Journal of Theoretical and Applied Information Technology
30th September 2016. Vol.91. No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

DESIGN AND IMPLEMENTATION OF AN EMBEDDED SYSTEM TO ANALYSIS AN ECG SIGNAL FOR HEART DIAGNOSIS SYSTEM

[1]AZMI A. BASAIF, [1]S. A. ALJUNID, [1]NASEER SABRI, [2]M. IQBAL OMER. [3]M. S. SALIM
[1]School of Computer and Communication Engineering,University Malaysia Perlis, Malaysia
[2]School of Mechatronic Engineering, University Malaysia Perlis, Malaysia
[3]Laser and OptoElectronics Engineering Department, ALNahrain Univrsity, Iraq
E-mail: az87mi@gmail.com

ABSTRACT

In recent times, Biometric recognition has appeared to be among the applications where there is necessity for privacy of information relating to health care matters. The focus of this study is on embedded Heart disease diagnosis system for individual centered on the Electrocardiographic (ECG) biometrics. This proposed real time system design is a diagnostic algorithm that extracts information from the ECG wave signal on architecture based Single Board Computer (SBC) represented by the Raspberry PI Platform. The proposed system is targeted to be free standing, and in situ heart abnormality identifying beside warning system. In addition the system is easy to use in different environments. Preliminary results show the successful implementation in an embedded platform, enabling its usage on a countless of operations.
Keywords: *ECG Embedded System, Raspberry Pi, Diagnose of heart Diseases*

1. INTRODUCTION

The most influential prime mover of rhythmic information patterns of the human body is the heart. The heart did not only pumps blood in each breathe taken, but also pass on complex patterns of pressure, hormones, electromagnetic and neurological information to the brain and all over the body. Serving as crucial nodal points to many of the interacting systems of the body, the heart exclusively stood as a powerful point of entrance to the communication network connecting the mind, spirit, emotions and the other part of the body[1][2][3].

Electrocardiogram (ECG) can be regarded as a graphic tracing of the voltage generated from the heart muscle or cardiac through a heartbeat. It gives a very precise evaluation of heart performance. An electrochemical whim spreading all over the heart is generated by the heart. This electrochemical whim causes the cells to relax and contract in an appropriate order and therefore provide the heart a characteristic pumping[4][3]. A group of nerve cells known as the Sino atrial (SA) node instigated this sequence, ensuing into polarization and depolarization of heart cells[5][1], because the activity is naturally electric in form and the body is in comportment with its fluid content. The electrochemical activity can be determined at the body surface. Between numerous point of the body, a real voltage potential of approximately 1mV is developed [2][6]. This may be determined through the placement of electrode contacts on the body. The chest wall the four extremities have turn out to be standard sites to apply the electrodes. The possibility to compare from one person to another and in different time from one person was due to the standardization of the electrocardiograms. The usual ECG displays normal upward and downward deflections reflecting the heart's alternate contraction of the atria (the two upper chambers) as well as the ventricles (the two lower chambers) [4]. Fig. 1 below shows a typical single cardiac cycle waveform of a normal heartbeat.

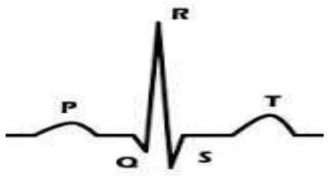


Figure 1: Atypical ECG Waveform

The ECG signal is graphical registration of the electrical signal generated by the human heart against time[7] [8]. The ECG is applied to interpret some different kinds of cases caused by abnormal heart like conduction disturbance, arrhythmias and

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

heart morphology (e.g., evolving infarction or myocardial ischemia, and hypertrophy). The clinical practices show that some cardiac disease can be diagnosed accurately[9][10][11]. The ECG diagram is also helpful when assessing the performance of portable pacemaker devices to control abnormal heart rhythms. For example, in the United States more than 50% of hundred-million ECGs recorded annually are identified and diagnosed by computer systems[12][13].

Embedded system has burial and feature such as low cost, officiant processing, and portability in addition to its open source support platform. Thus embedded system such as simple board computer type raspberry PI is well suit to interface and monitors heart signal probes with embedded monitory and diagnosis software. The flexibility offered by BCs present them to be adopted for new various applications and heart diagnosis is such an example.

