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Ubiquitous Real Time ECG Monitoring System Using Android Smartphone

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***Abstract*— In this paper we propose design and implementation of an ubiquitous energy efficient real time ECG monitoring system using android Smartphone. It is motivated by the increasing awareness of Cardiac arrhythmias and coronary heart disease due to population ageing and stressful modern life. If proper medical care can be given to the patients at the right time their lives can be saved, for that we need is a system that continuously monitors ones ECG signal, so this system is develop. This system can be used by patient for self-diagnosis, and remote-diagnosis for chronic heart disease patients before sudden outbreaks. This system will continuously monitor the ECG signal from the body and if any deviation is found will generate an alert. This system is mainly useful for patient living alone and has disability. The System will measure the ECG (EKG) signal using three lead electrocardiography and transmit these signals to Smartphone via Bluetooth for processing and generating proper alert.**

***Keywords*—Bluetooth, ECG, EKG, Electrocardiography, Smartphone, Ubiquitous.**

I. INTRODUCTION

In the past few decades there has been a revolution in computing and communications and resulted in increased usage of smart phone and their application. These devices can be used for medical diagnosis of Cardiac arrhythmias and coronary heart disease patient by continuously monitoring the electrocardiogram (ECG). Electrocardiography (ECG) is an interpretation of the electricity activity of the heart over a period of time, as sensed by electrodes attached to the outer surface of the skin and recorded by a device external to the body. Our aim is to design and implement an ECG measurement device and an App system based on the Android OS platform which can monitor and diagnose patients' heart conditions in real time.

This system can useful especially by patient like senior citizens or having physical disabilities or who are alone. Therefore, this system can be utilized for remote medical systems to assist the elderly patients, for self-testing diagnostics, or for physicians to diagnose diseases of the circulatory system. The purpose of the paper is to investigate the possibilities to develop a battery powered system capable of measuring three analogue channels of ECG on subject and sending them using Bluetooth to android smart phone and analyse and monitor the ECG and generate proper alert.

II. LITERATURE SURVEY

A. The Anatomy of Heart

The heart wall, consist cardiac muscle called the myocardium. It also has striations similar to skeletal muscle. There are four compartments in heart Left atria, Left ventricles, Right Atria, Right Ventricles. The Orientation of heart is such that the anterior aspect is the right ventricle while the posterior aspect shows the left atrium. Heart can be divided as two unit Atria as one unit and Ventricle as another. This is having a special importance in the electric function of the heart. The right ventricular free wall and the septum is much thinner than the right ventricular wall. This is because the left ventricle need to pumps blood to the complete body, where the pressure is considerably higher than for the pulmonary circulation, which emerges from right ventricular outflow.

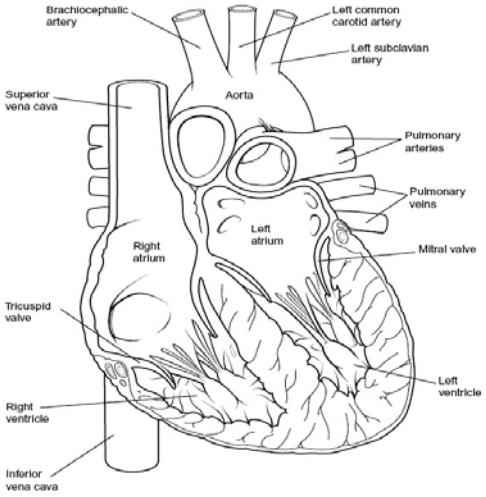

Fig. 1 Anatomy of Heart

The cardiac muscle fibers are divided into four groups: Two groups of fibers wind around the outside of both ventricles. Below these fibers a third group winds around both ventricles. Below these fibers a fourth group winds only around the left ventricle. All these four are oriented spirally. The cardiac muscle cells are oriented more tangentially than radially, and the resistivity of the muscle is lower in the direction of the fiber has importance in electrocardiography and magnetocardiography.

