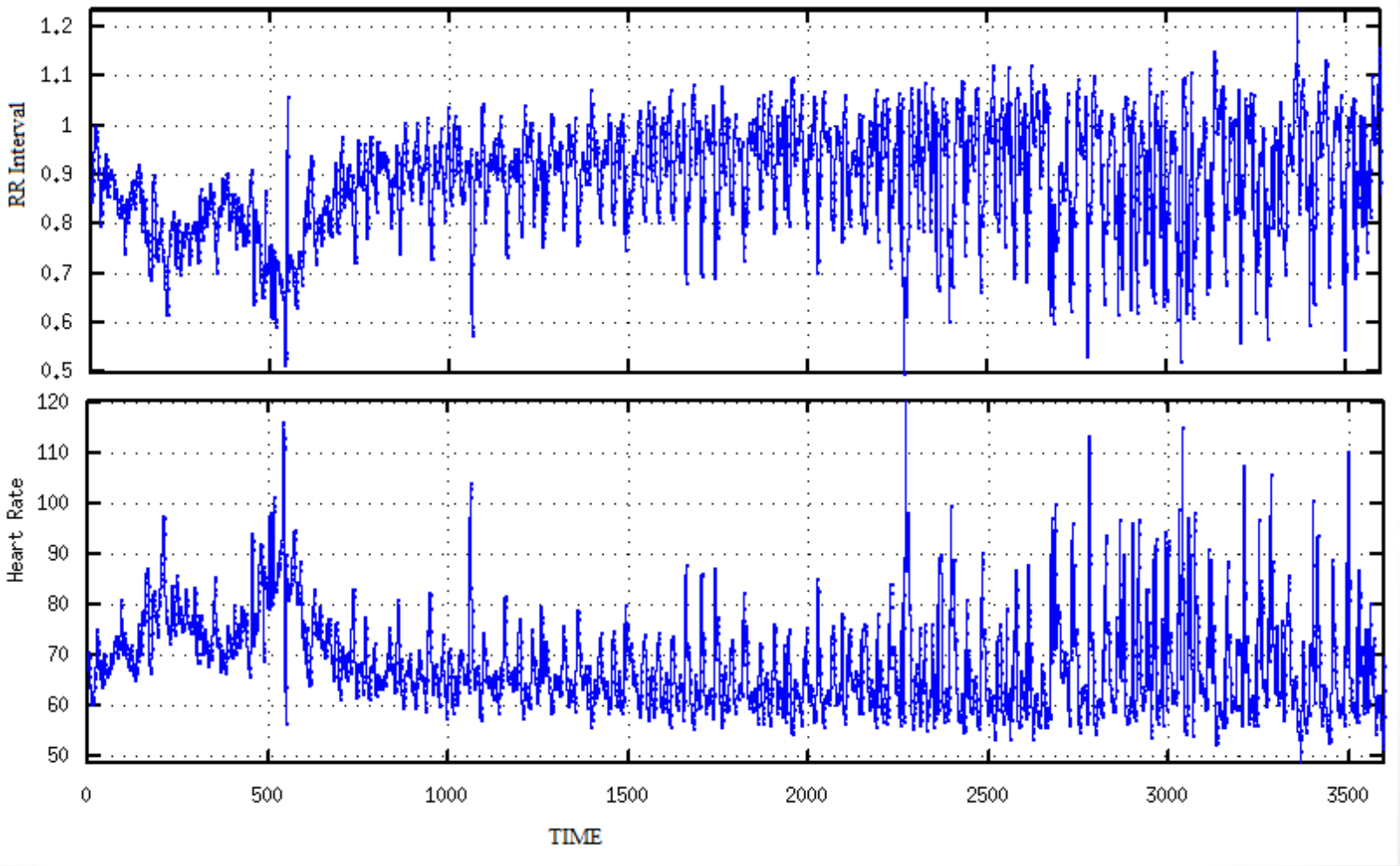
R-R INTERVAL & HEART RATE



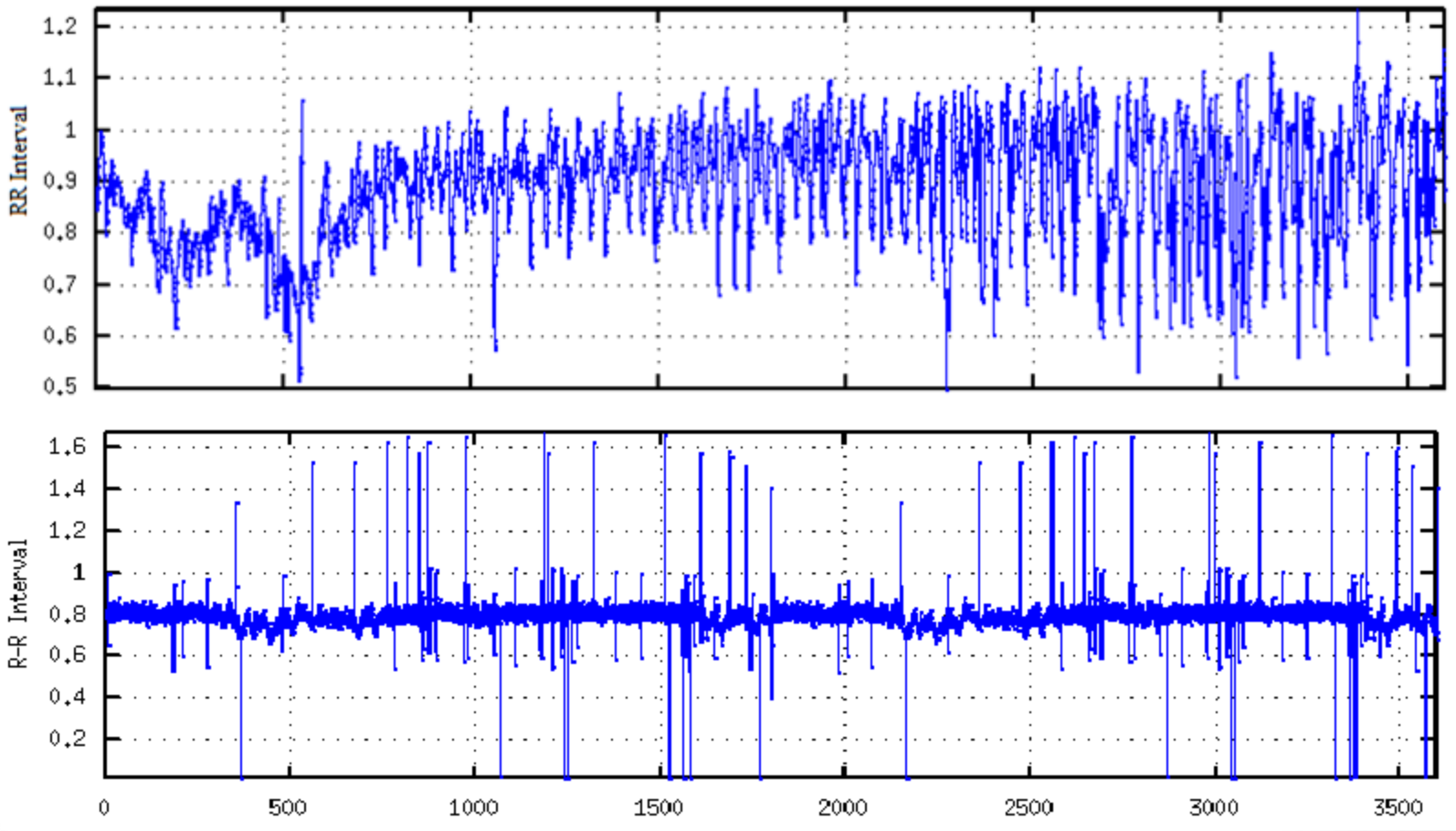
