Portable and Personal Independent Digital Health Monitoring System Based on Android OS

Kevin Paulson, Jatin Desai

Abstract— In this paper we are attempting to reproduce the ECG, Pulse rate and the Body temperature signals that we observe individually on the monitor screen of the hospitals on an Android device collectively. The signals are transmitted from a data acquisition system in real time to the Android device via Bluetooth. The system is compatible with the Android app that has been designed and developed and is much more precise as compared to the other available apps. The system is capable of handling numerous Android devices and distributes the collected data for diagnostic purpose and evaluation taking into consideration the architecture of Android OS. The system has three switches which can be turned on or off to view the parameters on the Android screen. It has its own power source and as such can be used for a longer duration of time. Also the app that has developed is easy to understand and as such can be used by anyone who possess a Smartphone thereby turning it into a virtual health monitoring system.

Index Terms— Android OS, Android app, Arduino, Bluetooth Module, Dynamic, Patient Database, Real Time, Raspberry Pi,

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1 INTRODUCTION

IN the last decade there have been a rising number of cardiac illnesses that has claimed the lives of numerous people around the globe. Many have fallen victims to cardiac illnesses that have been the primary cause of death in both the developing and the developed countries. Based on many factors such as lifestyle, environment and surroundings it has been predicted that the number of people that will fall prey to the cardiac illnesses will go on rising further in the future. This is a serious cause of concern because people in the agr group of 30 – 40 are more prone to cardiac disorders than in the age group of 60 – 70 and the number of people suffering in the former age group are losing their lives earlier than before. The most commonly used method for detecting the cardiac disorders is by observing the Electrocardiogram (ECG) of the individual which provides us with vital information about the condition and the state of the heart. This situation is worse in the underdeveloped and the poorer nations as they don't posses the modern technological machines and sophisticated techniques which are necessary to identify these disorders and provide the proper treatment to prevent the death of the individual [1]. Hence to monitor and to prevent such kind of attacks many new advanced and sophisticated systems and techniques have been developed for early detection and recognition of these cardiac disorders. These techniques have been developed keeping in mind to provide the best possible diagnosis with the least cost to everyone so that everyone's life can be saved too.

Similarly is the case of Body Temperature and Pulse Rate which are also important as the ECG of a person as they both provide critical information regarding the health of the person concerned. The slightest difference in either of the two parameters can direct us to a specific or multiple changes taking place in the body of the individual.

Hence more advanced and sophisticated machines were created to diagnose the problems at the earliest. However a problem arose and that was these machines were large in size and as such had to be kept in one place and the patients had to travel to the hospital to be diagnosed. People who lived in far and remote areas were not able to travel such large distances and as such suffered an untimely death. It was later realized that the only way to provide the best healthcare facilities was not by designing large, heavy advanced machines but by designing smaller, compatible and easy to understand machines and at low cost so that it could be used by the common people so that they themselves can monitor their body parameters effectively. This gave rise to a new era of smaller 'Patient Monitoring Systems' that was designed to make it easier for both the pateints and the doctor. The main goal of these systems was to reduce the number of visits to the doctor considerably, thus reducing the need to leave their houses for the smallest problems, providing medical services to a large number of people with these devices in their homes and also to provide services over larger distances and to a large number of people that cannot be possibly covered by a doctor. The major problem in today's world is that the individual needs to be constantly connected to the large machines and also that the person needs to be in the hospital for monitoring purposes. In homes also the machines are very large and as a result the individual is restricted from freely walking around. The next major problem is the location of the individuals who are sometimes situated in the remote mountainous areas where the doctor or medical services cannot reach on time due to which they are denied the benefit of a fair treatment [2]. Due to all these problems many new facilities came into existence such as 'Telemedicine' to provide medical education, consumer medical and health information, and long distance healthcare at a distance to improve a patient's health. 'mHealth' which is a division of 'eHealth' pratices and provides medical health care facilities and knowledge with the help of mobile devices such as mobile phones, PDA's and tablets. It has largely been used in developing countires due to their low cost and portability to anywhere while still being connected to the network. Many other facilities have also been developed which has greatly changed the lives of people around the world.