This research presents with upcoming sections; the related ECG monitoring and analysis work followed by applications of embedded system with biomedical fields with the challenges of using emedded systems in medical applications. The ECG embedded system architecture is presented then abnoralities in cardiac signals and thus expected results and conclusions .

2. RELATED WORK

The innovative improvement of Medical Monitoring Systems can be traced to the rapid development in the area of Embedded Systems and Wireless communications, which has improve the healthy life of human beings [11].

In some years now, technology improvement particularly in software engineering and microelectronics have led to the advent of powerful processors for embedded systems which include microcontrollers, microprocessors, digital signal processors, and FPGA; and refined personal computers (PC) as well as communications networks with various standards (Wi-Fi, TCP/IP, Bluetooth, GSM, ZigBee, etc.)[7][2].

The procedures of designing computing systems have been modified by the great technological evolution, which is gradually leading to high level of formalism. This formalism can be used specifically for the ECG recognition. The sensitive strength of these formalisms in a substantial number of applications will increase the use of a combine declarative and procedural models[14].

The automatic mapping of applications shown in the above formalism on distinct purpose embedded systems can considerably increase the implementation time. The health sectors benefits more from this by producing more dependable equipment that is user friendly and easy to access by all part of the society; also saving more lives as well as creating valuable data for diagnostic and research. A significant usefulness of it is for monitoring people with heart disease who may at any time be subject to a heart attack. In this case, this system we have designed and implemented is a simple prototype example of an embedded system for such situation[15].

Embedded systems invade our daily life as they are used within all kinds of devices such as entertainment, communication and transportation. Beside fusion with industrial and military integrated solutions, the need for more sophisticated solutions and the availability of increased computational power has an effect on the pristine single purpose systems. Existing solutions have to assist their users for a wide variety of orthogonal designed based on a real time operating system that is raspberrian, as an exemplar. In this project ECG system is presented based on a single board computer represented by Raspberry PI as an embedded solution[16].

This project describes the use of low cost single – board computer Raspberry Pi with wireless/wire interfacing. This work is focused on developing an ECG Diagnose embedded system based Raspberry Pi Single board computer that detects abnormality in heart functionality and to response speedily by capturing and relaying images/data to admin monitor based interfacing module of ECG device and the SBC and thus activate the alert system both at patient side and office admin. The adopted system of Heart Diagnose system is based on a networked single board computer, raspberry pi, 12 led ECG capturing device and sophisticated software package for signal capturing and data analysis. This proposal presents the idea of monitoring a particular heart disease in a portable manner. The system also can be administrated by a remote user from any workstation when the SBC is connected to cloud server. The new technology is less expensive and longer life of remote battery powered units. The project aims to develop a ECG monitoring and diagnosis embedded system which captures and hosting, real time heart signal as an images/signal and arises of alerting alarms for abnormality issues. The proposed system has potential benefits for various medical hearts diagnose applications such as, but not limited to, elderly monitoring in remote area, in situ patient monitoring, self-diagnose and warning system for

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

heavy duty workers and athletic people. The proposed solution offers efficient stand alone, flexibility to upgrade and cheap development and installation as well as cost effective ECG based raspberry pi embedded solution.

3. EMBEDDED SYSTEM FOR MEDICAL APPLICATIONS

Nowadays, the medical embedded systems have gained much attention of worldwide organizations and governmental institutes. The integration of physical body activities signals into an embedded devices system is becoming more attractive to build an efficient medical system. This research is motivated by the following:

- Elderly monitoring and in situ embedded monitoring Heart need efficient monitoring and warning system.
- A semi-autonomous ECG system based on human monitoring assistance is not optimum.
- Costly solution is emerging form localized ECG system in clinics and hospital.

This research is focusing on the design and implementation of cost effective solution that capable to handle in an efficient way the abnormalities in heart and determine its identity and medical historical information. And thus, the ECG system will be investigated the functionality of the embedded system platform used and qualitative its performance. As well as, Supplementary code has to be deployed on the system to identify the objects and to manage system peripheral configuration besides analyzing of data of the whole system. This proposal addresses the problem into two divisions. The first part is the extra software to be implemented on the system in order to identify objects, configure, and manage the heart signals. While the later part is concerned with the enhancing detection algorithm of the system throughout, improving system awareness of the vision heart signals. Alerting of abnormalities within the human heart is important because of the sensitive nature of having worst cases in a case of delayed diagnoses and awareness (or other premises) due to the expectation of Introduction privacy of people who are in the home with the home owners' permission. Most of ECG system are semi diagnoses image streaming system that depends on specialist doctors who read signals and diagnoses in addition keep watching all the time the monitors. Thus, as humankind's nature, the system may miss important monitoring issues such as abnormal activities due to tiredness or amusement. The issues arise with monitoring systems are commonly fused with alerting and identifying warning. For remote and scattered heart disease people, need a hybrid system of all time signals monitoring during working hours in addition of warning and image identified system at all time.

