IoT Based EGC Monitoring System For Automatic Detection Of Abnormalities

A Project Report
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requirements for the degree of
Master of Technology
by,

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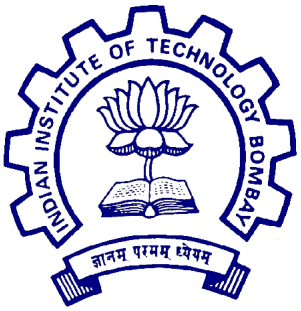

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Abstract

In this era of the Internet, almost every *thing* is available on tip of a figure, moreover due to the vastness of mobile devices and availability of connectivity, wearable devices are becoming abundant. At the same time advances in silicon technology have made local processing and cost of hardware cheap, causing a boom in the field of embedded electronics. Along with this, availability of cloud infrastructure makes it a perfect time to have IoT based wearable health monitoring devices that can help to improve quality of life by predicting abnormalities with the help of basic machine learning algorithms while looking at data gathered from wearable device.

I. Introduction

Globally, Cardiovascular diseases(CVD) led to 17.5 million deaths in 2012. More than 75% of these deaths occurred in developing countries Mainly there are two types heart disease as discussed in paper [1], firstly heart rate related abnormalities and secondly heart related disease. By reading ECG one can detect these abnormalities, but predicting about them is a tough task. Lack of predicting mechanism is due to unavailability of ECG readings in electronic format. In current situation one has to visit a cardiologist in order to generate and get interpretation of ECG and there is no way to persist data generated by ECG reading device. As these devices are legacy in nature there is no way to modify their hardware in order to persist measured ECG signal.Bulkiness is also a pain point of these devices which make them stationary. Only noise removing ability of these devices makes them still alive. Persisting readings collected from ECG sensor needs a large amount of storage and prediction of abnormality and visualization of graph demands real-time database.

This report describes the way to implement a system which will persist ECG sensor data and visualize real time graph on mobile device along with notifications of abnormal conditions. Basics of ECG signal, embedded technology and cloud based real-time database signal is discussed in background section. Approach and Result session flashes methodologies used to implement such system and results obtained after implementation. Challenges in implementation provide a brief idea about challenges faced while making the whole system up for end users. Conclusion followed by future work is discussed at end of this report.

II. Problem Statement

Building a system which collect ECG readings from user and send it to firebase cloud. Creating android application to visualize real-time ECG graph and to detect and notify heart rate related abnormalities.

III. Requirement

1) Hardware
   - Node MCU
   - AD8232
2) Software
   - Android Studio
   - Arduino IDE

IV. Background

This section covers background require to understand implementation of system, it contains information related to ECG signal along with abnormalities of heart, overview of Embedded technology and IoT and finally a bit information of real-time database

A. Abnormalities In ECG Signal

Paper [1] describes about typical waveform of ECG signal and abnormalities that can be detected using ECG signal. Amplitude of wave, distance between wave patterns and width of wave are used by cardiologist to diagnose heart disease. In medical science ECG wave of mainly divided in 3 portions, paper [1] describes these partition as follows,

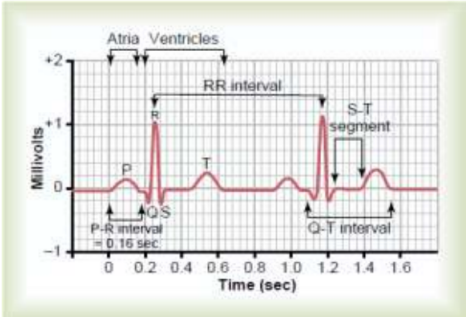

Fig. 1. Typical Waveform Of ECG signal As Described in [1]

- P wave: is a small increase in the voltage (.1 mv) which represents the depolarization of the atria during atrial systole.
- QRS complex: is a small drop in voltage (Q) followed by voltage peak (R) and another small drop in voltage (S). The QRS complex represents the depolarization of the ventricles during ventricular systole. The atria repolarize on the same period of the QRS complex, however it does not show any effect on the ECG plot due to the size of the atria compared to the ventricles.
- T wave: is a small peak (slightly bigger than P wave, .3 mv) which follows the QRS complex which represent the repolarization of the ventricles during the relaxation of the cardiac cycle.