AVERAGED RR INTERVAL AND HR



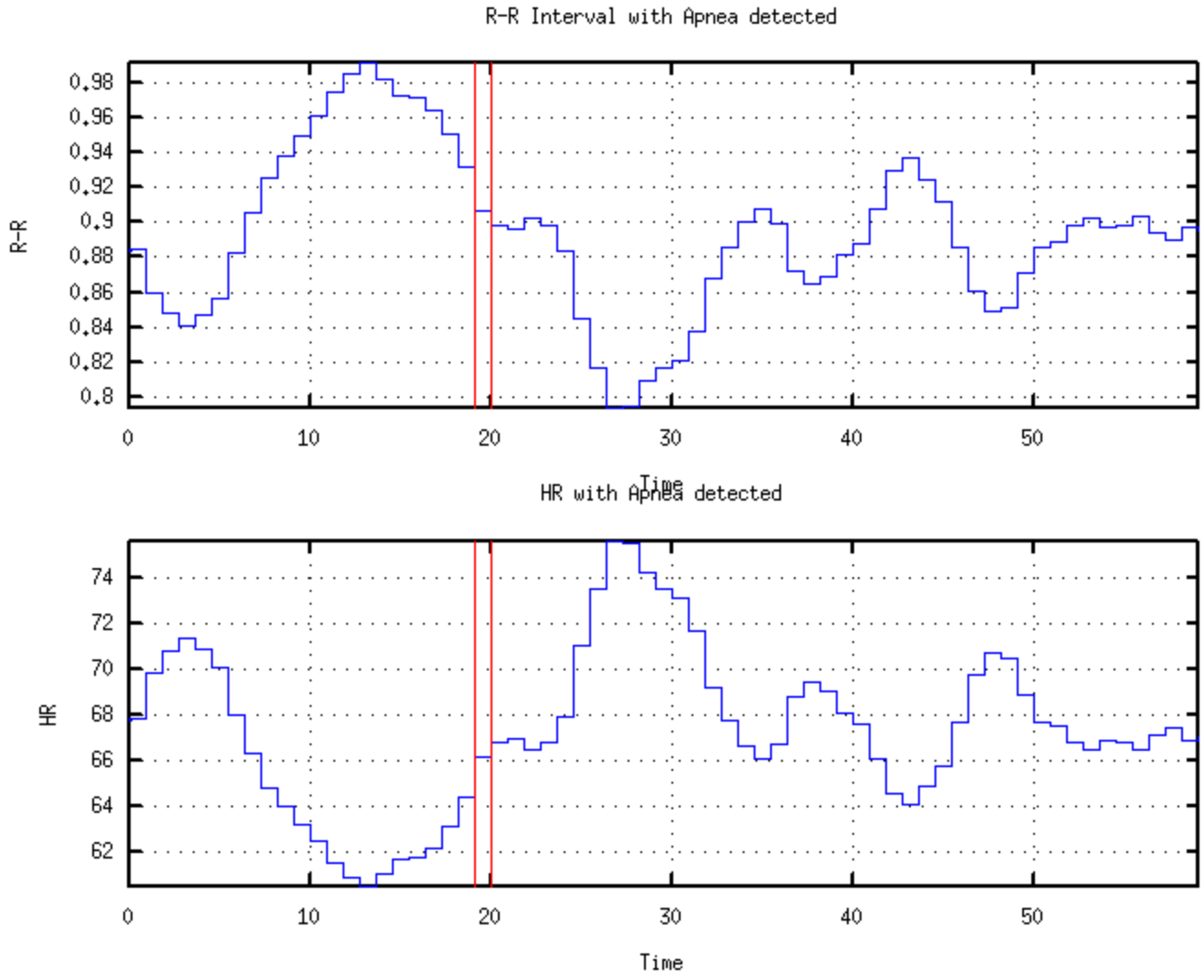
RR INTERVAL AND HR



