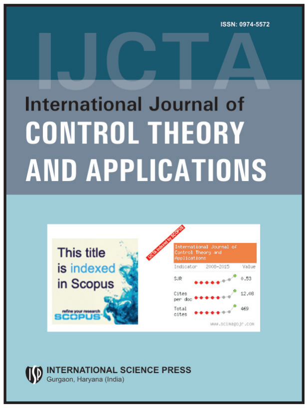

International Journal of Control Theory and Applications

ISSN : 0974-5572

Volume 9 • Number 44 • 2016

Detection of Cardiac Arrhythmias through ECG Signal Processing: IoT Based Approach

Mukesh M. Rathod[a] and Anil R. Surve[b]

[a-b]M.Tech. Student, Assistant Professor, Computer Science and Engineering, Walchand College of Engineering Sangli, Maharashtra, India. Email: [a]mukesh.rathod@walchandsangli.ac.in; [b]anil.surve@walchandsangli.ac.in

Abstract: Context-aware monitoring is an emergent technology that provides real-time medical services. Detection of Arrhythmia has been a major challenge due to human's lifestyle. Due to advancement in the domain of IoT, heart monitoring has been done with help of low powered wearable sensor devices. In this paper we proposed a system for detection of an arrhythmia in early stages by using a smartphone thus making system mobile and have access anywhere. In this system we use a Pan and W.J. Tompkins algorithm is used to find the QRS complexes and RR Intervals parameter on ECG waveform. This algorithm was tested on MIT-BIH arrhythmia database and found accurate of the QRS complexes resulting in accurate classification of arrhythmias. This research attempt will benefit all heart patients across the world facing economic and medical problems with heart issues.

Keywords: Android smartphone, Arrhythmia, Context-aware, ECG signal, IoT, Wearable sensor.

1. INTRODUCTION

In healthcare, IoT is a mobile medical application of wearable mobile devices that allow patients to capture their health bio-data. In pervasive computing the context aware monitoring is emergent technology such as modern integrated voice and data communications equips the hospital staff with smart phones to communicate vocally with each other, "wireless hospital", "mobile healthcare" require the development of bio-signal acquisition devices to be easily integrated for the medical purposes. This involvement of technology in device makes system a cheap and effective especially for health monitoring.

In today's era most of the people lost life due to the several diseases but among them some diseases are common which are nothing but heart related diseases. The total number of deaths due to cardiovascular disease read 17.3 million in the year 2015 as per WHO survey. It is also predicted that the number is expected to grow more than 23.6 million by 2030, representing 31% of all global deaths. Out of the 16 million deaths under the age of 70.With millions of people today affected with heart disorders, patient care has become extremely necessary. Most heart disorders have to be taken care by a patient for longer time duration and immediate help when needed is to be made available at the hospitals on priority. We thought of going a step further to facilitate patient care and with making available the vital signs like ECG (Electrocardiogram) at home using a low-cost reliable device. We could give the patient a warning of any cardiac arrhythmias detected by our system and similarly classify them and indicate the risk level to his/her care taker. This is made possible because of the different traits that various heart diseases exhibit. After proper study and analysis of the ECG signals and obtaining the processed signal will give a clear ECG based analysis which could be framed to devise the system to notify the abnormalities.

This proposed system aims to obtain ECG signal from patient body and further processing ECG parameters on a smartphone. Upon abnormal arrhythmia, alert message notification will be initiated to their Doctor or caretaker and server. ECG sensor device having Bluetooth communicator connects to the smartphone's Bluetooth port. The aimed system is based on android platform to analyze the real time ECG signals and different wave parameters are extracted to calculate the arrhythmia type. Alert messages are generated for information captured in real time for even nomadic users. Cardiac arrhythmias can be detected using this principle thus improving the quality of patient's life.

Arrhythmia is a heart related disease that means continuous variations present in heart beats and such variation in heart beats may cause high or low in blood pressure which can be dangerous to the patient which may lead to severe health conditions such as heart attack or death. Cardiac arrhythmia is abnormality in the working of the heart's electrical activities. Such variation results in abnormal functioning in rate and rhythm are hence called arrhythmias. The arrhythmia is of mainly two types. *1) Bradycardia:* Bradycardia in which patient's heart rate under 60 heart beats per minute. *2) Tachycardia:* Tachycardia in which patients heart rate rapidly increase above 110 heart beats per minute. Our system will be programmed to compute both Bradycardia and Tachycardia.

