ANDROID BASED PERSONAL HEALTH MONITOR

By

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ABSTRACT

Personal health monitoring or personal health tracking is done by individuals using intelligent tools like wearable sensors and mobile applications to collect, process and display a wealth of personal data to help them monitor and manage all aspects of their personal health. In this paper, a personal health monitoring system is proposed based on Android based mobile phone. The system is able to collect the sensor data to monitor the basic vital parameters such as heart rate using PPG signal from the non-invasive body sensors to the patient's android based Smart phone using Bluetooth technology. An Android application is developed to read the PPG signal over Bluetooth. The received signal has been further processed to acquire vital parameters such as heart rate. A live streaming graph as part of the mobile application is used to display the physical parameter in easily understandable manner. If the received signal range is beyond the threshold level, then a warning message will be send to the doctor and the caretakers. The captured data in Android will be stored in local SQLite database and sent to the centralized server when connectivity is available in the mobile phone. The centralized server offers web services that will receive data from various mobile and other client devices and log the data into a centralized database. The data will be available for consultants to track history of records. The proposed system will allow users, especially seniors with heart diseases and other continuous monitorable diseases, to conveniently record daily test results and track long term health condition, and their changes regardless of their locations. It does so without having to ask users to manually input them into the system. This system further integrated with GPS, and Google Map functionalities facilitate the user to trace the hospitals and consultants near their current location.

Keywords: Photo Plethysmo Gram(PPG), Pulse Sensor, Android, GPS, Google Map, SQLite, Premature Ventricular Contractions, Respiratory Induced Variation.

INTRODUCTION

Healthcare has been changed in clinics and hospitals globally. With rising costs of healthcare, aging population, the desire to stay healthy even while indulging on an unhealthy lifestyle and the most importantly, the availability of affordable but capable technologies have started the trend in personal health monitoring, anytime and anywhere, where and how the authors measure vital signs, has become boundary-less[1][6]. In this paper, the authors proposed a modular approach to develop an Android based personal health monitoring system using non invasive sensors.

1. Problem Definition and Solution Approach

Health care is an essential part of everyday life for all human beings on the planet. Each of us require a periodic monitoring of vital parameters and right treatments based on this data. These processes become even more crucial when people reach a certain age and are not able to follow their health condition properly without a special medical personnel or sophisticated equipment to do the monitoring. The older a person gets, the wider spectrum of possible diseases and unexpected emergency situations might occur. In order to avoid this, he or she needs to be transported to the hospital, that has been observed by medical staff and provided with the immediate help if some of the parameters are abnormal. In many cases, even a short delay might lead to dangerous consequences including death of the patient. However, normally, these basic health parameters are being monitored and measured by medical personnel only at discrete intervals. This common approach can sometimes lead to the loss of crucial data. Therefore, a particular interest is focused on continuous monitoring techniques. Unlike the spot checking, this kind of monitoring is capable of providing a long term information about the patient, helps to register the emergency situations and react adequately to any significant change in person's health conditions in a real time. However, the correlation between certain health parameters during a long period of time is yet unclear. Therefore, this type of system could assist in studying this correlation and eventually provide with a full and complete patient's health profile, which will be subsequently analyzed by professionals. The main goal is subsequently divided into two parts: In the first part the authors establish a reliable connection between mobile device and a sensor to collect continuous data from patients. In the second part they examine the collected data using different sorts of processing techniques and algorithms. Patient mobility is also an important aspect to consider. They want a person to maintain his normal activity level while using monitoring system. Summarizing all mentioned above facts, they combined a list of desired steps:

- Reliable connection
- Maintain patients mobility
- Data collection
- Data analysis, logging, and reporting
- Alerting abnormal conditions
- Assisting patients to locate nearby medical facilities
- Maintain a centralized database of health records
- Locating the patients in case of emergency

By this paper, the authors are proposing an approach to cater to the above needs. It will serve as an assistant device which is measuring the patient's health parameters, triggering alarm in case of emergency, assisting patients during illness to locate health care units and maintaining a centralized database for health records. They have taken heart rate measurement using Photo Plethysmo Gram(PPG) technique as a medical parameter to propose the health monitoring system. With the help of an ATMega328 processor interface, they can easily integrate additional sensors to measure any kind of physical parameters.

