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A Wireless System for Health Monitoring Using Mobile Phone Accessories

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Abstract:
This paper presents the design and prototype of a wireless health monitoring system using mobile phone accessories. We focus on measuring real time Electrocardiogram (ECG) and Heart rate monitoring using a smart phone case. With the increasing number of cardiac patients worldwide, this design can be used for early detection of heart diseases. Unlike most of the existing methods that use an optical sensor to monitor heart rate, our approach is to measure real time ECG with dry electrodes placed on smart phone case. The collected ECG signal can be stored and analyzed in real time through a smart phone application for prognosis and diagnosis. The proposed hardware system consists of a single chip microcontroller (RFduino) embedded with Bluetooth low energy (BLE), hence miniaturizing the size and prolonging battery life. The system called "Smart Case" has been tested in a lab environment. We also designed a 3D printed smart phone case to validate the feasibly of the system. The results demonstrated that the proposed system could be comparable to medical grade devices.

INTRODUCTION:

Health care monitoring through smart phones has been increasing rapidly in recent years, due to its ubiquity, accessible and easy to use. However, quality and affordability of the health care systems are major problems around the globe. A large number of people with low income facing issues with the high cost of healthcare system; moreover, many individuals are not able to get the quality of health care they need. The cost of healthcare monitoring in the United States alone is 393.5 billion in the year of 2005 [1].

According to [2], total medical cost is 4 million each year for non-cardiac cases. With the help of a smart phone based healthcare monitoring system, we can reduce these costs. This system can allow users to have instant medical checkup, lab reports and store these data for later use. The stored information can be used [3]- [4]. Smart phone applications like prescription reminder, calorie measurement, appointment with medical doctors, hospital locators can ease the accessibility. Nowadays, smart phones are not only for communication purpose as they used to be, and they could support a wide range of applications. A large number of smart phone based medical devices are becoming more popular for fitness [5]- [8]. Health monitoring devices are being miniaturized in size and are more user friendly, which allow complex computation and sensing vital information such as heart rate, ECG, Oximetry and respiration. Statistics show that remote monitoring devices have played a vital role to reduce the re-hospitalization rate.

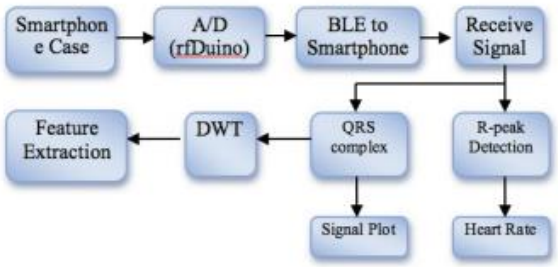

Fig. 1. Basic architecture of the proposed system.

The system consists of two silver plated sensors with proposed analog signal and low power wireless module. Heart disease is one of major causes of death, especially for the elderly people.

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More than 50% of the population in North America have heart diseases aged to be older than 55 [2]. The current ECG monitoring system is robust but it is a tedious and costly procedure. Additionally, more than 20% of the population in the USA lives in pastoral areas, with only 9% of physicians amiable. Many organizations are predicting a deficit in primary health care due to the high amount of insurance. There are some literature reviews for healthcare performance in pastoral area. Portable and wearable health monitoring devices are great candidate to virtually minimize the distance between patient and physician. Moreover, patients have to be monitored for a long period of time, which might not be feasible. all the collected data have to be processed, stored and analyzed which consumes additional time and costs. However, a portable ECG monitoring could address the challenge, serving real time monitoring and analyzing data. The patients can regularly monitor their health with these portable devices and medical staff can analyze the collected information remotely. A portable monitoring is helpful to diagnose and prevent heart diseases. Recent developments in microelectronics have revived interest in this type of biopotential sensing.

The most common clinical cardiac test is ECG analysis. The advancement of mobile computation has allowed us to analyze, store and monitor vital information in real time. Therefore, researchers are developing algorithms based on cardiovascular diseases which can lead to effective treatments. There are some on-going research works to develop efficient and effective ECG analysis algorithms through smart phone computing. In this project, we developed a smart phone App which can display ECG signals, calculate heart rate and provide suggestions. There are many smart phone based applications to monitor health, but most of them are optical based pulse monitor or require an external device to pair. For example, Polar has developed a heartbeat belt based on android OS. Zephyr has a similar product for health monitoring.

Our proposed system is easy to use and with low power and cost. Especially, we use RFduino to minimize the size and power consumption. In this paper, we present a miniaturized low-power wireless ECG system for remote health monitoring. We verified our system with EPIC sensor from Plessey Semiconductor. Our proposed system consists of high precision analog front end, microprocessor and BLE (RFduino) to send the data to Android based smart phone. The portable systems provide acquisition, processing, storing and visualization of the ECG signals. The following section II presents the design including hardware, software and algorithm. Section III presents the experimental results and discussion the potential issues. Section IV describes the future work and applications that can be done with this unique prototype.

SYSTEM DESIGN:

Development of Smart Case for a health monitoring system with RFduino has been discussed in this section. Dry sensor measurement of electrophysiological signals is of a great interest in healthcare setting. Moreover, it overcomes the disadvantages of conventional gel based sensors. The existing system is not hindering the natural activity of the target and may cause skin irritation but also bulky and expensive. Electric Potential Integrated Circuit (EPIC) sensors can measure the electric field deviation without any physical contact with the skin [4]. It can detect electrocardiograms (ECG) in a non-contact manner. Therefore, we have compared the results of our system with EPIC sensor

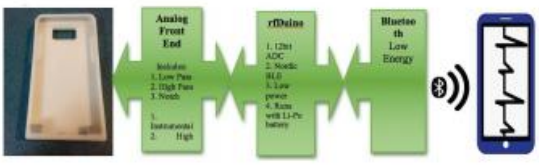

Fig. 2. Block diagram of the Smart Case with prototype.