Android is mobile operating system platform which is now days used in large number of mobile and wearable devices. Android has proven very user friendly and easy to operate for even layman. It is an open source mobile operating system to run many of application simultaneously.

The further organization of this paper has system working explanation in the following sections. Where section II explains related work of similar attempts and notion of our proposed system. Section III focuses on architecture of healthcare system in detail. Section IV deals with the Methodology and Pan-Tompkins algorithms and it's working of ECG signal. Lastly, section V shows experimental analysis followed by overall summary in Section VI.

2. RELATED WORK

A. *Ambulatory Monitoring System:* The Ambulatory electrocardiogram (ECG) - holter monitoring is a device which monitors electrocardiogram (ECG) continuously for 24 to 48 hours and the ECG signals are continuously recorded by the patient. In other ECG devices needed 12 ECG lead to capture electrical signals of heart for only a few seconds. The ambulatory ECG monitor can record such signals over an extended period at the patient's own home or work environment. Hence, any abnormal heart activity or ECG abnormalities can be captured during the 24-hour monitoring period only. This is useful for detecting arrhythmia, which is not detected at the time when an ECG capturing is done. The main drawback of this system is shortcomings of standard 24 hours holter monitors include poor detection rates of temporary arrhythmic events and traditional ECG holter is inconvenient to carry anywhere because it has many electrodes and heavy in weight.

B. *Pervasive Computing:* Pervasive computing is emerging new area leveraging distributed, mobile computing technologies to configure applications as per profiled user needs. Some of the major techniques utilized under pervasive systems are namely Context-aware computing, Wearable computing & Ambient intelligence. The proposed system can be configured by embedded compact computing entities such as smart devices, microcontrollers, sensors, actuators etc. which can sense day-to-day life surrounding objects allowing them to communicate information of our interest. A permutation of technologies is used to make pervasive computing possible, such as networking capabilities using wired/wireless communicators such as Bluetooth, wifi, NFC etc. Bitalino kit is one such integrated pervasive device which has bio sensors to capture ECG signals of human being. Pervasive computing also has a number of prospective applications, which extends from smart home, health care, geographical tracking and transport systems.

C. *IOT as extension to Pervasive Computing:* The Internet of Things aims to connect devices through the internet which permits people and objects to be connected anyone, anytime, anyplace fashion. The Internet of things establishes path/network between devices and provides services as per context requirement. Now days IoT has been utilized in many potential areas such as healthcare, smart home, ambient living, connected cars, Industrial applications and agriculture. IoT can be categorized into major two types: (*1) Human Internet of Things (HIoT)* in which different types of sensors and wearable devices are connected with the human. (*2) Industrial Internet of Things (IIoT)* which is related to industrial IoT applications like as smart office, smart home etc.[4]. The popularity of IoT usages in the healthcare is because of these facts. (*1) Reduced costs*: reduce unnecessary physician visits (*2) Improved treatment outcomes:* access to real-time information. (*3) Real-time disease management:* due to the continuous monitoring of real-time healthcare data disease detected in early stages. (*4) Minimizes errors:* due to reducing human intervention the system in working automatically and collect accurate data with minimum errors. (*5) Improved patient experience:* The system provides accurate information to diagnose disease also improve treatment facilities.

3. ARCHITECTURE OF HEALTHCARE SYSTEM

The use case scenario of the applicability includes both the patient and the doctor. The doctor side application will be a simple android app while the patient side app will be equipped to take input from the ECG device via a Bluetooth connection. The processing of the app is to be done on the client side with specific instances and send it to the server for data storage and predication the disease with the present ECG data with historical data reference. The entire set-up will require internet connectivity for doctor-patient remote consultations. If any continuous variation occurs in the ECG data then send alert message to the caretaker and which may help to the patient immediately.