2 RELATED WORK

The earliest known work that was carried out using the above

concepts was the design of the 'Personal health Assistant (PHA), a Smartphone application based on Android. This application was created in the starting version of Android 2.1 and the main goal of this application was to reduce the number of visits to the doctor and provide an easy way of interacting with the doctors which also made the doctor's job easier too. It had four major modules namely 'Home' which was accessed with the help of a Login Screen with the user's Google credentials, 'Wellness Diary' which gathered information about the user's health status and enabling the users to rate their health based on Observations of Daily Living (ODL) on a scale of 1 – 10 which will then be time stamped and uploaded to a server therby generating a timeline of the patient's wellness. The 'Medication Alarm' alerts the user to grab their medication from 'Google Health'. Even if the alarm is off it will alert the user about their medication. The 'Reports Module' generated a graphical report based on the data gathered from the Wellness Diary thereby showing the user a graph of the user's health over a period of time. The next notable work was the development of the Smartphone application 'BeWell' a real time continuous sensing application which kept a daily track of the user's physical, mental and social well being with the help of a wide variety of sensors embedded within the Smartphone. This application kept a track of parameters such as the user's physical activity, social interactions and sleep and how it affects the user's well being. It provided a feedback to the user so that the user becomes aware of what parameter or parameters is affecting their lifestyle and by how much thereby taking necessary measures to ensure that it doesn't affect them again in the future. BeWell opened the gates by providing valuable knowledge to the healthcare industry thereby creating new medicines and better treatment for people [3].

Many other such applications were further created however; all of these applications just collected data and provided feedback. It did not exactly display their parameters to them on the Smartphone. Next came were the techniques of displaying the parameters on the mobile devices. The most common parameter that was displayed on a mobile screen was the ECG. There were many techniques that were used to display the ECG on the mobile screen. First technique was using the Personal Digital Assistant (PDA) along with the LabVIEW program which was followed by using the Bluetooth technology to display the signal [4]. The next technique was to use Android to display the signal which was a major breakthrough as the system was less complex and cleaner ECG signal could be seen [5]. Till now no system was developed to display the Body Temperature and Pulse Rate on the mobile screen and that too in real time. There were many apps designed but they all suffered from limitations as they ulilized

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• *Kevin Paulson is currently pursuing master's degree program in electronics and telecommunication engineering in Fr. C. R. I. T, VASHI, and MUMBAI, INDIA. E-mail: kevin.paulson22@mail.com*
• *Jatin Desai is the Assistant Professor in Fr. C. R. I. T, VASHI, and MUMBAI, INDIA. E-mail: jatindesai2@mail.com*

the phone's internal sensors which resulted in wrong and inaccurate readings.

3 HARDWARE SECTION

3.1 Pulse Rate

The hardware section included the design, implementation and the testing of the Pulse Rate and the ECG amplifier circuit. For measuring the Body Temperature the LM35 Precision IC temperature sensor was used. The Pulse Rate circuit consists of PIC16F877A, INA128P which is an instrumentation Amplifier and two Low power dual operational amplifiers LM358. The following Fig.1 illustrates the Pulse Rate circuit as shown below: The whole circuit is nested inside a plastic box which
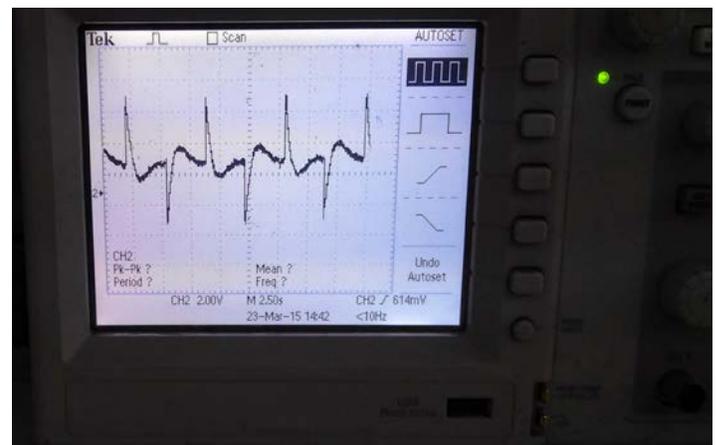
Fig.1: Pulse Rate Circuit