4. EMBEDDED ECG SYSTEM CHALLENGES

The embedded SBC for heart disease diagnosis has too many severed challenged, such as the accuracy of sensed heart signal, the identification of the signal, and processing time of diagnosing. These challenges can be evaluated previously after implementation the real time monitory.

5. EMBEDDED SYSTEM ARCHITECTURE

The proposed system is designed as shown in Fig. 2. The 12 lead capturing devices of heart signals are interfaced to raspberry pi SBC where all data is received are diagnosed and saved. The interface module ensures serial data transmission between the raspberry pi and the 12 lead devices. Decision making unit is implemented inside the SBC and determines the abnormality in the heart signals besides arising of an alert with warning message about the functionality of the heart at moments. The display unit is used to show the information in situ and the heart signal while the remote monitors system is used for local specialist. System information about the patient under vision can be transferred wireless to remote admin such as clinic or hospital and even doctors in addition cloud server can be fed with this information for wide sharing specialist and care people. The proposed system will consist of hardware modules represented by the SBC and the 12 lead device and peripherals integrated with sophisticated software for data capture, archive, analysis and classification and thus diagnosing. Abnormality in heart functionality is shown on displays with warning messages.

5.1 Parameters of ECG Signal

Atypical ECG wave of the cardiac cycle signals, Fig. 3, consists of a different information hold by a P wave, QRS complex, and T wave which normally seen in 50% to 75% of ECGs signals.

Journal of Theoretical and Applied Information Technology
30th September 2016. Vol.91. No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

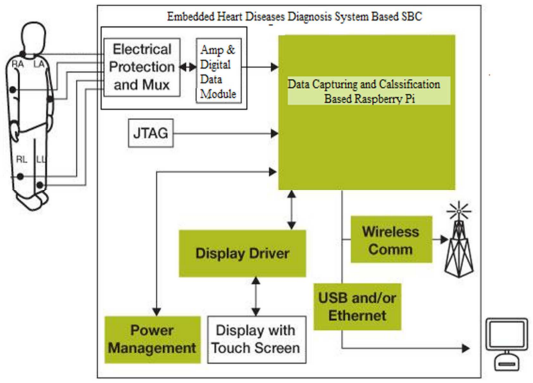


Figure 2: Embedded Heart Diseases Diagnosis System

The flat segment represents the portion of the wave that follows the T wave and precedes the next P wave. In normal healthy heart, the baseline is equivalent to the isoelectric line [10].

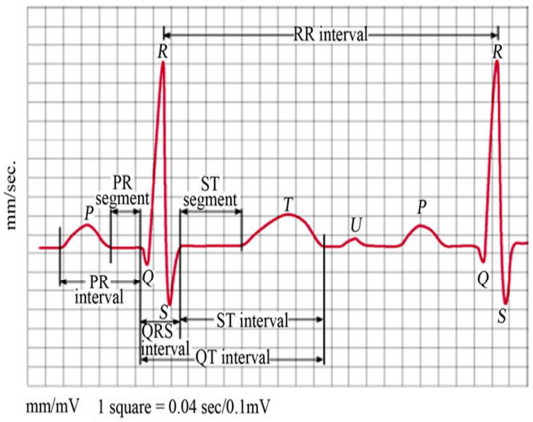


Figure 3: Ideal ECG wave Representation [2], [8]

The P wave and the QRS complex give and clear information about the heart muscular relaxations of atria and ventricles respectively. When Ventricles enlarge, the blood is replenished into them following which T wave is generated. The elapsed time for electrical charge to travel form SA node to AV node is known as a PR interval [9]. Whereas QRS complex define the time taken for electrical signal to move through the ventricles. QT defines the time needed by ventricles to recuperate and initialized to beat over. The number of the sequences taken from P, QRS complex, and T gives the heart rate of the human being and the change in the signal represent the change of the heart muscles. The analysis of ECG provides exact information about an individual heart beats. In detecting the precise positions of R peaks several of procedures have been established and part of them is Hilbert and Wavelet transforms, which have been proved to be optimal. This study choses Hilbert Transform to process the ECG signal in line with the characteristics discussed in later sections.