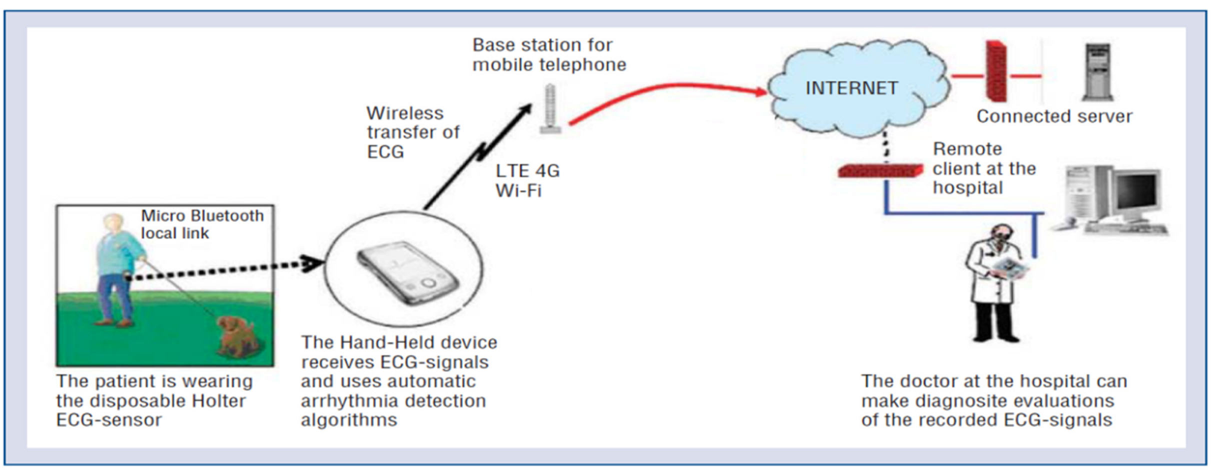

Figure 1: The wearable ECG sensor device connected to patients and ECG data sense continuously. The ECG data is transmitted from the wearable ECG sensor device to a hand-held smartphone device via Bluetooth. The smartphone is capable of detecting the arrhythmia. After that, these data are sent to the server through the internet and maintain log records for future use. [1]

We need a healthcare system which can opt the major pervasive computing principals and IoT to make system complete. The essential principals include *1) Ubiquitous:* Patient can use the system anywhere ubiquitously such as wearable devices or smartphone. *2) Unobtrusive:* The wearable devices automatically sense ECG signals from the patient body without attracting any kind of attention or disturbance. *3) Portable:* Overall healthcare system is wearable due to that patient can carry with itself. *4) Automation:* The acquired ECG signal be processed by the algorithm to detect any heart abnormalities and upon that alert message automatically to be sent to their respective caretakers. *5) Accuracy:* In this system, we use the Pan and W.J. Tompkins algorithm [2] to find out the R-R interval and QRS complex with high accuracy. *6) Remote alerts:* any alert message to be sent to the caretakers or doctors.

4. METHODOLOGY

A. *Pervasive Model [using Bitalino hardware kit]:* In market different types of healthcare devices are available but in that, some are weird or wireless devices. In those devices uses different types of sensor for acquisition of data. In our case having several devices embedded with ECG sensor in that Bitallino [5] is one device which is useful for to acquire ECG signal from patient's body.

The Bitallino hardware is made up of a different component. It contains control block with ATmega328P microcontroller, a data transfer block that uses to transfer data to another device with the help of Class II Bluetooth v2.0, a power block and two connectivity blocks enable RJ22 plugs to be added to the device.

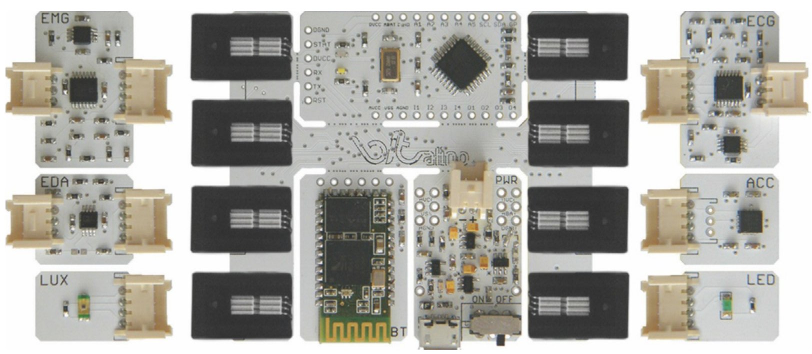

Figure 2: BITalino bio-signal acquisition hardware

The specifications of the Bitallino kit are as follows.