contains a plastic holder or pocket where one's index finger is
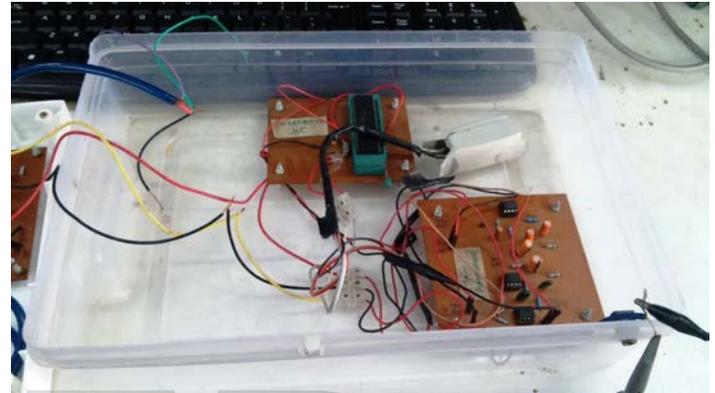
inserted inside. It contains an Infrared LED placed on one side, which illuminates the finger and a photodetector placed on the opposite side. The photodetector measures the small variations in the light intensity that is been transimitted. The Pulse Rate circuit designed works on the principle of photoplethysmography (PPG) for detecting the pulse wave from the finger tip which in this case is the right index finger. It is a non invasive technique that is used for detecting changes in the skin color that occurs with each heartbeat. The changes in the skin color correspond to each heart beat and as a result can be used for detecting the pulse or the heart rate of an individual. As one can see the right index finger is inserted into the plastic pocket and the power supply is switched on. The Pulse Rate waveform is observed on the oscilloscope as shown is Fig.2 as

Fig.2: Pulse Rate observed on an Oscilloscope

below. Generally the pulse begins at zero volts or ground, ris-

es rapidly to a set voltage value, remains at that value for a

brief period and then falls back to zero.

3.2 ECG Amplifier Circuit

The ECG amplifier circuit consists of INA128P Precision Instrumentation Amplifiers and OPA4227 Operational Amplifiers and various resisitors and capacitors. The INA128P and OPA4227 along with the various other components were drilled into a rectangular plastic case. The circuit has its own power supply to ensure that there was no noise or distortions while acquiring the signal as indicated in the Fig.3 shown below.

Fig.3: ECG amplifier circuit

As mentioned before that the signals would be displayed in real time it was critical that the ECG signal be extracted in real time. Hence to meet these requirements three holes were drilled into the side of the box which was then fitted with RCA cable sockets. The input to the ECG amplifier was given via the three cables attached to the body with the help of the ECG leads. The leads were placed on the Left Arm (L.A), Right Arm (R.A) and the Right Leg (R.L). The three holes were accordingly labellled and colored so that the specified cables would be connected to their corresponding sockets. A variable gain of 0 – 1000 was also attached beside the sockets which could be tuned to obtain a clear ECG signal. The output of the ECG signal is observed on the oscilloscope as shown in Fig.4 below:

Fig.4: ECG signal observed on the oscilloscope

3.3 LM35 Sensor

The LM35 Precision IC Temperature Sensor was used for measuring the Body Temperature. There are three regions in the human body where the Body Temperature can be taken namely the oral, rectal and the axiliary regions. In this project the temperature was taken by placing the sensor near the armpit of the individual. The LM35 is a low cost and hence can be easily available and operates in the range of 55° C - 150° C [6]. The LM35 sensor is shown in Fig.5 as below:

3.4 Arduino Mega 2560

Arduino is an open source software and hardware tool that can be used for sensing and reading data from a variety of sensors and switches and can also be used to control them. The main advantage of using the Arduino board is that the

software is freely available and can be easily downloaded from the internet and also it can read both analaog and digital values at the same time which is the most critical aspect of the project. It is also compatible with most of the operating systems such as LINUX, MACINTOSH and WINDOWS. The Arduino Mega 2560 is powered with the help of the USB cable attached to the computer. The green light on the board indicated that the device is powered up and ready to be used. The program for reading and writing (displaying) the values are uploaded and dumped on the Arduino board. The Arduino Mega 2560 is as shown in Fig.6 as below [7]:

Fig.6: Arduino Mega 2560

3.5 Bluetooth Module HC-05

Bluetooth Module HC-05 is a class 2 Bluetooth module with a Serial Port profile, which can be configured either as a Master or as a Slave. The Bluetooth module is small in size and is very simple to use. It has 6 pins namely KEY, RXD, RXD, 5V, 3.3V, GND out of which only the RXD, TXD, 5V and the GND pin were used [8]. The 5V and the GND pins of the Bluetooth module were connected to the 5V and GND pins of the Arduino Mega 2560. The pins 2 and 3 of the Arduino Mega 2560 were initialized as the Bluetooth Transmitter and Receiver. The RXD and the TXD pins of the Bluetooth module were connected to pins 2 and 3 respectively. This is because the pin 2 of the board acts as the Transmitter which is in turn connected to the RXD pin which acts as the Receiver and vice versa thus enabling the Bluetooth communication between the Arduino and the Android device. The following Fig.7 displays the connection between Arduino Mega 2560 and the Bluetooth module HC-05. The blinking red light on the Bluetooth module indicates that the connection has been made is ready to transmit the data.
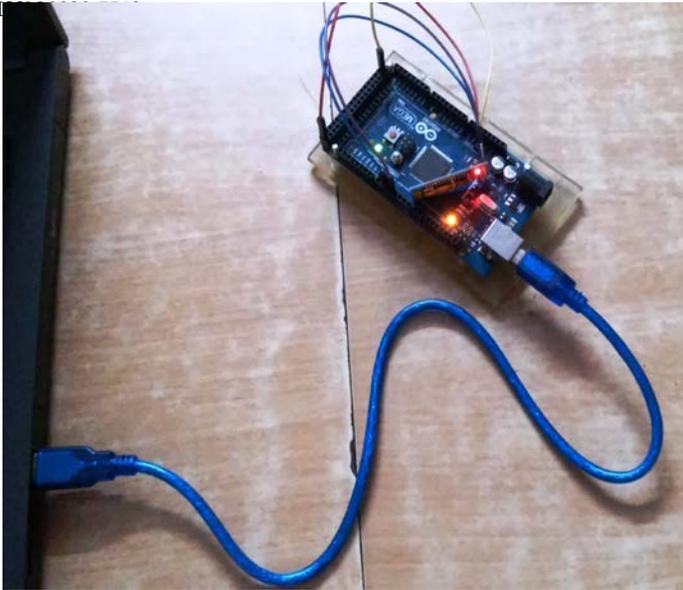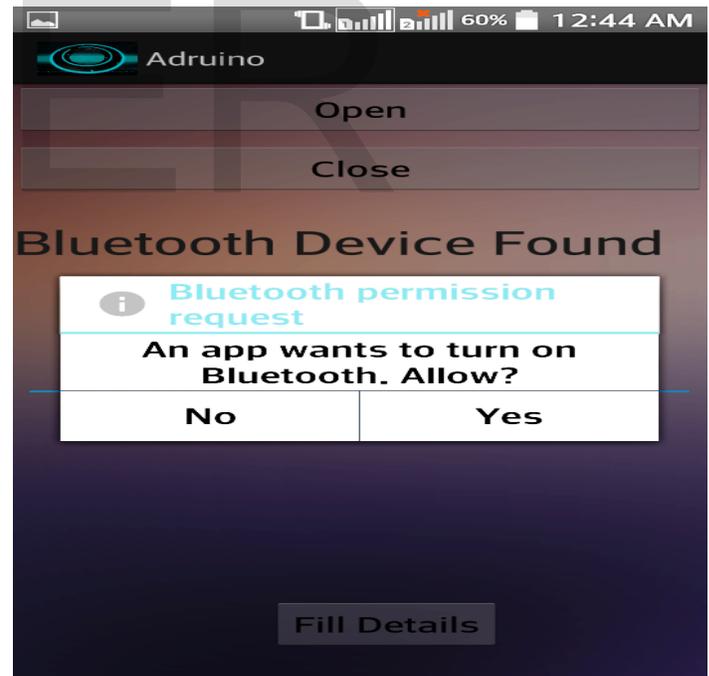
Fig.7: Connection between Arduino and the Bluetooth Module HC-05