Table 1: Ecg Diagnosis Feature LIST [17]

FEATURES	DESCRIPTION	DURATION
RR Interval	The interval between two consecutive peak of R to R signals	0.6 TO 1.2s
PR Interval	The interval between the start points of the P wave to the following start point of the QRS complex.	120 TO 200ms
QRS complex	The time space between end points of PR interval and S wave. It has a higher peak (R peak) when compared to the P wave because of rapid depolarization of ventricles in the heart	80 to 120ms
ST Interval	The interval between end point of QRS complex to the end point of T wave	320ms
QT Interval	The interval between starting point of the QRS complex to end point of T wave.	Up to 420ms in heart rate of 60bpm

5.2 System Design

The purposed embedded diagnosis system is shown in Fig. 4. The main system is composed of

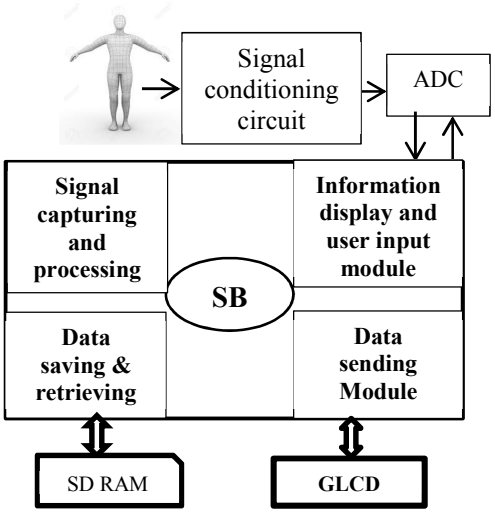


Figure 4: Block Diagram of ECG Monitoring System

5.2.1 ECG sensor leads

The 12 leads acquitter device is used to capture the heart signals from the body surface, the 12 provides spatial information about the heart's electrical activity in 3 approximately orthogonal

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

directions (Right ⇔ Left) ,(Superior ⇔ Inferior), (Anterior ⇔ Posterior)

Each of the 12 leads represents a particular orientation in space, as indicated below (RA = right arm; LA = left arm, LL = left foot)

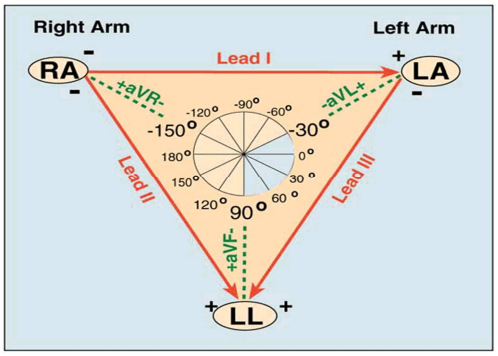


Figure 5: The 3 Approximately Orthogonal Directions

We have using electrocardiogram device (SKU:EKG-903A3) to capture the signal from the body surface and save it as excel file in the memory which already insert to save the data as numbers with 12 columns to describe the 12 leads of the signal detected from the heart. Therefore, the data will transfer to the embedded system through USB connection as data file.

5.2.2 Single board (Raspberry BI)

A single-board computer (SBC) is a computer which is a complete computer in which a single circuit board comprises memory, input/output, a microprocessor and all other necessary features. Unlike a personal computer, it does not rely on expansions for other functions. A single-board computer reduces the system's overall cost as the number of circuit boards, connectors and driver circuits are all reduced.

Raspberry Pi is microcomputer a low cost, credit-card sized computer that plugs into a computer monitor or TV, and uses a standard keyboard and mouse. It's capable of doing everything you'd expect a desktop computer to do, from browsing the internet and playing high-definition video, to making spreadsheets, word-processing, as show in Figure (2.2) Raspberry Pi Model B +.

5.2.3 MONITORING SOFTWARE

Figure 6 presents the main monitory flow chart and embedded system design. As shown the main tasks of the utilization by the need of the 12 leads signal to be normalization for analysis & diagnosis. The diagnosed ECG information will be archived and shown on the output LCD.