2. The Proposed System

2.1 Framework for Android based personal health monitor

Multi-module software architecture is developed in Android mobile platform and integrates the software components with web service technologies. Every module in the architecture is loosely coupled and is implemented by using Activities, that intents and services in the Android platform. Framework for software architecture of mobile personal health monitoring system is illustrated in Figure 1, which includes GUI (Graphical User Interface), interface module, inference module, and notification module, common database operation interface with internal database SQLite and interface with web services.

Pulse sensor based on Photo Plethysmo Gram(PPG) is used to measure the pulse rate by measuring the instantaneous change in blood volume in blood vessels in an optoelectronic way. The pulse variation is captured and sent to Analog input pin AO of ATMega328. The received signals are then transmitted over Bluetooth using module HC-06 Bluetooth transceiver. The Bluetooth transceiver module must be paired with the processing Android device. They have the option to make them paired as part of our Android application. The transmitted signal is then received by the Android application, streamed to split the required signals, and DC components are removed the signal for reducing unwanted noise is processed and the ADC samples are scaled to 1-1023, Then the 21-point moving average filter

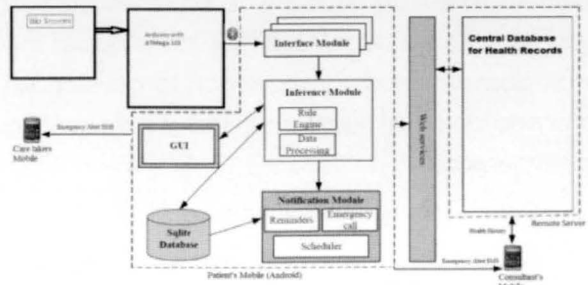

Figure 1. Framework for Android based personal health monitor

is applied to smoothen the PPG waveform and then compute the heart rate. The processed signal is then displayed in the smart phone along with measured Beats Per Minute (BPM). The processed signal is then stored in SQLite database available in Android mobile. When network connection is available in smart phone, the processed parameters are passed to the centralized server through web service. The health care providers then access the data from anywhere. Using GPS feature available in the smart phone, the patient's current location can be easily tracked and information sent to care takers over SMS on critical situations.

2.2 Photo Plethysmo Graphy

Blood Pressure monitoring devices are used for non-invasive examination of the blood pressure. Having been developed to identify patients with white coat hypertension, they become very useful for the determination of hypertensive end-organ damage risk. A photoplethysmogram (PPG) is an optically obtained plethysmogram, a volumetric measurement of an organ[2]. A PPG is often obtained by using a pulse oximeter that illuminates the skin and measures the changes in light absorption. A conventional pulse oximeter monitors the perfusion of blood to the dermis and subcutaneous tissue of the skin [3].

With each cardiac cycle, the heart pumps the blood to the periphery[4]. Even though this pressure pulse is somewhat damped by time, it reaches the skin, and it is enough to distend the arteries and arterioles in the subcutaneous tissue. If the pulse oximeter is attached without compressing the skin, a pressure pulse can also be seen from the venous plexus, as a small secondary peak.

The change in volume caused by the pressure pulse is detected by illuminating the skin with the light from a light-emitting diode (LED) and then measuring the amount of light either transmitted or reflected to a photodiode. Because the blood flow to the skin can be modulated by multiple other physiological systems, the PPG can also be used to monitor breathing, hypovolemia, and other circulatory conditions[5]. Additionally, the shape of the PPG waveform differs from subject to subject, and varies with the location and manner in which the pulse oximeter is attached. While pulse oximeters are commonly used medical devices, the PPG derived from them is rarely displayed, and is nominally processed to determine the heart rate. PPGs can be obtained from transmissive absorption (as at the finger tip) or reflection (as on the forehead). In outpatient settings, pulse oximeters are commonly worn on the finger. However, in cases of shock, hypothermia, etc. blood flow to the periphery can be reduced, resulting in a PPG without a discernible cardiac pulse. In this case, a PPG can be obtained from a pulse oximeter on the head, the ear, nasal septum, and forehead. The PPG signal is further used to monitor the heart rate and cardiac cycle [12], monitoring respiration and monitoring depth of anesthesia.