There are four main values in heart. Right atrium and ventricle is guarded by tricuspid valve, and mitral valve lies between the left atrium and ventricle. Pulmonary artery and Right ventricle is guarded by pulmonary valve, and the aortic valve is positioned between the aorta and the left ventricle (controlling flow to the aorta). The deoxygenated blood returns to right atrium from systemic circulation then it is pumped to right ventricle through tricuspid valve. When the right ventricle is filled with deoxygenated blood they are pumped to lungs through pulmonary valve while the tricuspid valve is close. The left atrium collects the oxygenated blood from lungs and through mitral value is sent to left ventricle. The mitral valve close and finally the oxygenated blood is pumped to rest of the body through aorta guarded by aortic valve.

B. Electrocardiography

ECG is a graphic display or recording of the electrical variations produced by heart muscle during a cardiac cycle. The activity of the heart creates an electrical field which is conducted through the surrounding body tissues to the surface of the body.ECG or EKG is derived from Greek: kardia, meaning heart. Electrocardiography is an interpretation of the electrical activity of the heart over a period of time, as sensed by electrodes attached to the surface of the skin and recorded by a device external to the body. The recording generated by this noninvasive procedure is termed electrocardiogram (also ECG or EKG).

C. Function of ECG

An ECG is a way to measure and diagnose abnormal rhythms of the heart, and helps to diagnose properly. An ECG is used to measure the regularity and rate of heartbeats, also in the position and size of the chambers, the existence of any damage to the heart, and the impact of devices or drugs used to regulate the heart. In a myocardial infarction (MI), the ECG can identify if the heart muscle has been damaged in certain areas, though all the areas of the heart are not covered.

The change in electrical activity is seen under the following situation.

- Variation in ionic environment of the heart.
- A flaw in the conduction system of the heart.
- Damage to muscle fibers due to decreased blood supply.
- Several heart diseases are detected by ECG

D. ECG Graph Paper

The output of an ECG recorder is a graph (or sometimes several graphs, representing each of the leads) with voltage represented on y axis and time represented on the x-axis. A dedicated ECG machine would usually print onto graph paper having a background pattern of 1mm squares (usually in green or red), with bold divisions every 5 mm in both horizontal and vertical directions.

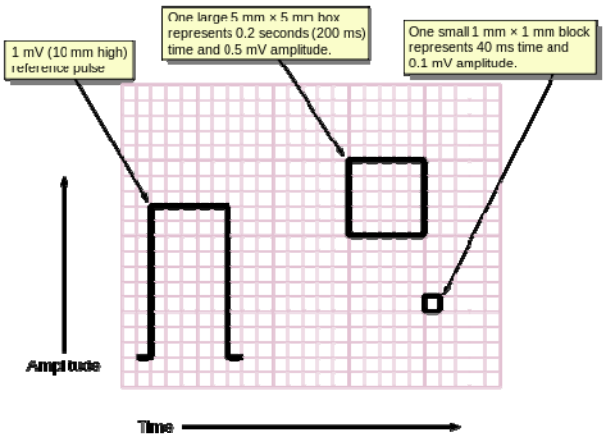

Fig. 1 ECG Graph Paper

Although it is possible to alter the output of most ECG devices but it is standard to represent each mV on the y axis as 1 cm and each second as 25 mm on the x-axis (which is a paper speed of 25 mm/s). We can also use faster paper speeds, for example, to resolve finer detail in the ECG. One small block of ECG paper translates into 40 ms at paper speed of 25 mm/s. One large block is made up of five small blocks, which translates into 200 ms (figure 2). Therefore, there are five large blocks per second. A standard signal of 1 mV should displace the stylus vertically 1 cm, which is, two large squares on ECG paper.