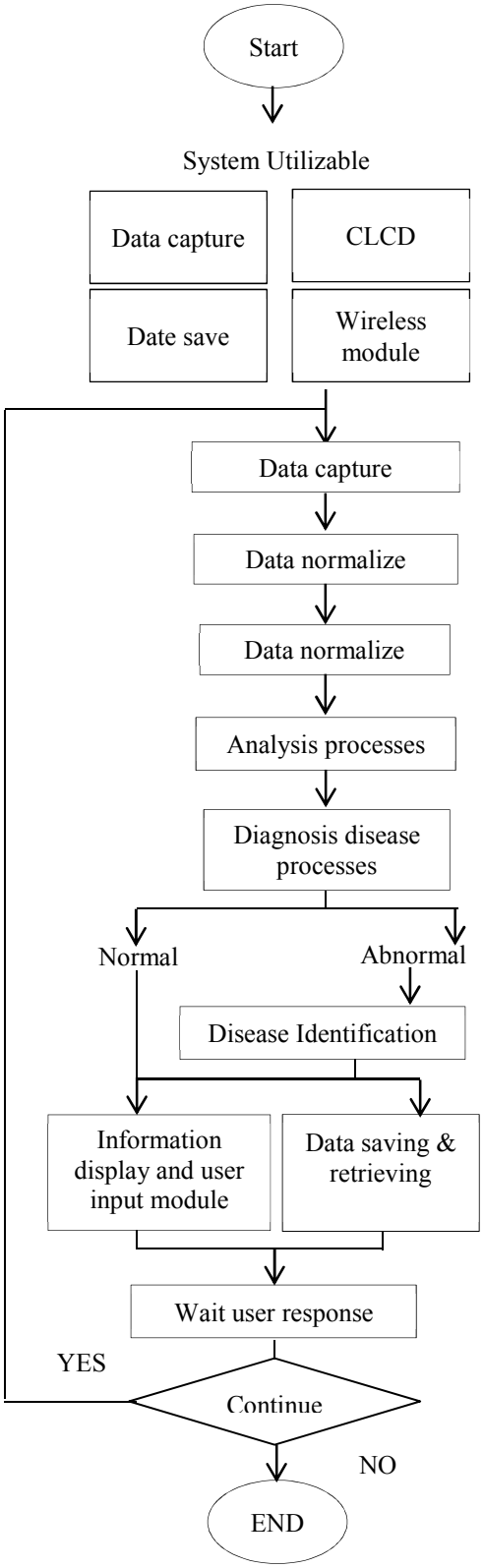


Figure 6: Embedded ECG System Flow Chart

Journal of Theoretical and Applied Information Technology
30th September 2016. Vol.91. No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

The diagnose process is carried out within high speed algorithm for detecting ECG waves (P, QRS complex, and T). The Monitors & Disease define Algorithm is implemented with scilab software and the program language.

Scilab is of high potential with embedded single board computer. Its open source software that can be adopted and enhanced as requested for personal or commercial usage. It motivated with a transparent structure and user interface. It is also easier to use in countless facets for example, you can program a function right into an immediate application no need to store the function, and call it up separately. Scilab is a methodical software bundle for numerical computations in a user friendly environment[18].

6. DETECTION OF ABNORALITIES IN CARDIAC SIGNALS

In this research work, SINGLE BOARD COMPUTER represented by raspberry PI is adopted as the main core of capturing of the data and decision unit. The flexibility of margining the embedded development board with C and Python programing languages are used to integrate the complete system functionality. Figure 6 presents the basic structure of the proposed system. It consists of three units namely, Data Acquisition Unit, Data Processing Unit and Data Communication Unit.