2.3 Reading pulse using Arduino and Pulse Sensor

One important part of the proposed system is the interface of physical parameters such as pulse, blood glucose level etc., and they have taken pulse analyzer as a sample parameter. The basic setup comprises a pulse analyzer using optical reflection methods with required circuitry which will be interfaced with Arduino board over analog data input.

The circuit in Figure 2 shows that the ON/OFF control scheme for the infra-red light source is inside HRM-2511E. Note that the Enable signal must be pulled high in order to turn on the IR LED. The photo detector output (VSENSOR) contains the PPG signal that goes to a two-stage filter and amplifier circuit for further processing.

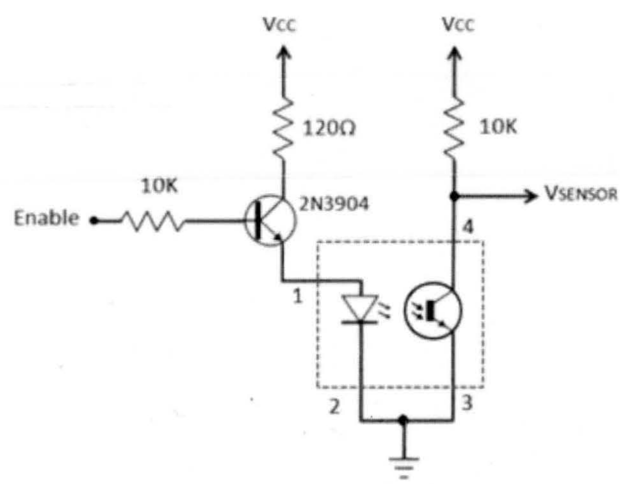

Figure 2. Pulse sensor circuit

The PPG signal coming from the photodetector is weak and noisy. So they need an amplifier and filter circuits to boost and clean the signal [9]. Figure 3 describes the Stage I instrumentation. In which the signal is first passed through a passive (RC) high-pass filter (HPF) to block the DC component of the PPG signal. The cut-off frequency of the HPF is 0.5Hz, and is set by the values of R (=68K) and C (=4.7uF). The output from the HPF goes to an Opamp-based active low-pass filter (LPF). The Opamp operates in non-inverting mode and has gain and cut-off frequency set to 48 and 3.4Hz, respectively. In order to achieve a full swing of the PPG signal at the output, the negative input of the Opamp is tied to a reference voltage (Vref) of 2.0V. The Vref is generated using a zener diode. At the output is a potentiometer (P1) that acts as a manual gain control. The output from the active LPF now goes to Stage II instrumentation circuit, which is basically a replica of the Stage I circuit. Note that the amplitude of the signal going to the second stage is controlled by P1. The Opamp used in this project is MCP6004 from Microchip, which is a Quad-Opamp device and provides rail-to-rail output swing.

Figure 4 shows the second stage instrumentation circuit that consists of similar HPF and LPF circuits. The two-step amplified and filtered signal is now fed to a third Opamp, which is configured as a non-inverting buffer with unity gain. The output of the buffer provides the required analog PPG signal. The potentiometer P1 can be used to control the amplitude of the PPG signal appearing at the output of the buffer stage.