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Prototyping:

The block diagram of the ECG system integrating front end, analog circuit and wireless microprocessor on a smart phone case is depicted in Figure 2. The ECG sensor was developed to compete with medical grade standard. The Sensor was compared and verified with a commercial grade EPIC sensor which has been described later in this paper. These sensors convert the variable electrical signal into voltage signals which is then fed to the front end analog circuit. The analog circuit starts with a buffer amplifier to make high input impedance, then it goes through different stages of low pass filter (LPF), high pass filter (HPF), notch filter, and lastly, a high gain amplifier. However, there was an additional noise due to the 60Hz AC power supply, and to reduce this noise, we have used a notch filter [40]. The active electrodes were designed to extract the ECG signal with a touch of a fingertip. The sensor has been tested on an adult male. The goal is to calculate the ECG, Heart rate and respiration from extracted signals and then store it to local cloud server for further analysis. An Android application has been developed for real time monitoring and storing the data. The ECG signals send to smart phone in real time with graphical interface on the screen, including heart rate, respiration and suggestions based on your current health condition. In addition, medical professionals can share advice with the same application. This system can also detect the physical activity of the patient with built in mobile phone sensors. This can improve the accuracy of the current health condition.

Algorithm:

The flow chart of the functions is depicted in Figure 3. The process starts with collecting ECG signals from fingertip given that the phone is turned on. The Bluetooth allows automatic searching for peripheral devices. The ECG is filtered and amplified by the AFE module and then converted into strings using ADC. If the peaks are greater than threshold value, they are counted as R peaks. The RFduino has been programmed to collect the ECG signal from AFE.

This Bluetooth module allows you to create functional IoT applications using the Arduino IDE development environment. This processing software provides a preliminary guide for ECG interpretation based on time-plane analysis and feature extraction from the stored ECG data. This is supplemented by displaying plots of the reconstructed signal and the RR interval plot. In this algorithm, the raw data, heart rate, and ECG type were saved to the SD card.

Android Application:

For this project of wireless heart rate monitoring, we built an Android application to obtain and display data from physical electrical circuitries. The android application has functionality to transform the signals to a graph in real time plotting. Thus we get an ECG signal and display of real time ECG signals on the smart phone . Along with this, the android application has other functionalities. It can look for unusual signals in ECG and predict critical situations from the anomalies in the signal. It can keep track of the signal all day long and suggest various health related suggestions. It is also capable of maintaining a track record of the ECG and help doctors with the data if ever required.

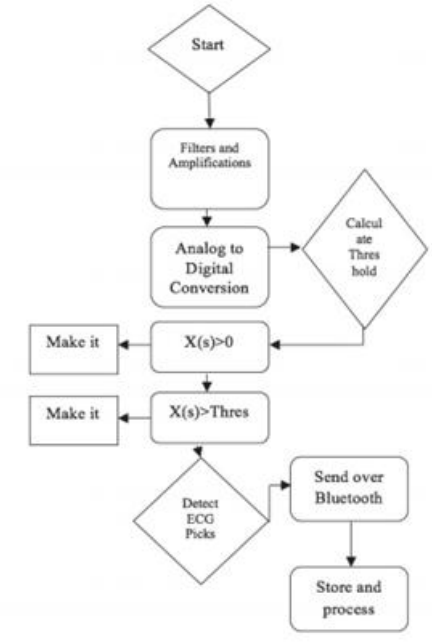

Fig. 3. Flow chart of overall system.

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We also added an alert feature in the application. The case has a button that triggers an alert signal. The android application always keeps looking for the alert signal. If the emergency button is pressed, it sends an alert. Through this feature the application sends an alert message with the GPS location of the user including voice message. The alert messages will be sent to the emergency contacts of the user. The user has authority to customize the contacts and message content. This feature is helpful for the elderly people who want to notify the doctor and relatives in an emergency health situation. For the android application, we used Bluetooth low energy (BLE) API. BLE is known as Bluetooth Smart. It is a wireless personal area network technology designed and marketed by the Bluetooth Special Interest Group.

BLE devices give the same performance on much lower energy consumption than usual Bluetooth technology, which is cost efficient. Bluetooth Smart is not backward-compatible with the previous (often called "Classic") Bluetooth protocol. But a device can have either or both of the two technologies. Bluetooth Smart uses 2.4 GHz radio frequencies. BLE devices can have multiple services associated with different UUID [8]. Communication with BLE devices is more complex than classic Bluetooth. BLE is also more secured as it can connect to only one device at a time.

Conclusion:

In this paper, we presented an health monitoring system using smart phone accessories. Our proposed system is lightweight, cost effective and user friendly. The major advantage of our device is that the users do not have to carry an extra device while maintaining their health and safety. Additionally, we made efforts to improve the accuracy of the ECG measurements, which are close to medical grade. We also demonstrated that the silver plate can produce more stable results, which is capable of detecting R, P and T waves. One possible future work is to add extra sensors in the smart case to monitor vital signs like SpO2, temperature and diabetics.

There are some challenges related to materials, packaging, miniaturization, signal processing and prediction theory, which need to be addressed in the future.

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