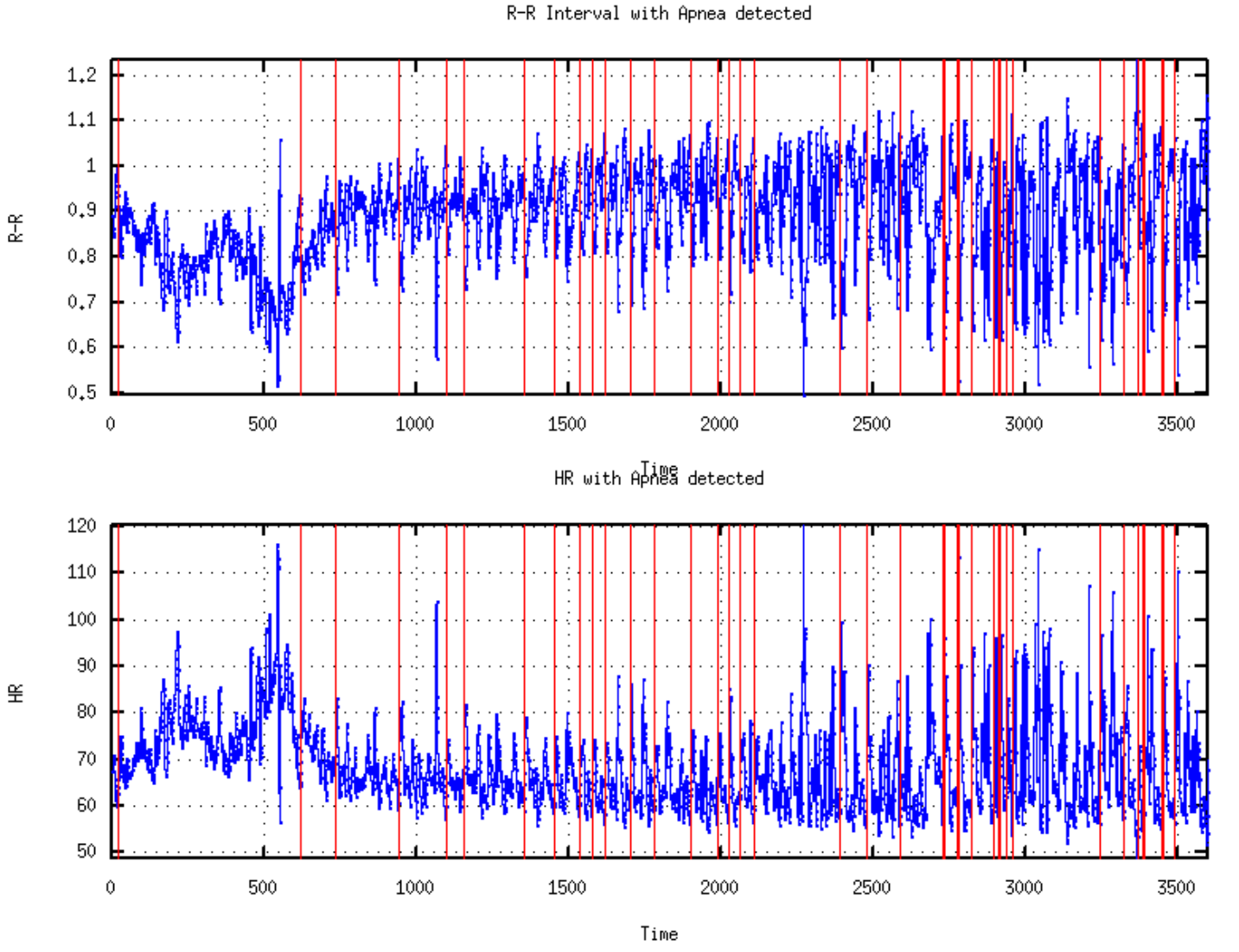
R-R INTERVAL


RR Interval
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
R-R Interval
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
500
1000
1500
2000
2500
3000
3500

