A SMARTPHONE BASED PHYSIOLOGICAL PARAMETERS MONITORING SYSTEM

By

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ABSTRACT

In medical treatment, diagnosis plays a very important role. A reliable, affordable wireless patient monitoring system has been designed. The designed system records the physiological parameters - body temperature, oxygen saturation in blood (SpO_2), heart rate, as well as two bioelectrical signals-Electrocardiogram (ECG) and Electroencephalogram (EEG). The recorded parameters and signals are then transferred via bluetooth communication protocol to an android based smartphone. The recorded parameters/signals can be transferred to the physician through internet storage and generates alert messages in case of abnormal situations. The android based application comprises of the following features such as, storing the location of the patient, data on the device and internet drive, and view of ECG and EEG graphs. In addition, it helps in monitoring the patient's physiological parameters over the smartphone. An alert mechanism is also provided, which will send the message to the physician when the abnormal condition arise.

Keywords: Health Monitoring, Android Application Design, Smart phone, Bluetooth, Body Temperature, SpO_2, ECG and EEG Signals, Body Area Network (BAN).

INTRODUCTION

At least 400 million people do not have access to one or more essential health services and 6% of people in low- and middle-income countries are tipped into or pushed further into extreme poverty because of health spending, a Joint WHO/World Bank Group Report of June 2015 says. Also, facts and figures presented in Atlas 2011 indicate that resources for mental health remain inadequate [13]. Nearly 27% of the total deaths in India happen with no medical attention at the time of death, according to the 2013 civil registration data released by the Census directorate data based on 27 states and Union territories, which also indicated that only 43% of the total deaths happen in institutions and only the rest 3.9% are under the care of a qualified allopathic doctor.

- The issues of traditional health monitoring system are enlisted below.
- Patients must travel long distances to gain access to healthcare.
- Patients fail to receive continuous care.
- Shortage of medical professionals and hospitals.
- Time consuming tests and lack of equipments.

To overcome the above issues, the authors have designed an advance wireless health monitoring system based on android. The system uses Bluetooth technology as the medium for transferring the data between the portable data acquisition unit and the android device. It will be utilized for continuously measuring the vital physiological parameters such as ECG and EEG signals, body temperature, oxygen saturation of blood (SpO_2), heart rate, etc. The designed system comprising of an android application provides the advanced features like transferring of data from acquisition unit to a smartphone via Bluetooth and to view them in different formats, intimating the physician in case of emergency, and alert in case of abnormal conditions. The block diagram of the system is shown in Figure 1.

The system consists of mainly two parts. One is the

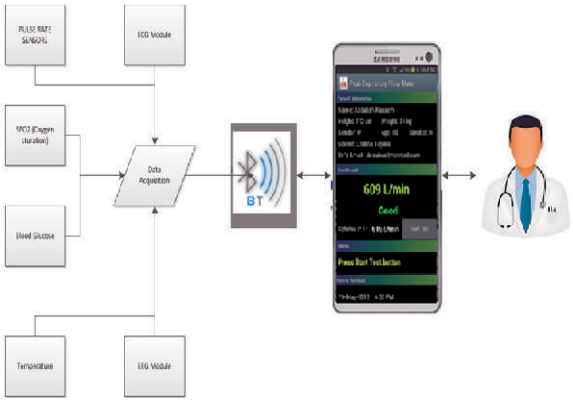


Figure 1. Block Diagram of System

hardware which contains all necessary circuitries of the sensor modules and the microcontroller and the second part is the android application which consists of a User Interface (UI) for controlling the graph view and graphical parameters and communication options.

1. Related Works

In [1], the authors have designed an android application which communicates over bluetooth with the hardware module which consists of ECG module and respiration module for displaying data in graphical form. Some authors have designed an app for ECG recording [2], and disease detection/verification [3], [11]. In [4], the authors have proposed a web based health monitoring system that uses sensor modules connected to bluetooth for transmitting data to computer and from there these data are uploaded on the server and it can also be retrieved to a mobile by the physician or the patient. In [5], the authors have utilized the photoplethysmography (PPG) technique for heart rate calculation. A microprocessor is used to covert a biosignal from analog to digital format, suitably for feeding into an RF module (nRF24L01 for RF transmission). The same technique can be utilized to measure the oxygen saturation in blood [6], [12].