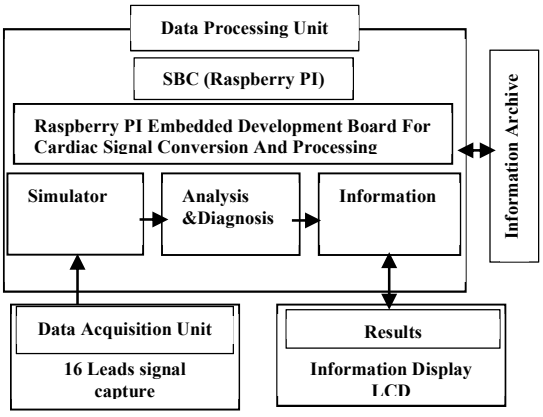


Figure 6: Basic Architecture of the proposed system

6.1 Data Acquisition Unit:

Scilab software is adopted beside python and c programming languages. It is real time software permits a different range of adaptable settings, including minimum and maximum heart rate computation. The ECG data acquisition is synchronized in the host system programmed in Scilab software. Figure 6 shows the main blocks of the proposed system. It consists of the ECG signal simulation and acquisition. The biomedical kit in scilab software has been adopted to simulate the ECG signals within 500 samples per second as a sample rate. This sampling rate will offer a high resolution signal that includes all the details of the heart wave. With the facility offered by scilab, it easy to start acquisition and save of data and thus offers more elasticity to the cardiologist. The simulated ECG waves are captured using of the Single board computer, Raspberry PI.

6.2 Data Processing Unit:

The data processing block in figure 6 contains the embedded development board and the local network created with the USB port communication. Using of USB ports available with raspberry PI, all the heart wave data will be captured into data sheets. The captured data from the real time software in the data acquisition unit is provided through the USB port in the embedded board. C programming is used to organize these data into proper sets so as the diagnosis software diagnoses it.

6.3 Data analysis & Diagnoses:

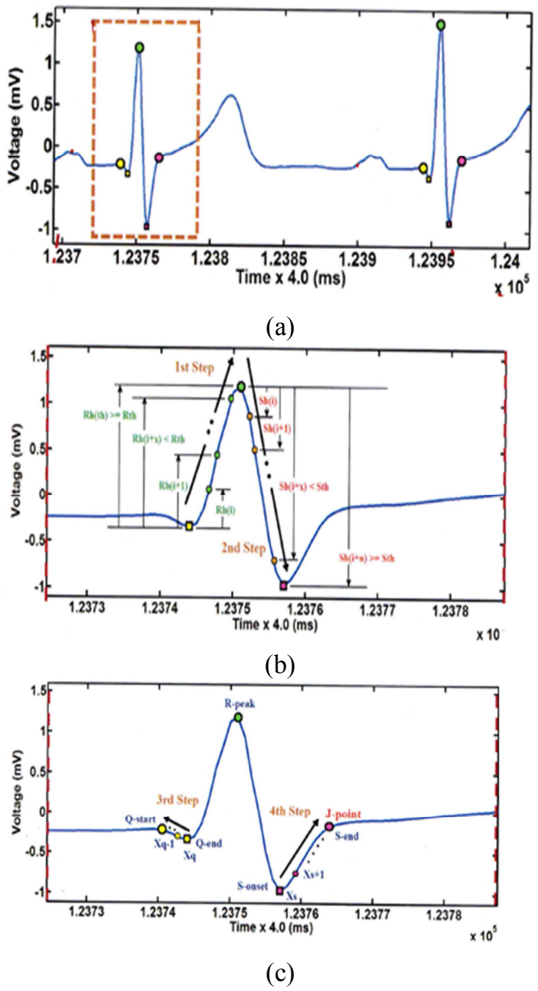
To delineate the time location point of the QRS complex, and then represent these locations as the reference points to delineate other time locations in the P and T waves. Additionally, the obtained diagnosis features from these locations are used to make a diagnosis for different cardiac diseases. Therefore, the detection of the QRS complex can be seen as the core of analyzing and interpreting ECG signals. As a result, a developing new approach for detecting and delineate the QRS complex accurately is essential.

To delineate the time characteristics of the QRS complex (QONSET, QEND, RPEAK, SONSET, and SEND) has been proposed using an instantaneous algorithm applied directly on the ECG signal without the need for any mathematical transform, additional filters, or classification with the intelligent technique. The proposed detection approach takes the advantage of mutation from tall rising to falling edge as the basis for delineating the time location point of the QRS complex. The first stage which represented as a pre-processing unit, simple calculations are performed to compute two threshold values (R_{th}, and S_{th}) which determined by computing the maximum positive and negative difference along the beats of two or three ECG cycles. Next, the largest two sequential sets are extracted as a maximum positive

Journal of Theoretical and Applied Information Technology
30th September 2016. Vol.91. No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

difference Rt and maximum negative difference St. To delineate time location (onset, peak, and end) of P and T waves respectively. Both delineate algorithm scan the target ECG signal within the adaptive interval than can be identified relative to the time characteristic of the QRS complex.