APNEA EPISODE DETECTION



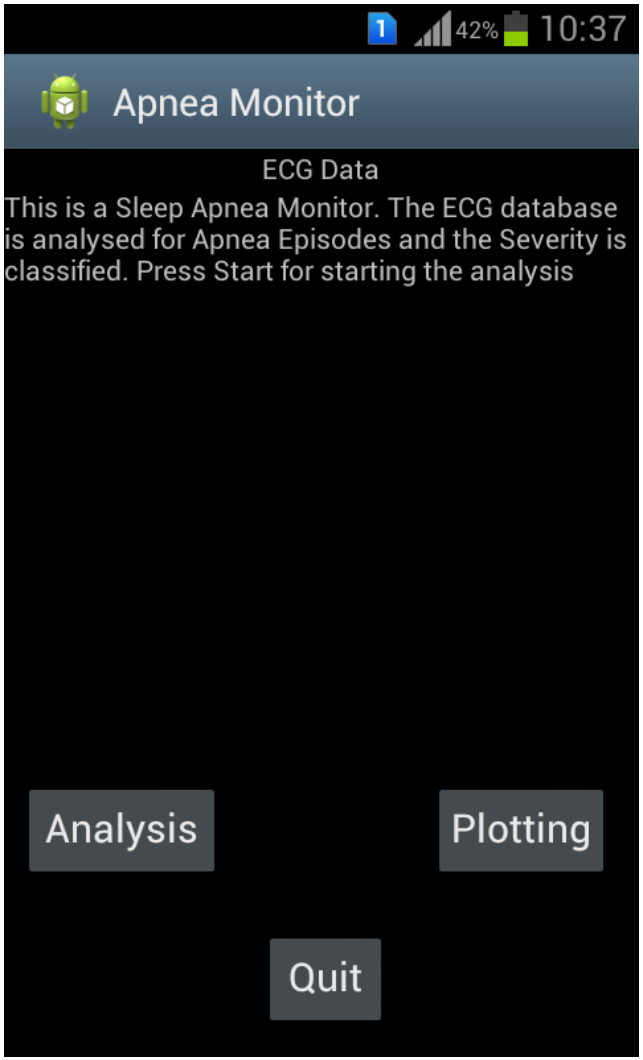
APNEA EPISODE DETECTION



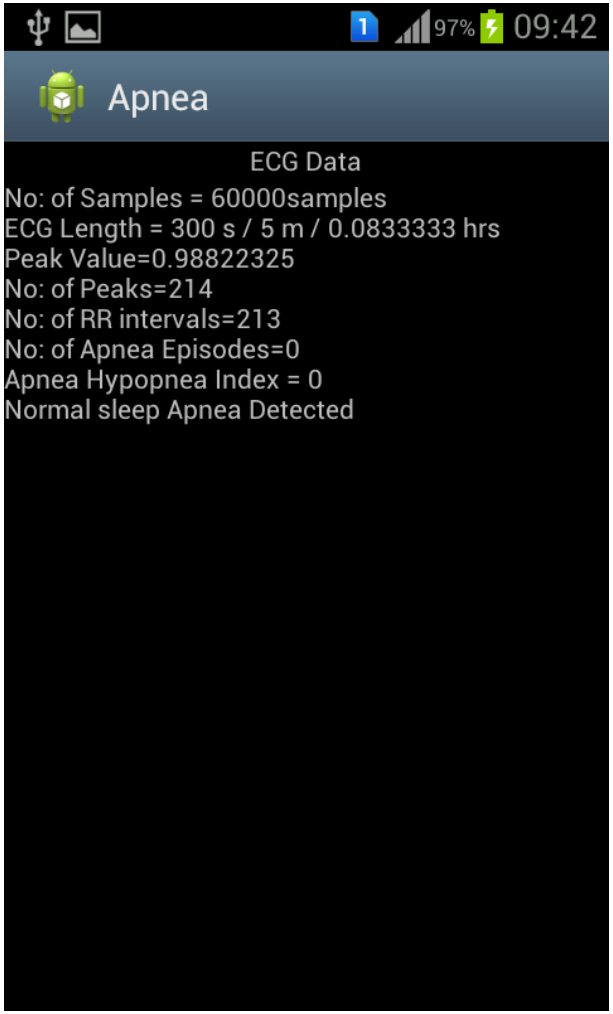
ANDROID IMPLEMENTATION

- Android Implementation of Pan Tompkins Algorithm.
  - Low pass filter, High pass filter, Derivative filter, Squaring, Moving window integration
- Heart Rate and RR Interval.
- Epoch Length, NN50 variant 1 and variant 2.
- Apnea Hypopnea Index
- Apnea Classification.