Table 1
Specifications

Specification	*Description*
Sampling Rate	Configurable to 1,10,100 to 1,000 Hz
Analog Port	4 input(10 bit) + 2 input(6 bit)
Digital ports	4 input(1 bit) + 4 output(1 bit)
Data Link	Class II Bluetooth v2.0 (10m range)
Actuators	LED
Sensors	EMG, ECG, EDA, ACC, LUX
Weights	30g
Size	100*60 mm
Battery	3.7-V LiPo
Consumption	65 mAh (with all peripherals active)

B. *Signal Processing Module:* The main functionality of Bio signal processing is achieved by Pan and W.J. Tompkins algorithm [2]. When ECG sensor wearable device captured ECG signal from the patient body with the help of electrode and these bio-signal frames arrive on smartphone Bluetooth serial port, the serial port event listener on the smartphone will call a method for saving the incoming frames. The stored data further processed in buffers of the smartphone. After filtering the ECG signal we get different parameter likes R Peaks, RR Interval, QRS complex etc. For QRS Detection Pan and W.J. Tompkins algorithm [2] is used. These parameters help to detect Arrhythmia. User Interface (UI) of the smartphone is easily operated by the lay person. These data is stored in a database at server side for future use.

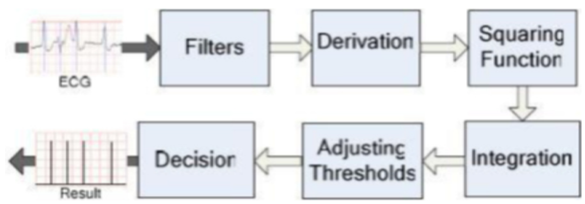

Figure 3: Pan-Tompkins QRS detection Algorithm [3]

C. *ECG Signal Acquisitions:* ECG signals are acquired using Bitalino device, these signals are then sent to a smart phone for further processing. The following step shows how to remove raw noise signal.

1. *Signal Filtering:* Signal filtering is used to trying eliminating the noise signal.

1.1. *Low pass filter:* Eliminate noise which is produced by electrical activity produced by skeletal muscles (EMG).

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

$$yl[n] = 2y[n-1] - y[n-2] + x[n] - 2x[n-6] + x[n-12]$$

1.2. *High pass filter:* To eliminate the motion artifacts like P wave and T wave.

The transfer function for the high pass filter is:

$$H(z) = Y(z)/X(z) = (1 + 32z^{-16} + z^{-32})/(1 + z^{-1})$$

$$yh[n] = yh[n-1] - yl[n]/32 + yl[n-16] - yl[n-17] + yl[n-32]/32$$

2. *Derivative:* To obtain the information of slope of ECG and to overcome the baseline drift problem like patients motion, deep breathing, metal dust on skin, dirty tips of electrodes cable, voltage changes in wall electricity. After, it provides QRS complex slope information.

We use a five point derivative with transfer function:

$$H(z) = 0.1(2 + z^{-1} - z^{-3} - 2z^{-4})$$

$$yd[n] = (2yh[n] + yh[n-1] - yh[n-3] + 2yh[n-4])/8$$

3 *Squaring function:* Emphasize the higher frequency component and attenuate the lower frequency components to get the absolute value and positive value.

The equation is,

$$y[n] = (x[n])^2$$

$$ys[n] = yd[n] * yd[n]$$

4. *Moving window Integration:* It is used to obtain wave feature information in addition to the slope of R wave.

   It is calculated as,

$$y[n] = (x[n-(P-1)] + x[n-(P-2)] + \cdots + x[n])/P$$

$$yi[n] = (ys[n-(P-1)] + ys[n-(P-2)] + \cdots + ys[n]/P$$

   where, P is the number of samples in the width of the integration window

5. *Adjusting the Thresholds:* The value of threshold is automatically adjusted to float over the Noise. Low thresholds are possible because of the improvement of the Signal-to-Noise ratio by the Band pass filter.