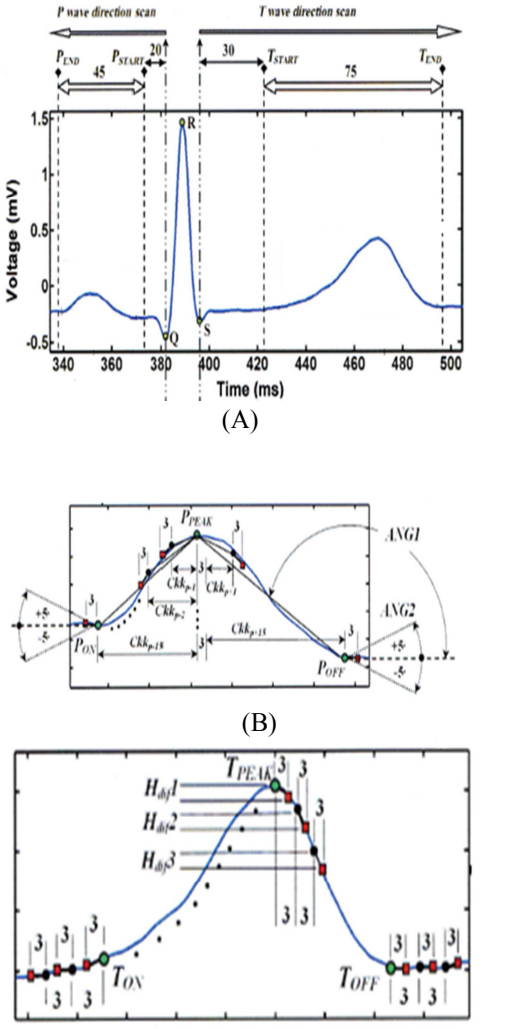
(a)

(b)

(c)

Figure 7: Graphical representation of high speed approach, (a) Original ECG signal. (b) Delineation of Q_{END} , R_{PEAK} ,S_{ONSET} Time location Points. (c) Delineation of Q_{ONESET}, S_{END} Time location Points.

The new approach includes two algorithms to delineate time location (onset, peak and end) of P and T waves respectively. Both delineated algorithm scan the target ECG signal within the adaptive interval that that can be identified relative to the time characteristics of the QRS complex which are pre-detected by another detector. Figure 8 show Graphical representation of high speed approach for detecting P and T waves.



(A)

(B)

(C)

Figure 8: Graphical representation of high speed approach for detecting P and T waves, (A) Search Period Limits Utilized by Algorithm for P and T Peak Delineation in Single ECG Record of Dataset From ST Change Category in QTDB, (B) P-wave Segment Marked with Angles and Intervals Utilized by PWONOFF Subroutine to Extract the Oneset and the END time location of P wave, (C) T-wave Segment Marked with Three Sequential Stairs Utilized by TWONOFF Subroutine to Extract the Oneset and the END of T wave.

7. EXPECTED RESULTS:

The Embedded systems are known as computer system that are inside a larger system performing a particular function and performs a task in highly particular situations, and need distinctively tailored software and systems to work, working on a high speed operation with a very low power. It is cheaper, more reliable, and better than a discrete

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

hardware design for some other reasons. Embedded systems are frequently needed in providing Real-Time response. For using this embedded system we proposed to diagnosis some of heart disease due to the change which happened to the wave from different reading using the RFEM approach to detect the QRS complex in the ECG signal and delineate its time characteristics, two graphical evaluation are performed to compute accuracy of the delineated result. More ever by using the HSDPTW approach which proposed to detect the P and T waves in the ECG signals and delineate boundary and peak time location of these waves in cause to identify and detect some of heart disease by easy process.

8. CONCLUSION

The designing approach of this research is based on utilizing of SBC of raspberryPi features to design of heart abnormality detection system with alerting facilities. The ECG embedded system target to be real time embedded detection and warning portable system that can be worth for patients and health care institutes. The designing approach utilizes the open source system, small in size with cost effective solution. It offers local and remote heart diagnosis information. The system can be further developed on wearable style and thus offers highly feature over traditional ECG systems.