4 SOFTWARE SECTION

The software secton of this project includes the design and the testing of the Android app as mentioned earlier. For this project the app was designed in Android and not on any other Operating System like Windows and iOS because of the various advantages that Android offers as compared to them. The most important advantage that Android offers is because of its openness. Android is an 'Open Source' system which basically means that anyone can develop applications of various kinds in whichever way they want as there are no restrictions to the design and the functioning of the app. This is not the case in Windows and iOS which are not Open Sourced as Android. Also there is no registration charge, copyright form and agreements that have to be signed while uploading the app to the 'Google Playstore' thus making it hassle free for developers to upload their apps. This is not the case in the other two operating systems where a number of procedures must be followed while uploading an app. Another major attractive feature of Android is that it is very easy to understand and design the application. Moreover all the material and tutorials are easily available on the internet and can be downloaded freely [9]. Thus by studying these materials thoroughly anyone can make an Android app in their home. The Android Software Development Kit (SDK) along with the Android Development Tool (ADT) can be freely downloaded from their main website and most importantly it is compatible with Windows, LINUX, and MACINTOSH operating systems thus providing everyone with a chance of building their own app without having to switch to any other operating system. The design and the programming of the app was done in 'Eclipse' which is an Integrated Development Environment (IDE) which is an important tool mainly used for design purposes. The testing and the simulation of the app were carried out on the Android device by connecting a Universal Serial Bus (USB) cable to it and launching the app on the Android device itself.

The main aim of designing the app was that it must be simple and easy to understand for anyone using it for the first time. The app has Bluetooth capability which will prompt the user to switch on the Bluetooth connection in order to view the signals on the device. The app has one more interesting feature called as the 'Doctor-Patient Database' which contains all the necessary information about the Patient and the Doctor such as the Nme, Address, Contact Number and Email id. The main aim behind the creation of such a database was that it was not sufficient enough to just view the signals at that time instant and not save them for future use. Hence it was decided to create a database that would store all the details along with their signals just like it is done in the hospitals except that here it is been done on the Android device itself. The app can currently hold the details of a single patient however it cannot save the signals beside it. The only way to save the signals is by taking a scrrenshot and saving it on the device itself. The advantage of this is that the screenshot can be forwarded through any of the social networking medium such as whatsapp, facebook etc to a doctor or a physician and consult with them without ever having to leave their homes. This is similar to the healthcare facilties mentioned above thereby satisfying their goal. On lauching the app it will ask the user to switch on the Bluetooth and then the user will be directed to the database view of the app. Fig.8 (a), (b) and (c) illustrate the different view of the app along with the Doctor-Patient Moni-
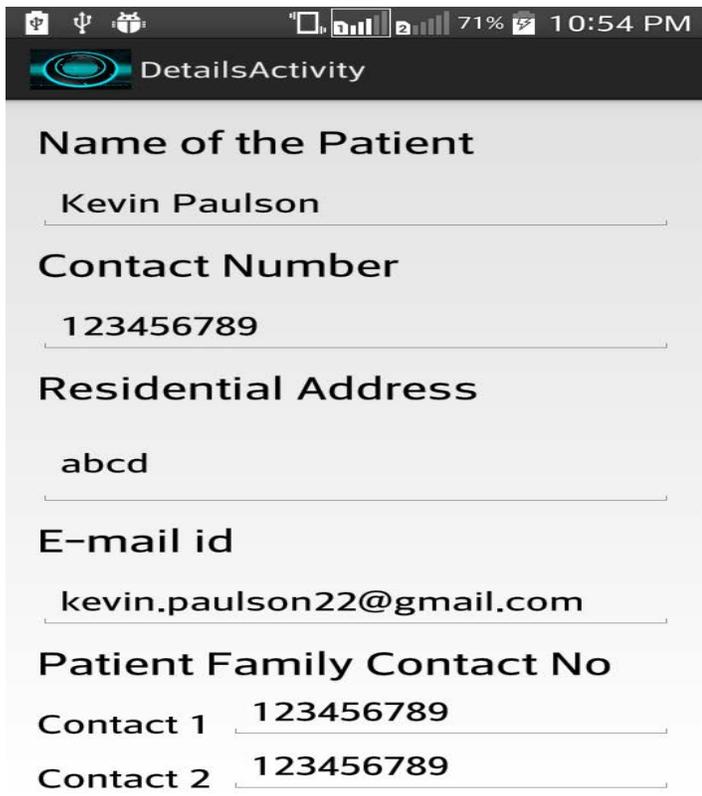

toring Database. All the necessary details have been filled in the database.