Table 2
System Requirement

Sr. No.	*Components name*	*Used*	*Specification*
1	Bitallino Kit	To sense the ECG signal from user's body and it sends to the smartphone for processing.	1. ECG Sensor 2. Bluetooth 3. Light weight and Chargeable Battery
2	Android Smart-phone	To send/receive notification to/from the caretaker and also processing ECG signal.	1. 500 MB RAM 2. 1 GB Memory 3. Bluetooth 4. 3G
3	Server	To store and analysis of detect heart diseases from historical and present ECG signal of users.	1.Server(Cloud, Big-data)

5. EXPERIMENTAL ANALYSIS

1. *Raw ECG signals:*

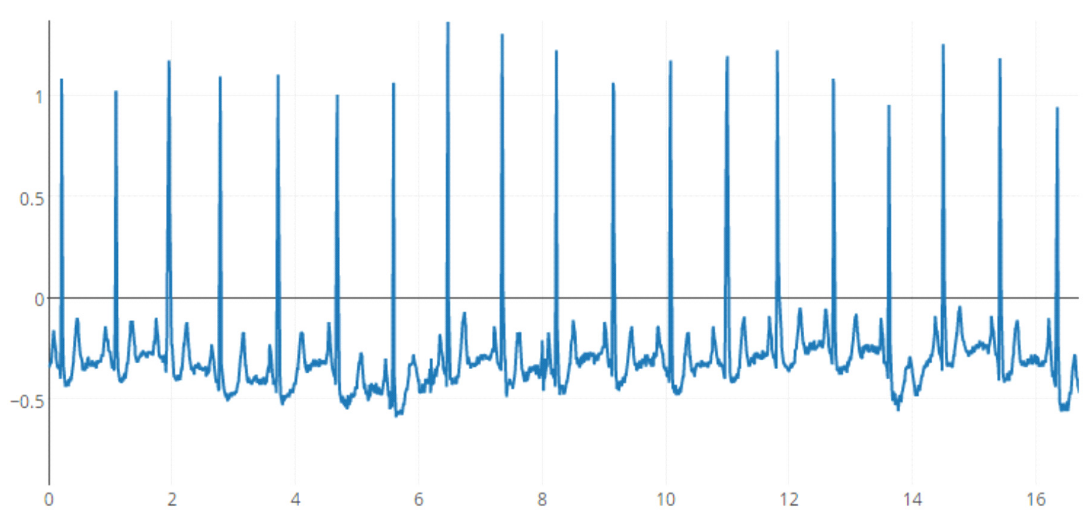

Figure 4: Raw ECG signal

2. *Signal Filtering:*

   2.1. *Low pass filter:* The cutoff frequency is nearly about 11 Hz and the gain is 36.

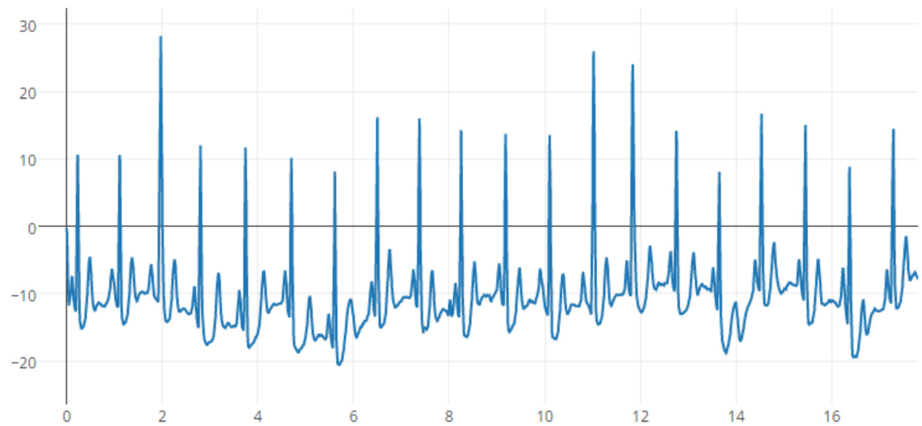

Figure 5: Low pass filter

   2.2. *High pass filter:* 32 is the gain of this filter.