The excellent features of SBC represented by Raspberry will help highly to vitalize an efficient heart diagnosis embedded system. Since Raspberry Pi has cost effective and small size as well as power processor and sufficient memory and port support. The SBC needs a wireless module so that all measurements can be saved immediately for future analysis and archival.

REFERANCES:

[1] I. Journal and O. F. Engineering, "INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY Real Time ECG Acquisition System using Raspberry PI *1," *Compu Upeu*, vol. 3, no. 6, 2014.

[2] M. Atkinson, "ENGR 499 : Wireless ECG," 2012.

[3] A. Martínez, R. Alcaraz, and J. J. Rieta, "Application of the phasor transform for automatic delineation of single-lead ECG fiducial points.," *Physiol. Meas.*, vol. 31, no. 11, pp. 1467–85, 2010.

[4] a Maheswari and V. Ramachandran, "System for Detection of Vital Signals with an Embedded System," vol. 6, no. 1, pp. 22–30, 2011.

[5] A. Al-omary, "Heart Disease Monitoring System Using Web and Smartphone," pp. 8265–8273, 2014.

[6] N. Amour, A. Hersi, N. Alajlan, Y. Bazi, and H. Alhichri, "Implementation of a Mobile Health System for Monitoring ECG signals," pp. 1–7, 2014.

[7] N. Belgacem and F. Bereksi-reguig, "Bluetooth Portable Device for ECG and Patient Motion Monitoring," *Nat. Technol.*, no. January, 2011.

[8] G. Camps-valls, A. J. Caama, and J. F. Guerrero-mart, "ECG Signal Processing, Classification and Interpretation," *Zhurnal Eksp. i Teor. Fiz.*, pp. 195–217, 2012.

[9] P.-C. Chang, J.-J. Lin, J.-C. Hsieh, and J. Weng, "Myocardial infarction classification with multi-lead ECG using hidden Markov models and Gaussian mixture models," *Appl. Soft Comput.*, vol. 12, no. 10, pp. 3165–3175, 2012.

[10] J. P. Martinez, R. Almeida, S. Olmos, A. P. Rocha, and P. Laguna, "A Wavelet-Based ECG Delineator Evaluation on Standard Databases," *IEEE Trans. Biomed. Eng.*, vol. 51, no. 4, pp. 570–581, 2004.

[11] A. C. Matos, A. Lourenço, and J. Nascimento, "Embedded System for Individual Recognition Based on ECG Biometrics," *Procedia Technol.*, vol. 17, pp. 265–272, 2014.

[12] R. Prakash, "Remote Monitoring Of ECG And Body," vol. 3, no. 5, pp. 12543–12550, 2014.

[13] S. K. Salih, S. A. Aljunid, S. M. Aljunid, and O. Maskon, "Robust Approach of De-noising ECG signal using Multi-resolution Wavelet Transform."

[14] M. L. T. Cossio, L. F. Giesen, G. Araya, M. L. S. Pérez-Cotapos, R. L. VERGARA, M. Manca, R. A. Tohme, S. D. Holmberg, T. Bressmann, D. R. Lirio, J. S. Román, R. G. Solís, S. Thakur, S. N. Rao, E. L. Modelado, A. D. E. La, C. Durante, U. N. A. Tradición, M. En, E. L. Espejo, D. E. L. A. S. Fuentes, U. A. De Yucatán, C. M. Lenin, L. F. Cian, M. J. Douglas, L. Plata, and F. Héritier, *No Title No Title*, vol. XXXIII, no. 2. 2012.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

[15] X. Cui, "A NEW real-time ECG R-wave detection algorithm," *Proc. 6th Int. Forum Strateg. Technol. IFOST 2011*, vol. 2, no. 2, pp. 1252–1255, 2011.

[16] C. Lin, C. Mailhes, and J. Y. Tourneret, "P- and T-wave delineation in ECG signals using a bayesian approach and a partially collapsed gibbs sampler," *IEEE Trans. Biomed. Eng.*, vol. 57, no. 12, pp. 2840–2849, 2010.

[17] S. Teja and S. A. I. Kumar, "ECG MONITORING OF A CARDIAC PATIENT USING EMBEDDED," pp. 74–79, 2014.

[18] N. Alphanso, P. Asolkar, K. Kulkarni, and V. Kamble, "Real-Time ECG Signal Analysis using Scilab," pp. 73–77, 2013.