Fig.8 (a): First View of the app asking for the Bluetooth Permission

Fig.8 (b): Entering the Patient Details
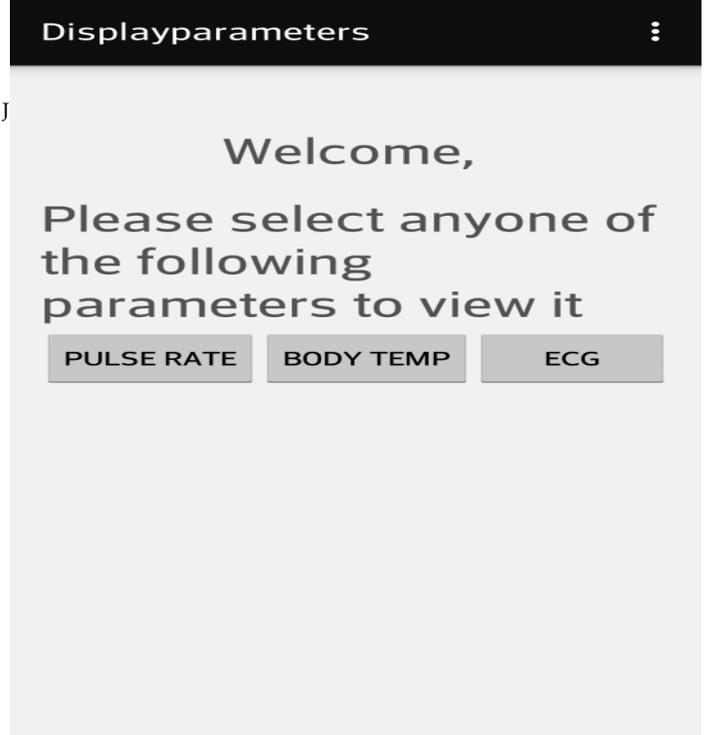Fig.8 (c): Entering the Doctor details

By clicking the 'Save and proceed' button the next view which

is the parameter selection view opens up as illustrated in Fig.9 as below. Here the user is free to choose anyone of the following parameters in whichever order they want in order to view it.

Fig.9: Selection of the Parameters

The Arduino software contains the program for reading the parameter values from the analog pin A0 of the board. A single program encapsulates the code for reading the values of all the three parameters. The values read from the Arduino board are directly displayed and plotted in real time on the Android screen via Bluetooth. The Arduino program or sketch is uploaded and dumped into the board via the USB cable connecting the board to the computer.

5 SWITCHES

As stated before switches were being used for viewing the parameters on the Android screen. 'Push button switches' were used for switching between the parameters. Since three parameters needed to be displayed it was essential that all the three parameters be read by the Arduino board. However the problem that arose was that the Arduino board was reading from all the three parameters at the same time. It was not able to differentiate between the parameters while reading. This posed a major problem while displaying the parameters because the output of Arduino would be the combination of all the three parameters at once which was not desirable. Also the Bluetooth module would just transmit the output of Arduino to the Android device. The Bluetooth module was also unable to distinguish between the values as its only job is the transmission of the values from the board to the device. The signal on the Android screen would also be the combination of the three parameters and as such it would be of no use to the user. Hence it was became necessary that the Arduino board must read only one parameter value at a time, transmit it, stop the reading and then read the next parameter value and so on, which essentially meant that the Arduino board must switch in between the parameters in real time. To overcome this problem 'Push button switches' were used so that the Arduino board would be able to read a single parameter and then move onto the next one. Three buttons were used for the three parameters. The push button switches that were used are shown in Fig.10 as below.

Fig.10: Push Button switch

It has two terminals the output of the parameters was connected to one terminal and the other end was connected to the Arduino end. Here since switching action was required the outputs of the other end of the switch were connected together so that a single connection was made between the three switches and the Arduino board which was given to A0. A resistor of 10 kΩ was connected between the parameter output and the first terminal and the other end of the resistor was grounded. This was done so that the Arduino would be able to read the state of the button if it is HIGH or LOW from the digital read pins 5, 6 and 7 which were assigned to the Body Temperature, Pulse Rate and the ECG respectively. The program reading whether a button is pushed or not was already available on Arduino and only minor changes had to be done. So when a button was pressed Arduino would sense it and a connection would be established only between the specific parameter and Arduino which would then read the parameter from A0. The Bluetooth module would then transmit the read parameter values to the Android device which would then plot or display the readings on the screen in real time.