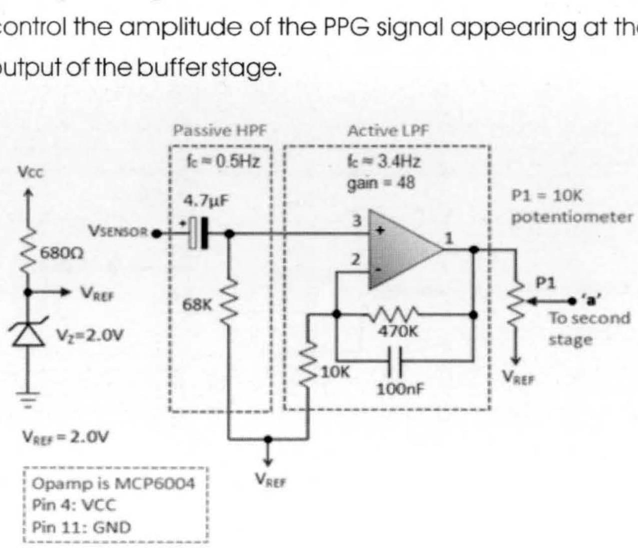

Figure 3. Stage I filtering and amplification

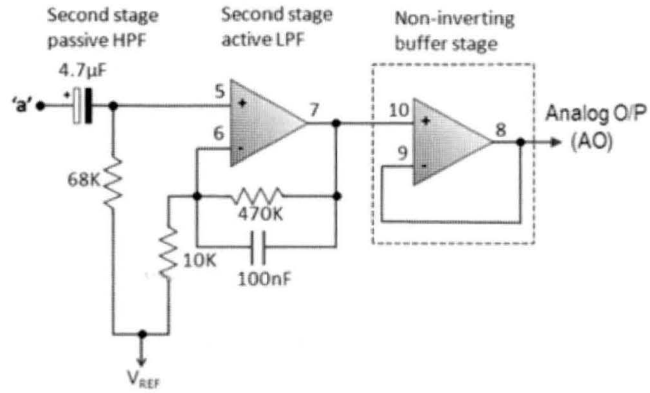

Figure 4. Stage II instrumentation circuit

The fourth Opamp inside the MCP6004 device is used as a voltage comparator. The analog PPG signal is fed to the positive input and the negative input is tied to a reference voltage (VR). The magnitude of VR can be set anywhere between 0 and Vcc through potentiometer P2 (as shown in Figure 5). Every time the PPG pulse wave exceeds the threshold VR, the output of the comparator goes high. Thus, this arrangement provides an output digital pulse synchronous to heart beat. Note that the width of the pulse is also determined by VR. An LED connected to the digital output blinks accordingly.

The Arduino IDE is a open source platform for developing and porting programs on Arduino boards. They have used the IDE to develop the program for reading pulse from pulse sensor over analog data line 0 periodically and send the same over Bluetooth continuously to make it available for the Android based mobile phone.

2.4 Reception of data over Bluetooth in Android Phone

The Bluetooth transceiver has been paired with the Android based mobile phone where it will receive the data and record/plot the signals. It will be further used for

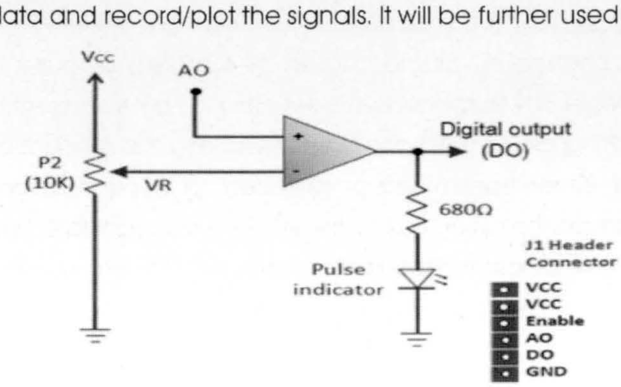

Figure 5. Digital pulse output circuit

diagnosis and data logging. The package android.bluetooth available in android's ADT bundle has classes such as Bluetooth Adapter, Bluetooth Device and BluetoothSocket to make Bluetooth connections, pairing devices and send/ receive data over Bluetooth[8]. As the data being transmitted over Bluetooth is in periodical intervals, a mechanism is needed in receiver end (Android application) to stream the data for proper separation of received signals. Once the data has been separated, and stored in a temporary buffer, it is further processed for removing dc components, and unwanted variation.

2.5 Signal processing in Android phone

From the pool of received signals in Android phone over Bluetooth, further processing of the incoming ADC samples are done to extract the PPG signal and heart rate. The following are the list of actions done in Android applications before deciding the heart rate:

- Read samples continuously
- Remove DC component
- Check if ADC sample range is enough. If not, then input data is noise that need to be discarded
- Apply 21-point moving average filter to smoothen the PPG waveform
- Compute the heart rate based on three successive peaks in the PPG signal.
- Plot the PPG waveform and heart rate in Android application.