Authors of paper have implemented an algorithm to detect abnormalities they also have filtered ECG signal using Butterworth in combination with FIR filters. ECG graph generated by their experiment is shown in figure 2

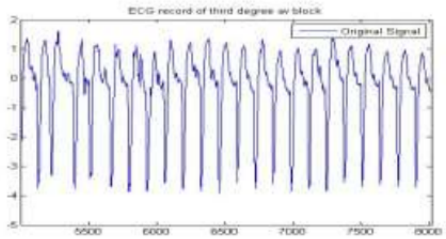

Fig. 2. Waveform Of ECG Signal Obtained After Removal Of Noise Using Filters Available In Matlab[1]

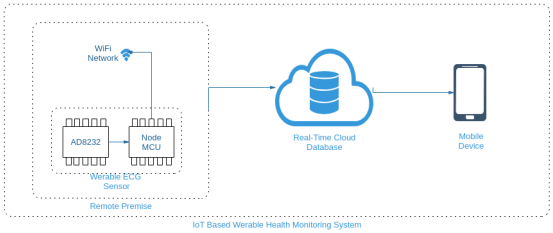

Fig. 3. Architecture Diagram Of Our System

B. Embedded Technology and IoT

Now a days every thing from refrigerator to bulb to car to health monitoring devices are connected Internet. Paper [3] say that by 2020 50 billion devices will get connected through Internet. This paper also flashes on importance of connected devices. It also states that more than 1 billion people will be classified as *"non working age"* as a result of increased population and lowering of death rate. In such scenario, wearable devices will play vital role to improve quality of life by monitoring health and prediction abnormalities by analyzing monitored data. Numerous micro controllers and tonnes sensor are available in market due to advancement in embedded technology. With the help of bare minimum micro-controller and "off the shelf" sensor one can bring device on Internet with least effort. SparkFun is one of the provider of off the shelf sensor of which AD8232 is ECG sensor. [4] document gives overview of connectivity of AD8232 with one of famous micro-controller *Arduino*. Architecture level details of AD8232 are mentioned in [5].

C. Real-time Database

Connecting device to internet is not only the thing to have IoT system in place, sensors and connected device will generate huge amount of data. And as paper [3] mentioned that devices will get connected to extract *knowledge/wisdom* from row data, it needs to be stored at location from where it is easily accessible for processing. Google has a platform named as *Firebase* which helps to store large amount of data with easy accessibility. It is something more than usual database as it pushes events whenever some data gets generated or updated and this makes it real-time. [6] is documentation for Firebase-Arduino, which give information regarding methods available to send/receive data to/from micro-controller to/from Firebase-cloud

V. Approach and Result

As shown in figure 3 ECG sensor(AD8232) is connected to Node MCU and which is connected to the Internet with help of available WiFi. Sketch(code) which runs on Node MCU takes WiFi credentials as parameter(as of now they are hard coded). Once connection gets established, sensor starts ECG readings to Node MCU and Node MCU on behalf of sensor sends those readings to the Firebase (real-time cloud database). Part of sketch manages to send data to Firebase, and this part need Firebase configuration information like host url of Firebase and authentication key. Upon receiving new data or any update, Firebase generates an event to which other subscribed mobile devices listen in order to get latest data. basic abnormality detection algorithm is written on Node MCU and after detecting abnormality it sends appropriate data to Firebase and then Firebase sends push notification to intended mobile device.

Board Label	Pin Function	Arduino Connection
GND	Ground	**GND**
3.3v	3.3v Power Supply	**3.3v**
OUTPUT	Output Signal	**A0**
LO-	Leads-off Detect -	**11**
LO+	Leads-off Detect +	**10**
SDN	Shutdown	**Not used**

Fig. 4. Pin Connection Information [4]

Figure 4 gives details of pin configuration which helps to connect AD8232 with any micro-controller. From this configuration it is clear that 3.3V is required and out of AD8232 should be connected to A0 port of micro-controller(any other port can be used as well, but micro-controllers sketch has to be updated accordingly).