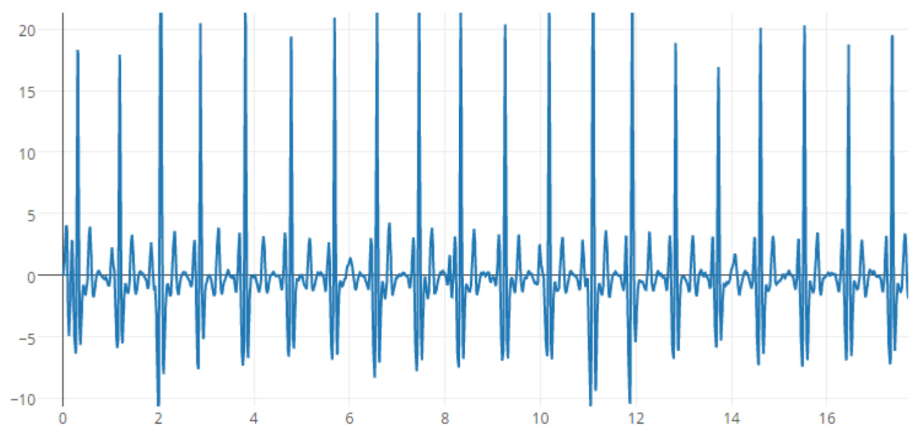

Figure 6: High pass filter

3. *Derivative:* Derivatively is nearly linear between dc and 30 Hz.

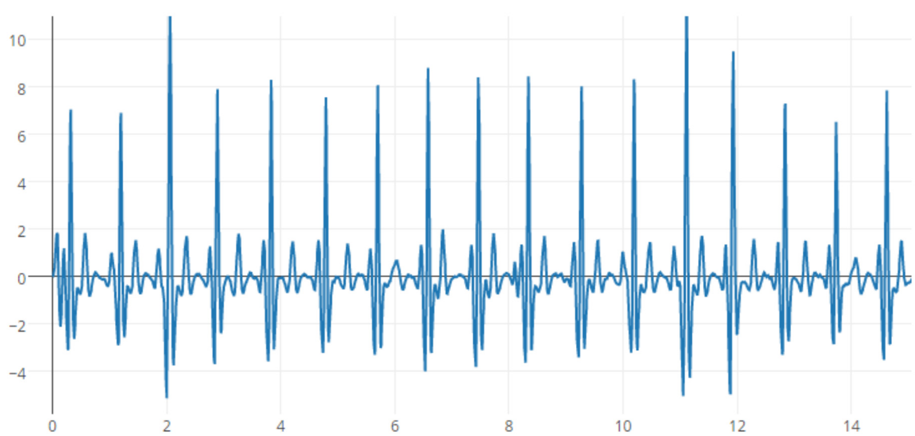

Figure 7: Differentiator

4. *Squaring function:* The signal is squared point by point.

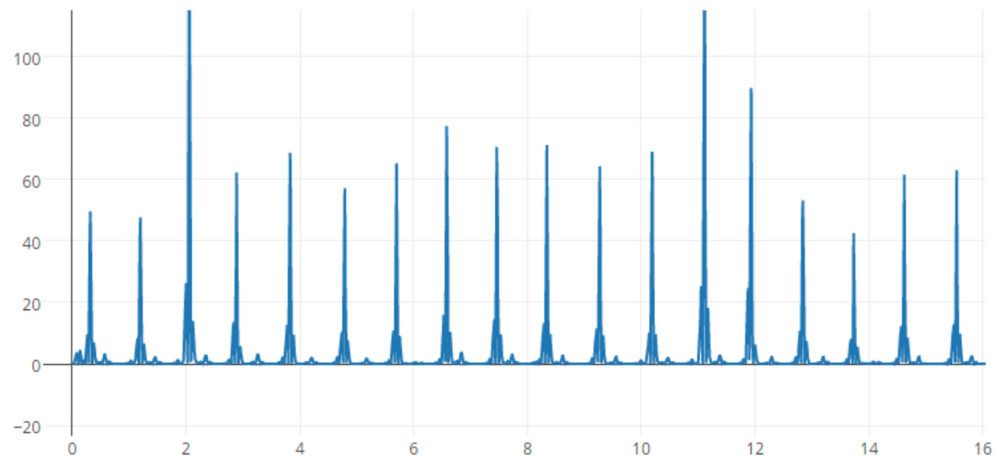

Figure 8: Squaring function

5. *Moving window integration:* Act as a smoother and perform a moving window integrator over 150 ms to get spike like signal