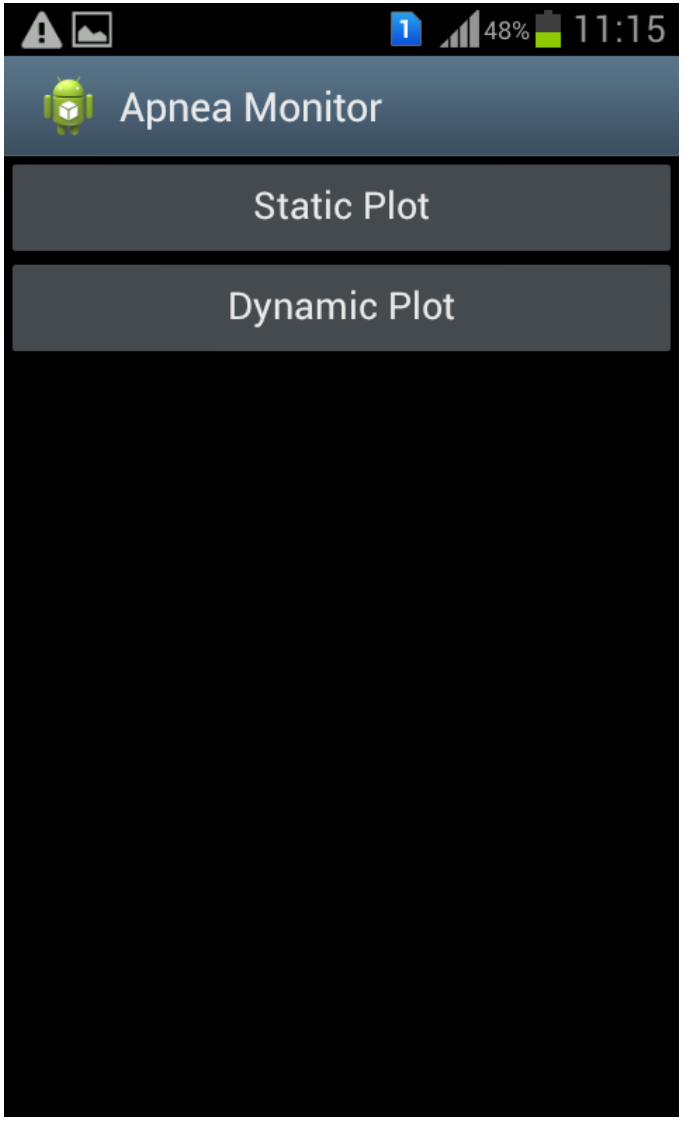
ANDROID MAIN LAYOUT



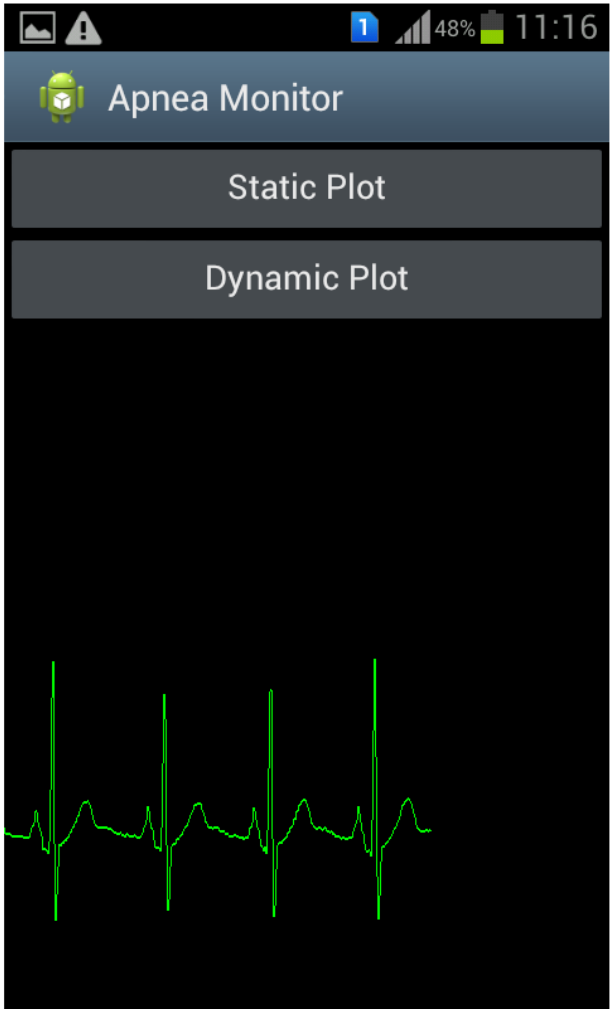
ANALYSIS LAYOUT

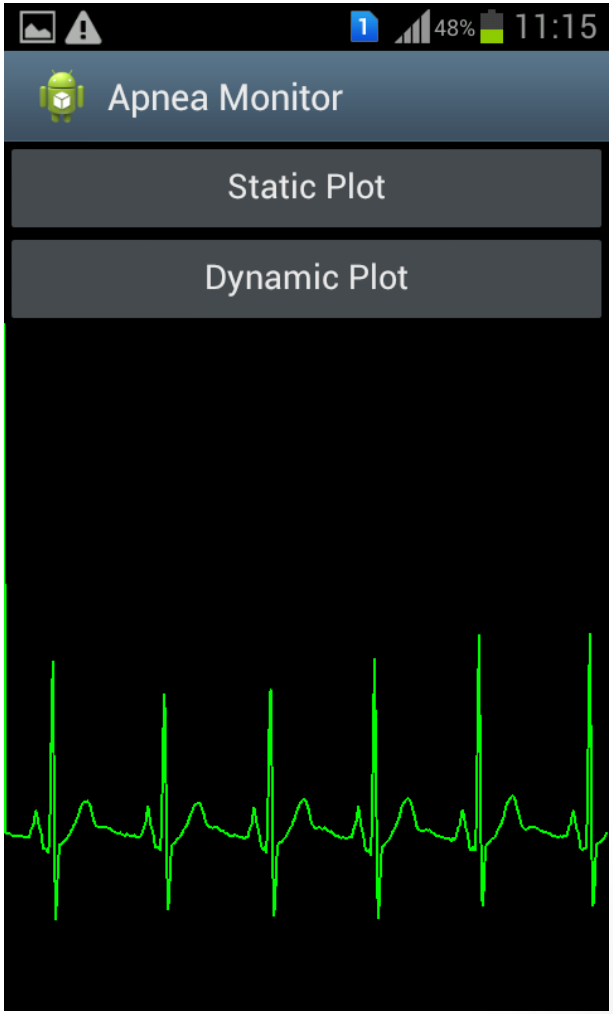


PLOT LAYOUT



ANDROID PLOT





RESULTS

Epoch	R-R Diff.	NN50	Apnea	Detected	Accuracy
5 sec	50 ms	4 No's	4493	2601	57.89 %
5 sec	55 ms	4 No's	4493	2657	59.14 %
5 sec	60 ms	4 No's	4493	2834	63.07 %
6 sec	50 ms	4 No's	4493	2472	55.01 %
6 sec	55 ms	5 No's	4493	2916	64.9 %
6 sec	60 ms	6 No's	4493	2983	66.4 %
7 sec	50 ms	4 No's	4493	2787	62.03 %
7 sec	55 ms	5 No's	4493	3118	69.4 %
7 sec	60 ms	6 No's	4493	3304	73.54 %
8 sec	50 ms	5 No's	4493	3195	71.10 %
8 sec	55 ms	5 No's	4493	3356	74.7 %
8 sec	60 ms	5 No's	4493	3375	75.12%

RESULTS

Epoch	R-R Diff.	NN50	Apnea	Detected	Accuracy
8 sec	60 ms	6 No's	4493	3535	78.67 %
9 sec	60 ms	5 No's	4493	3320	73.9 %
9 sec	60 ms	6 No's	4493	3421	76.13 %
10 sec	60 ms	6 No's	4493	3277	72.94 %

CONCLUSION

- The existing system has many criticism.
- ECG signal was used for the detection of Sleep Apnea.
- This would make the diagnosis much more easier, cost effective, easily available.
- The max accuracy was obtained as 78.67%.
- The max accuracy was obtained at epoch length=8sec, R-R difference = 60ms and the variant length(I & II) = 6.

FUTURE WORK

- Add more features to improve accuracy.
- Heart Rate Turbulence.

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THANK YOU!!!