E. ECG Interpretation

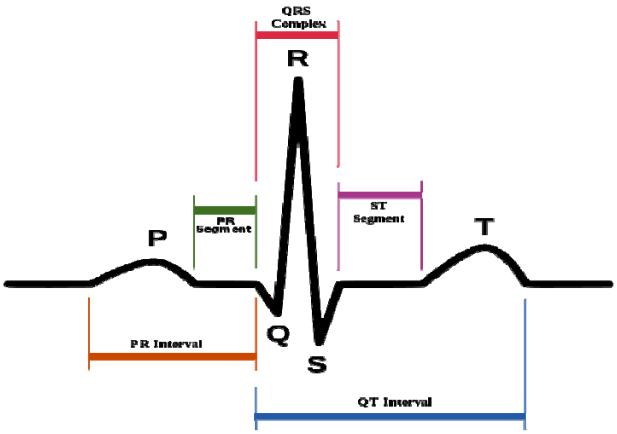

Fig. 3 ECG Interpretation

Heart is muscle that works continuously much like pump. Each beat of heart is set in motion by an electrical signal from within heart muscle. The electrical activity is indicated by an electrocardiogram known as EKG or ECG. Each beat of heart begin with an electrical signal from the sinoatrial node, also known as SA node. The SA node is located in heart right atrium.

When heart's right atrium is full with deoxygenated blood the electrical signal spread across the cell of right and left atria. This signal causes the atria to contact or squeeze. This pumps blood through the open valve from the atria into both ventricles. The P wave on the EKG marks the shrinkage of heart's atria .The signal arrives at the atrioventricular node near the ventricle that is AV node. Here it is slowed for instant to allow heart's right and left

ventricle to fill with blood. This interval on an EKG is represented by the start of the line segment between the P and Q wave.

The signal is released and moves next to the bundle of His located in heart's ventricle from the bundle of his the signal fibers divide into left and right bundle branches which run through heart septum. On the EKG, This is represented by Q wave. The signal leaves the left and right bundle branches through the purkinje fibers that connect directly to the cell in the wall of heart's ventricles.

As the signal spreads across the cells of the ventricle wall both ventricle contracts but not at exactly at same moment. The left ventricle of heart contracts an instant before the right ventricle. On EKG the R wave marks the contraction of heart's left ventricle. The S wave marks the contraction of heart's right ventricle. The contraction of heart's right ventricle pushes blood through the pulmonary valve to lungs. The contraction of heart's left ventricle pushes blood through the aortic valve to the rest of body. As the signal passes the walls of heart's ventricle relax and await for the next signal. On the EKG, the T wave indicates the point at which heart's ventricle is relaxing. This process continues over and over

III. System Requirement and Specification

A. Hardware Requirement

1) ECG Electrode: In the heart muscle cell, electric activation takes place by means of the same mechanism as in the nerve cell - that is, from the inflow of sodium ions across the cell membrane. The amplitude of the action potential is also similar, being about 100 mV for both nerve and muscle. We will be using 3 ECG sensor electrodes to measure the ECG signal. A bio potential electrode is a transducer that senses ion distribution on the surface of tissue, and converts the ion current to electron current. An electrolyte solution/jelly is placed on the side of the electrode that comes into contact with tissue; the other side of the electrode consists of conductive metal attached to a lead wire connected to the instrument. A chemical reaction occurs at the interface between the electrolyte and the electrode.

2) PIC 18: The purpose of the microprocessor is to acquire analogue signals ranging from 0 to 3.3V and sending them by standard serial protocol to a Bluetooth module. Requirements of the microprocessor:

- Ability to read four or more analogue channels at 0-3.3V
- Possibility to use in a 3.3V system.
- Programmable in circuit
- Built in USART
- Low power consumption

3) Bluetooth Module: Bluetooth is a short-range communications system intended for cable replacement between electronic devices in a low cost, low power, robust way. A Bluetooth system consists of a RF transceiver, baseband, and protocol stack offering services to connect and exchange data between devices.

B. Software Requirement

The mobile platform that we will be using is Android2.3 (Gingerbread) which was developed by Open Handset Alliance led by Google. We used Eclipse IDE halios (3.6) for the developing environment.

IV. System Architecture and Implementation

System architecture is divided in two parts Firmware design and android system app.

