4. Result Analysis

In this research, a novel heart beat signal propagation and heart rate computation model is developed for the patients using body wearable sensors for heart rate monitoring (also known as Holter) connected through Bluetooth Environment with the medical database through smart phone. These environments are usually designed to post-treatment or pre-treatment monitoring of the heart patients on the regular basis to avoid the critical health hazard situations, while they are at work, home, etc (out of the medical facility or controlled environment). In this research project, the aim is to improve the ECG QRS detection process by making the whole process energy efficient to maximize the smart phone battery life. In this research, a novel heart beat signal propagation from holter to smart phone and then towards the medical database. The smart phone is used as a transmission hub.

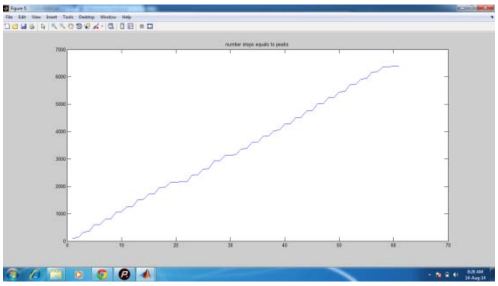

Figure 1: Number steps equal to peaks

The holter batteries choke more energy when running on the cellular networks than Bluetooth interface. Hence, the first objective was to maximize the holter battery life by making the connectivity of holter using bluetooth interface. Once the ECG data is obtained on the smart phone via Bluetooth connection, the second objective was to transmit the ECG data from smart phone towards medical database using the smart phone as transmission hub which utilizes cellular or wireless LAN network to send the ECG data. The third and the most important objective was to design and improve the heart beat detection using QRS detection algorithm to minimize the energy consumption by QRS detection using various programming methods. The proposed algorithm will take lesser time than usual added with effective energy consumption model to maximize the battery life of smart phone. The QRS algorithm for smart phones can be used to obtain the similar results they are getting from the medical databases. The QRS detection algorithm will generate the heart beat calculation results, which helps the patients to monitor themselves and to detect the emergency as earlier as possible. The medical databases monitor a number of patients at one point of time; hence, there is always a possibility of delay in case of emergency. Also, the medical services are hierarchical, which makes the process little slower which may put an adverse effect on the patient's life. A little delay made while detecting the emergency and the service provided can cause casualty, which can be easily mitigated by using the localized monitoring.

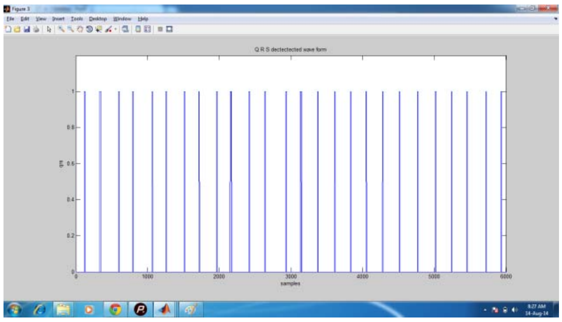

Figure 2: QRS detection wave form

The database contains 25 records from 25 subjects (aged between 27 to 70, mean 48.5; 17 men, mean age 38.5, and 8 women, mean age 42.6; ages were not recorded for 2 female and 3 male subjects). Each subject is represented by one ECG record. Each record includes the continuously measured signals. Each signal is digitized at 356 samples per second, with 16 bit resolution over a range of ± 16.384 mV. On special request to the contributors of the database, recordings may be available at sampling rates up to 10 KHz. The energy recorded for Bluetooth Environment has been recorded and displayed under this research project. The recorded/computer heart beat is computer by performing QRS-detection algorithm on the medical database server by using the optimized ECG signal as the input signal for QRS-detection algorithm. The ECGs in this collection were obtained using a non-commercial, PTB prototype recorder with the following specifications:

- 16 input channels, (14 for ECGs, 1 for respiration, 1 for line voltage)
- Input voltage: ±16 mV, compensated offset voltage up to ± 300 mV
- Input resistance: 100 Ω (DC)
- Resolution: 16 bit with 0.5 µV/LSB (2000 A/D units per mV)
- Bandwidth: 0 - 1 kHz (synchronous sampling of all channels)
- Noise voltage: max. 10 µV (pp), respectively 3 µV (RMS) with input short circuit
- Online recording of skin resistance
- Noise level recording during signal collection

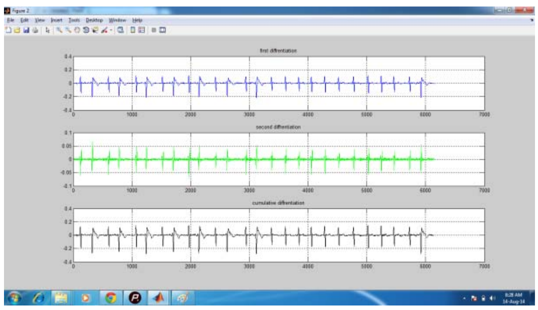

Figure 4: Signal plotting after two level differentiation and cumulative difference

Table 1: Energy Consumption by smart phone while receiving the data on Bluetooth interface

Patient ID	*Bluetooth Energy Consumption on smart phone*
Pat 1	23. 86
Pat 2	15. 63
Pat 3	40. 22
Pat 4	26. 79
Pat 5	34. 29
Pat 6	18.44
Pat 7	21.48

The results of the Bluetooth energy consumption has been obtained by using two Bluetooth enabled phones to transmit the data in the controlled environment where all other additional processes were shutdown on the receiver's end. The receiver smart phone is running its essential processes along with the Bluetooth data channel. The smart phone energy computed adds the energy consumed by the initial processes also. The essential applications consist of operating system and other related essential processes. It is not possible to run the smart phone and its bluetooth without its operating and some essential processes.

Table 2: Heart Rate Computation and Energy Consumption calculation after QRS detection

Patient ID	*Heart Beat*	*Energy Consumption*	*Elapsed Time*
1	127	0.649115	0.021123
2	132	0.731722	0.020373
3	157	0.647746	0.019857
4	168	0.450924	0.019831
5	158	0.547009	0.01958
6	170	0.296321	0.020239
7	258	0.744693	0.020242
8	223	0.188955	0.020299
9	159	0.183511	0.021009
10	167	0.368485	0.020092
11	265	0.625619	0.019779
12	171	0.081126	0.019885
13	152	0.929386	0.019921
14	253	0.775713	0.019807
15	217	0.486792	0.020083
16	125	0.446784	0.021197
17	107	0.508509	0.021361
18	135	0.817628	0.020186
19	218	0.794831	0.020479
20	218	0.644318	0.020307
21	117	0.81158	0.02015
22	138	0.350727	0.020012
23	243	0.939002	0.02057
24	270	0.875943	0.019837
25	160	0.550156	0.020182
26	217	0.622475	0.02003
27	217	0.587045	0.020061
28	94	0.301246	0.019933
29	129	0.230488	0.019989
30	179	0.194764	0.020286

The recorded/computer heart beat is computer by performing QRS-detection algorithm on the medical database server by using the optimized ECG signal as the input signal for QRS-detection algorithm. The energy consumed and elapsed time has also been recorded for QRS detection on each patient dataset. The results have shown that the new algorithm is very quick and consumed less than 1 joule energy for 90 seconds ECG data recorded at 512 samples per second.

5. Conclusion

The results of the Bluetooth energy consumption has been obtained by using two Bluetooth enabled phones to transmit the data in the controlled environment where all other additional processes were shutdown on the receiver's end. The receiver smart phone is running its essential processes along with the Bluetooth data channel. The smart phone energy computed adds the energy consumed by the initial processes also. The essential applications consist of operating system and other related essential processes. It is not possible to run the smart phone and its bluetooth without its operating and some essential processes.

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