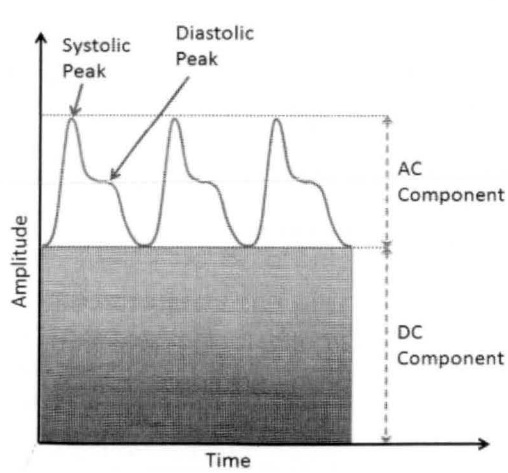

Figure 6. PPG components shown not to scale

The processed PPG signal will have AC components specified as in Figure 6, where the DC component has been filtered as part of the above steps.

2.6 Logging data in SQLite database

The processed PPG signal is then stored in SQLite database as part of the developed Android application. The package android.database.sqlite has list of classes such as SQLiteDatabase and SQLiteOpenHelper to support database operations[7][8]. The database acts as a medium for local storage of PPG signal and other live physical signals to view the historical data without network connectivity and also used as a temporary storage medium before the measured parameters are sent to centralized server. SQLiteDatabase has methods to create, delete, execute SQL commands, and perform other common database management tasks. Database names must be unique within an application, not across all applications.

2.7 Plotting the PPG signal

The processed PPG signal will be displayed in the application screen along with computed heart rate. They use AndroidPlot API for plotting the PPG signal in graphical format. AndroidPlot is an API for creating dynamic and static charts within Android applications. It was designed from the ground up for the Android platform, and is compatible with all versions of Android from 1.6. They have used classes available in com.androidplot.xy package for deploying PPG signal.

2.8 Web services and centralized database

Windows Communication Foundations (WCF) services have been used to expose the end points of the web services. WCF interoperate between WCF-based applications and any other processes that communicate via SOAP (Simple Object Access Protocol) messages[11]. Android application will consume these services to upload the measured physical parameters and patient information into a centralized relational SQL database.

2.9 Location discovery and sending SMS

The package android.location provides rich sets of API's that will be useful for location discovery in android devices. The Location Provider intelligently manages the underlying location technology and gives the best location according to needs[7][8]. The class java.location.Geocoder is for handling geocoding and reverse geocoding. Geocoding is the process of transforming a street address or other description of a location into (latitude, longitude) coordinates. Reverse geocoding is the process of transforming a (latitude, longitude) coordinate into a (partial) address. The class android.telephony.SmsManager manages the SMS operations such as sending data, text, and MIME SMS messages. We can this object by calling the static method getDefault().

3. Experimental Results

Experimental results show that the present system proposed is very helpful for individual human beings and health care providers to easily track the health records. By using the PPG signal sensing as a sample, the height of AC component of the Photo Plethysmo Gram(PPG) is proportional to the pulse pressure, the difference between the systolic and diastolic pressure in the arteries. A screen capture of plotted PPG graph with pulse rate is shown in Figure 7.

The Location discovery, critical alert management, patient registration and centralized data management over web services also have been tested with laboratory environment.

Conclusion

The paper introduces a framework for personal health monitoring based on Android based mobile phone, by using the proposed system, with a simple PPG pulse sensor

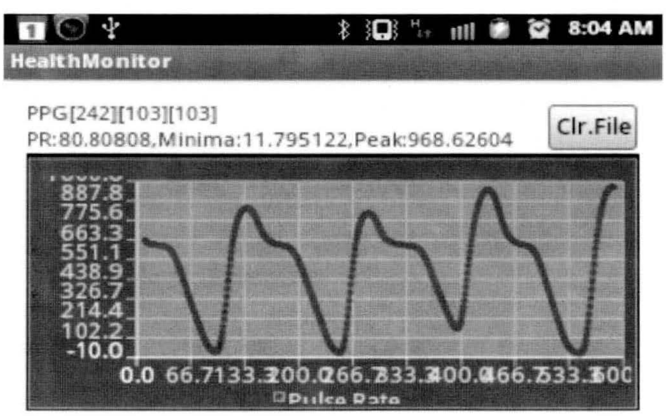

Figure 7. Pulse rate and PPG wave form in Android

and a smart phone. They can easily monitor the vital physical parameters such as heart rate, cardiac cycle, and respiration[10]. Further the system can be scaled up to accommodate more bio sensors such as glucose level monitors. The system will be more helpful for the patients whose health conditions need to be monitored in a consistent manner.

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