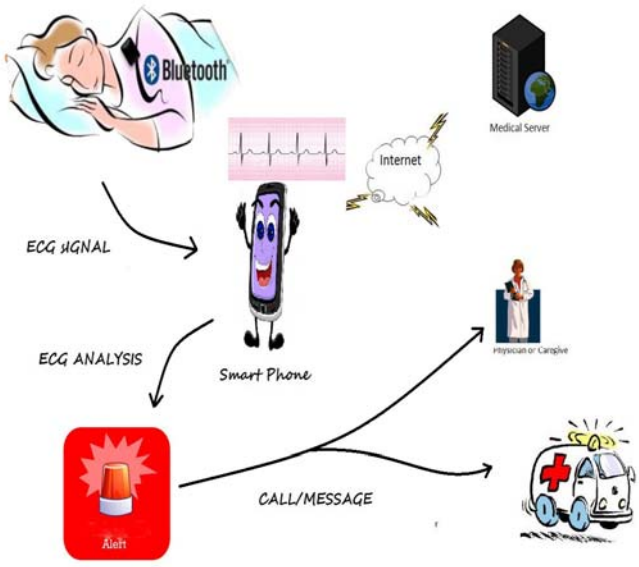

Fig. 4 System Architecture

A. Firmware Design

It consists of the ECG electrodes, amplifier, microcontroller and the Bluetooth module.ECG electrode will capture the electrical signal and send them to operational amplifier. The output generated by the amplifier is analog form and need to be converted in digital form. The microcontroller (PIC18) will process the output from operational amplifier and perform the following task

- Sample analogue values from ECG and convert then to digital.
- Serial port configuration.
- Controlled sample rate.
- Sending data via serial UART to Bluetooth Module.

The Bluetooth module will only act as connecting media between phone and the hardware. The Bluetooth module will be controlled by the microcontroller. When the system is turn on microcontroller will initialized the serial port and set the baud rate for communication.

B. Android System App

This consists of application developed on android operating system from Google. This will act as GUI of system and user can easily interact with the system. Data from the ECG sensing hardware can be shown in graphics with Smartphone applications. The ECG App frameworks

based on the Android OS (Operating System).The main functions of android app system are as follows

1) Initiate communication with the ECG system: This module is involved with setting up communication with the ECG device using the Android Bluetooth API. Indentify system for mutual recognition between the devices and network pairing by handshaking between the transmitter and receiver. Sending acknowledgement to the hardware and receiving the ECG packet. It also performs controlling the mode of operation of the firmware.

2) Read and display output from the ECG system: Smart phone reads the output received from Bluetooth module and displays it on screen. The ECG packet will be decoded and plotted using java layout.

3) Analyse the ECG wave: We will analyse the ECG wave by counting the spikes in each cycle of ECG wave. Highest spike value is calculated and compared with threshold value if it is not between the threshold then alert is generated.

4) Generate alert: Two types of alert can be generated call alert and message alert. A call or message can be send to the emergency phone number's stored in phone. A countdown will be displayed in case of false alarm so that user can cancel it.

5) Send data to server: The ECG wave can be periodically sent to doctor on his system for manual analysis. This ECG wave will be sent over internet after specific time or on doctor's request or even patient can send it.

V. ALGORITHM

Algorithm for Failure detection for ECG wave is as follows

```
while(ecg_connected)
 For each cycle
  Count spikes
   if(for_one cycle spike<3 OR spike>8
    fail->fail+1
    if(fail>=3)
     EXIT and
          SEND_GRAPH()
          SEND_ALERT()
 end For
EndWhile
Function SEND_GRAPH()
  If(GRAPH_REQUEST_ENABLED)
     Update and send last 25 cycles to server
     SEND_SMS(Doctor's number)
  End If
End Function SEND_GRAPH()
Function SEND_ALERT()
  If(ALERT_ENABLED)
    Initiate CALL to Primary number
    ON_CALL_END
    SEND_SMS(primary number)
    If(SECONDARY_ALERT_ENABLED)
    SEND_SMS(secondary number)
    End IF
  End IF
End function SEND_ALERT()
```

VI. CONCLUSIONS

In this paper, we proposed system which will continuously monitor the ECG of subject based on the Android OS platform. This system can monitor and diagnose patient's heart conditions in real time with an ECG sensor and generate alert when ever deviation is found. This system will analyse the ECG wave and generates the proper error message and also send the ECG signals if necessary to clinic or doctor's system. In future system can be made more accurate by adding more physiological sensors for sensing the ECG.

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