6 RESULTS

As stated before the signals had to be transmitted from the Arduino board to the Android device. This is accomplished by the Bluetooth module HC-05. The connection between them is as shown if Fig.7 as above. The entire connection of all the three parameters being connected to the Arduino board slong with the switches and the Bluetooth module is as shown in

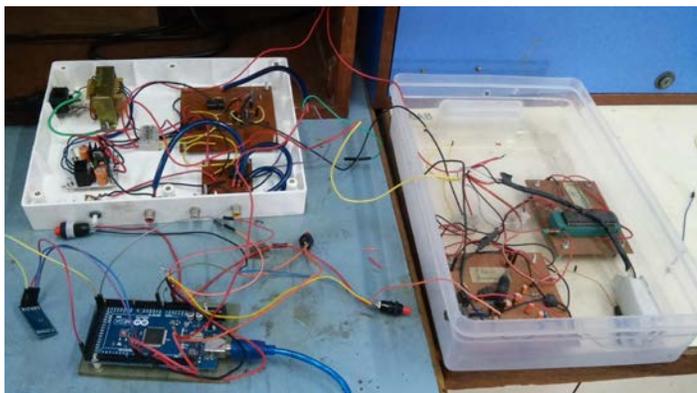Fig.11 as below.

Out of the three parameters anyone of the parameters could be selected first. Here the Pulse Rate was selected first. The button connected to pin 6 was pressed, connection was made and the Arduino started reading the values. The app was launched, all the details were filled and then the Pulse Rate

Fig.11: Entire Setup connection

button was clicked from the app .The Pulse Rate signal observed on the Android device is as shown in Fig.12 below:
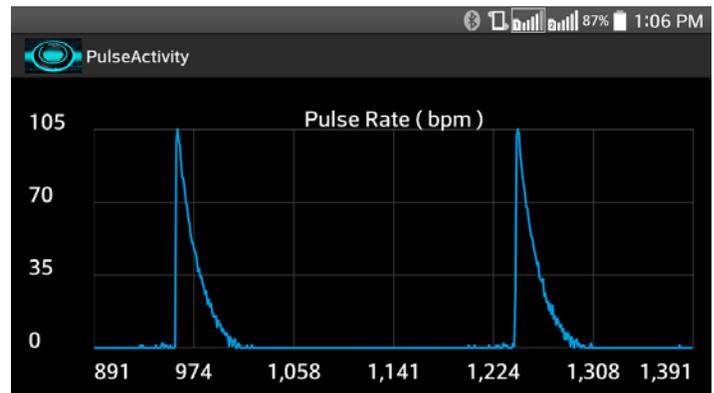

Fig.12: Pulse Rate observed on the Android screen

The points on the Y axis are the values that are read by Arduino i.e. the analog voltage of the wave is converted into digital values and being displayed on the screen. The points on the X axis indicate the data count of the Bluetooth packets that are being transmitted by the Bluetooth module and it is continously varying. The waveform observed on the Android screen is nearly similar to the waveform observed on the oscilloscope with the only exception that only the positive values are plotted and not the negative values. This is due to the fact that Arduino does not read negative values and as such converts all the negative values to 0. To select the next parameter the button was pressed again which made it off thus stopping the connection to Arduino which ultimately stopped reading the values. The graph on the Android screen also stopped.

The next parameter that was observed was the Body Temperature which was selected by pressing the button connected to pin 5. On connecting the connection was made and Arduino started reading the values. The same process is for ECG also. The Body Temperature button was pressed from the app and the readings were observed on the Android screen displayed in Fig.13 as below. The readings are displayed in Celsuis. However an asterisk mark is observed as arduio converts the celsuis symbol into asterisk. It can be seen that the temperature values are in synchronization with the time implying that the values are displayed in real time on the Android screen. The button is pressed again to stop the reading.

```
20:10:18 - 31.25*C
20:10:18 - 31.25*C
20:10:18 - 31.25*C
20:10:18 - 31.25*C
20:10:18 - 31.25*C
20:10:18 - 31.25*C
20:10:18 - 31.25*C
20:10:18 - 31.25*C
20:10:18 - 31.25*C
```