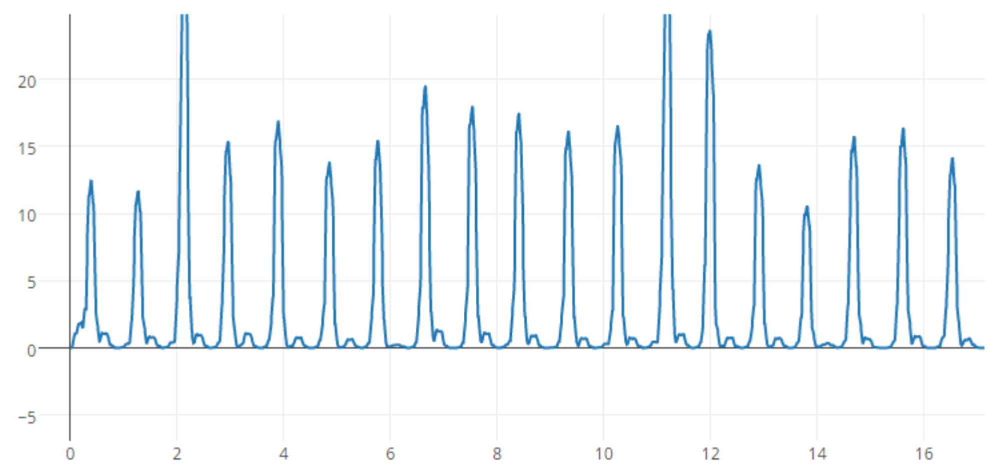

Figure 9: Moving window integration

6. SUMMARY

It's learnt that Context-aware health monitoring system using Pervasive approach assures user zeal of self-assurance in early health anomalies alert. The research attempt experiments the principles of pervasive computing in terms of automation, unobtrusiveness, ubiquity and context awareness of health care system with a determinant level of satisfaction. Our system provides real-time emergency medical services of detecting Arrhythmia with the advent of IoT and low powered wearable sensor devices such as Bitalino kit. This system will be pretty much helpful for detection of an arrhythmia in early stages by using a smartphone based ubiquitous access anywhere. The core functional part of the paper utilizes the Pan-Tompkins algorithm for finding the QRS complexes and RR Intervals parameter on ECG waveform which is tested on MIT-BIH arrhythmia database shows fairly good classification of arrhythmia detection. Hence this research attempt will benefit all heart patients across the world facing economic and medical problems with heart issues in their respective life style.

Acknowledgment

We sincerely thank CSE Department at Walchand College of Engineering, Sangli for providing experimental setup for this project. Also, we extend our sincere thanks to the research community for their reference support.

REFERENCES

[1] Fensli R, Gunnarson E, Hejlesen O. A wireless ECG system for continuous event recording and communication to a clinical alarm station. Conf Proc IEEE Eng Med Biol Soc, 2004; 3: 2208–2211.

[2] Pan and W.J. Tompkins] J. Pan and W.J. Tompkins A real-time QRS detection algorithm. IEEE Trans. Biomed. Eng.,vol. BME-32, pp. 230-236, 1985.

[3] A.M.Patil, P.K.Gakare, A.N.Cheeran Real Time ECG Feature Extraction and Arrhythmia Detection on a Mobile Platform. International Journal of computer applications, (0975-8887), Vol.44 -No.23,April 2010.

[4] M.A.Razzaque, Marija Milojevic-Jevric, A. Palade; S. Clarke "Middleware for the internet of things: a survey," IEEE Journals & Magazines, vol. 3, no. 1, pp.70-95, Jan 2016.

[5] http://www.bitalino.com/downloads/bitalino manual/manual.html.