Figure 5 give an idea about placement of Ad8232's electrodes. This is not the only way to place electrode, other placements as guided by cardiologist also works effectively. Basically AD8232 measures voltage drop between right and left electrodes, it is recommended to place them as apart as possible.

Figure 6 shows results obtained after successful

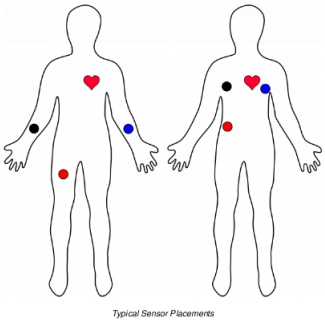

Fig. 5. Typical Sensor Placement [4]

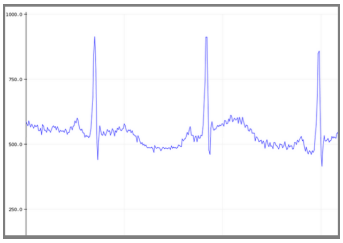

Fig. 6. ECG waveform obtained by method described in this report

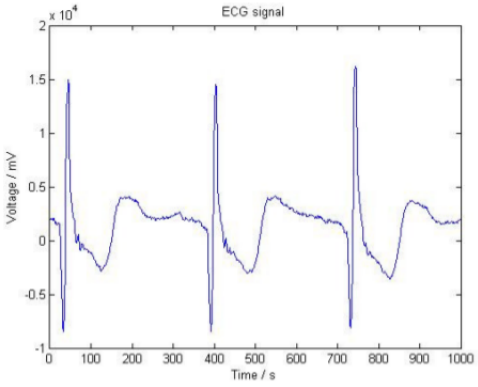

Fig. 7. Resultant ECG waveform from paper [3]

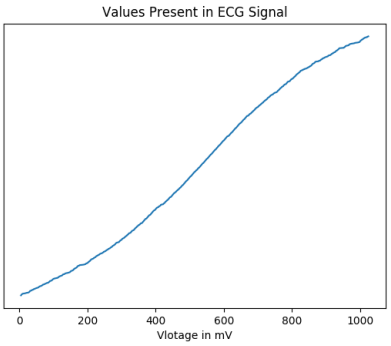

Fig. 8. Unique values present in ECG signal sampled over around 2800 data points

implementation of system discussed in this report. Whereas Figure 7 shows graphical results obtained and mentioned in paper [3]. Two results are very similar in the sense of ECG signal pattern as discussed in previous the session.

Information visualized in figure 8 is used for detecting abnormalities in ECG signal. As discussed in paper [1] heart rate related abnormalities gets predicted by values recorded with help of AD8232 sensor. For normal case of heart rate, most of the times histogram looks similar as shown in figure 9 i.e. histogram looks very similar to EGC waveform over one period. Therefore mean of values present in signal over specified data points is used to measure deviation from standard mean. Larger the deviation more the abnormality principle is used for prediction abnormality. And as mean is susceptible to outlier it will become easy to observe irregularity in pattern. Also, algorithm similar to histogram equalization can be used to get deviation of ECG reading from standard readings. 'Smaller the bin size of histogram more the accuracy of final result' approach is in thought process but as research around this procedure is still in progress more can not be discussed.