Fig.13: Body Temperature displayed on Android screen

The ECG button 7 was pressed and the ECG button on the app was also pressed. The ECG signal observed on the screen in Fig.14 is as follows. Here also the X and Y points are the same as that was observed for the Pulse Rate. The ECG waveform on the Android is nearly similar to the ECG waveform observed on the oscilloscope as shown in Fig.4. The negative S wave is not shown because Arduino does not read negative values and as a result Arduino treats all the negative values as 0 due to which it there is a straight line in place of the S wave.
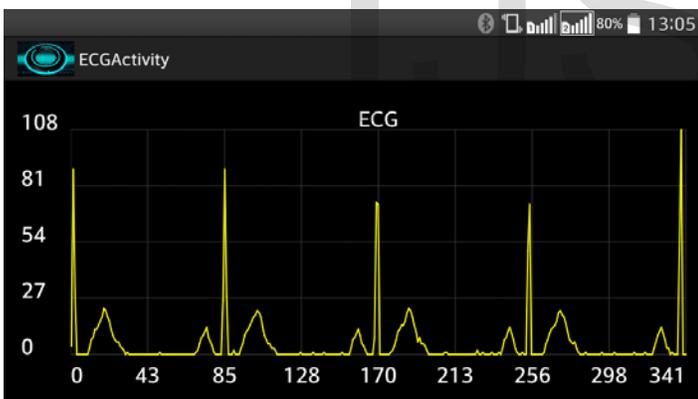

Fig.14: ECG signal observed on the Android screen

7 CONCLUSION

A simple and low cost system for acquiring the biological parameters from the human body and transmitting it via the Bluetooth technology was successfully accomplished. Except for the size of the ECG amplifier and the Pulse Rate circuit the system is not portable. However, the system can be made portable by reducing the size of the ECG amplifier circuit with the help of Surface Mounted Devices (SMD) IC's, resistors and capacitors. The Pulse Rate circuit can be made small by using the HRM-2511-E sensor which is small in size and can give more accurate readings [10]. The hardware components used are available in the market and at a considerably low cost while the softwares used are freely avaialable from the internet which can be downloaded. Thus anyone who reads the

documentation will be able to develop an Android app freely without any diffculties. The Android app designed is easy to understand and simple to use and can be downloaded in any Android device. The app has been designed keeping in mind that it should work in the latest version of Android that will come out.

8 FUTURE SCOPE

The app designed currently can store the details of only a single patient and as such is not feasible to be deployed on an alrge scale. If the details of another patient are entered then it will simply over write the details of the previous one and as such all the data will be lost. It is for this reason that a large database needs to be created which will hold the details of over hundreds of patients and can be updated in real time. An SQL database is the appropriate choice for stroing these details. However this databse must be hosted separately and it should not be hosted on the Android device. If the database is hosted on the Android device then everyone will be able to access the details of every patient and doctor which will violate the doctor patient confidentiality. Hence it is of the utmost importance that the database must be hosted on a separate server. The database can be hosted by the 'Raspberry Pi' which is a small sized computer that can be used for performing user defined programs [11]. It has a starting memory capacity of a 4 GB SD card and can be extended further. It is mainly based on the Linux operating system and contains a variety of different operating systems out of which 'Raspbian' is the recommended one. The app designed can only transmit the signals via Bluetooth and as such the range is limited. It can also be modified to transmit the signals via Wi-Fi or mobile internet thereby tremendously increasing the range of the system. Raspberry Pi can be programmed both as a Bluetooth or a Web Server thus increasing the range. If this is possible then all the people possessing the system will be directly able to display their signals in real time to the doctor without ever leaving their homes thus statisfying the main goal of the 'Patient Monitoring System' mentioned above. For this purpose a central Local Area Network (LAN) can be created inside a hospital with the Rapsberry Pi acting as the Web Server. The users sitting in their homes can directly connect to this server and upload their details and their signals in real time. The doctors in the hospital can directly access this database and see for themselves which user is critical and needs immediate attention. Same can be the case for the patients already admitted inside the hospital. The system can be placed beside each and every patient for monitoring their parameters which will then be connected to the hospitals LAN which can then be monitored by the doctors or the nurses.

Currently the app can only monitor the parameters and as such does not have the capacity to detect any abnormalities in the signals which can only be detected by the doctor or the nurse. To incorporate the diagnostic features special and sophisticated programs has to be developed so that the system can detect any abnormality in real time and alert the medical staff. Alert messages must also be added to the system if the patient goes critical so that precious time is not wasted and the patient can be attended quickly. Emergency Medical Services

can also be tied up with the system which will dispatch Ambulances on receiving alert messages to the home of the person who is critical. Thus the life of the person can be saved without a delay in calling the hospital after the person becomes critical. Three parameters can be displayed with the app designed which can also be modified further to display more parameters too. For this the programming in both the Android and Arduino needs to be modified.

ACKNOWLEDGMENT

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