VI. Challenges In Implementation

This session gives brief idea about challenges faced while implementing proposed system, they are as follows

- Due to communication over internet, handling delay in-order to meet real-time requirements is challenging.
- Having off the shelf ECG sensing device won't help a lot as requirements of underlying system forces real-time interaction of sensor with mobile application
- After repeated use, sensitivity of electrodes reduces, and it needs to be replaced.
- Placement ECG electrodes affects recorded value a lot, finding correct position in order to get exact voltage job is cumbersome. Once position is found this will not remain a challenge at all.
- Synchronization of data at sensor level and application level for visualization purpose is challenging task due to requirement of fine tuning of various parameters at application end

VII. Application View

After successful log in user will be directed to main view of application which looks as shown

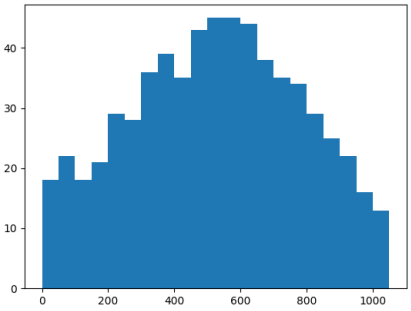

Fig. 9. Histogram of data points used to draw figure 8

in figure 10. Here he will see real-time ECG waveform and he can also set emergency contacts.

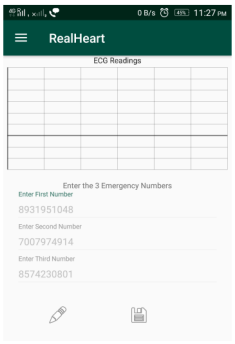

Fig. 10. Launching Screen of Application

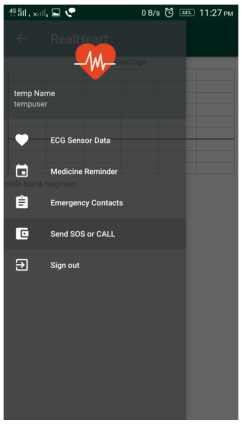

Fig. 11. Functionality provided in application

Figure 11 show how to navigate through different functionality provided in app. ECG sensor data will show real-time ECG waveform, medicine reminder will allow to set reminder to take medicine, SoS will allow user to call or send messages to emergency contacts.

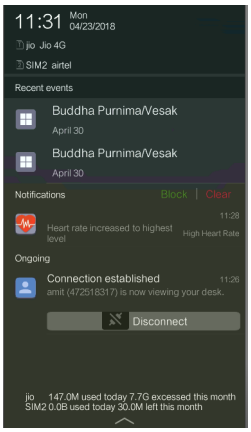

Fig. 12. Abnormality Notification

As shown in figure 12 in app notification of abnormality will get popped up upon detection of any abnormality.

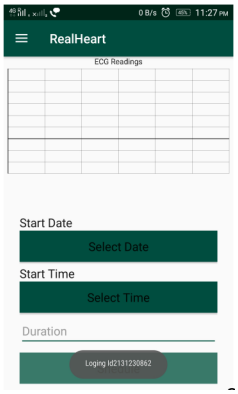

Fig. 13. Architecture Diagram Of Our System

User has option to set reminder for consumption medicine. As shown in figure 13 he has to set values accordingly.

VIII. Future Work

- Reading from AD8232 can be filtered a bit to get highly precise reading
- More robust machine learning algorithm can be applied for detection of abnormalities
- Semi-automatic configuration of WiFi credentials can be done
- Whole circuitry can be made standalone with help of AAA batteries

IX. Conclusion

Thus, the system which collects ECG reading with help of AD8232 sensor and send the same to real-time database over WiFi with help of Node MCU 8266 is implemented successfully. Heart rate related abnormalities are detected and notification regarding the same is sent to mobile application

which also visualizes real time ECG graph when sensors are connected to human body. Though entire system is up and gives results as per expectation, it can not be used for final conclusion since there may be errors due to small perturbation in recorded value as result of sensitivity of AD8232 towards WiFi and other electromagnetic field available around. But it can be used for primary diagnostic and as assistance for real-time remote monitoring.

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[3] Xiaoqiang Ji , Chunyu Ning, Chunhua Zhao and Xiaofeng Zhang, "Design of the HRV Analysis System Based on AD8232", *School of Life Science and Technology, Changchun University of Science and Technology, Changchun, China*.

[4] AD8232 Heart Rate Monitor Hookup Guide

[5] Single-Lead, Heart Rate Monitor Front End Data Sheet Ad8232

[6] Firebase-Arduino Documentation Release 1.0