Blood Pressure (BP) can be indirectly obtained by measuring Pulse Wave Velocity (PWV), which is related to both (ECG) and PPG. But it is very difficult to measure PWV. Another physiological parameter-Pulse Transit Time (PTT), is used to describe the relationship between PWV and BP [7]. EEG is the recording of the electrical activity of the brain from the electrodes placed on the scalp. Capturing a seizure with EEG is a necessary prerequisite for making a definitive diagnosis, tailoring therapy, moving toward certain kinds of solutions such as surgery, or even affixing the true rate of events [8], [9]. Watch based designs are also implemented [10]. In [14], authors have presented an android based application framework for acquiring and monitoring various health parameters like body temperature, heart rate and SpO_2; and bioelectric signals like ECG and EEG.

2. System Design

The system has mainly two components:

- Data/signal acquisition module with a bluetooth transmitter.
- Android based smartphone for display and monitoring.

The aim of this work is to design a cost-effective and optimal system that can last for a longer time on battery supply. The user module architecture is shown in Figure 2, which contains the submodules for measuring the physiological parameters with the RF transmitter, in this case it is a Bluetooth, with microcontroller interfaced with the sensors and power manager modules. This module senses the physiological parameters and after signal processing and conditioning transmit them to the android phone connected to the bluetooth. The following section describes these steps in detail. Table 1 describes the specifications of the designed system.

2.1 Hardware: Signal Conditioning and Data Acquisition

This section describes all the hardware components and

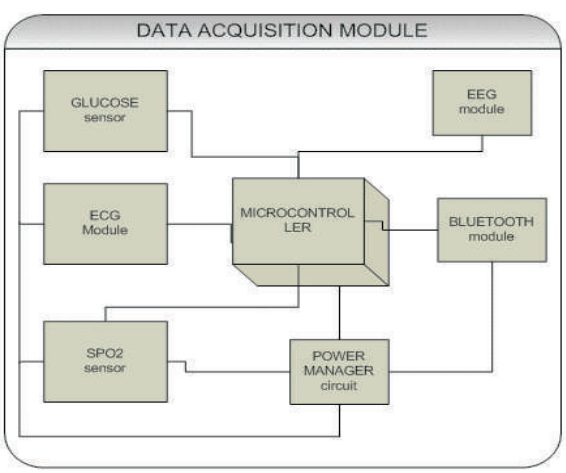


Figure 2. Data Acquisition Module

System Parameters	Values
Supply Voltages	3.3V, 5V, -5V
Data Streaming Rate	= 1Mbps
ECG Frequency Response	(0.05-150)Hz
EEG Frequency Response	(0.1-100)Hz
Analog to Digital Converter	10-12 bit resolution
Sampling Rate	~ 500 sps

Table 1. System Specifications

sensor details. The sensors/electrodes are used for acquiring the ECG and EEG signals, SpO_2 and body temperature.

2.1.1 Temperature Sensor

The LM35 series is a precision integrated-circuit calibrated directly in Celsius (Centigrade) temperature devices with an output voltage linearly-proportional to the Centigrade temperature.

- Calibrated Directly in Celsius (Centigrade)
- Linear + 10-mV/°C Scale Factor
- 0.5 °C Ensured Accuracy (at 25 °C)
- Rated for Full −55 °C to 150 °C Range.

2.1.2 EEG Module

In the design of this module, the authors have used differential instrumentation amplifier INA128 for gain and OPA2277U op-amp for high pass and low pass filtering. They designed the filter for the range of (0.5 – 40 Hz) suitable for all the ranges of EEG measurement. INA128 is designed for the range of -5 V to +5 V range and the reference is selected as 0 V. Gain is nearly 660 for INA128 and reset of the gain is provided by the filter op-amp OPA2277.

2.1.3 ECG Module

For ECG measurement and Heart Rate calculation, is used the AD8232 module which has the following features.

- Fully integrated single-lead ECG front end.
- Low supply current: 170 μA (typical).
- Common-mode rejection ratio: 80 dB (DC to 60 Hz).
- Two or three electrode configurations.
- High signal gain (G = 100) with DC blocking capabilities.
- Leads off detection: AC or DC options.
- Integrated Right Leg Drive (RLD) amplifier.
- Single-supply operation: 2.0 V to 3.5 V.

2.1.4 SpO_2 Module

Oxygen saturation is calculated based on the spectrophotometric principle. The basic principle is that each compound absorbs or transmits light over a certain range of wavelength. Based on this principle, the oxygen saturation in blood is calculated. It is defined as the ratio of the oxygenated Haemoglobin level over the total Haemoglobin level (oxygenated and depleted):

$$SpO_2 = \frac{\text{Oxygenated Haemoglobin } (HbO_2)}{\text{Total Haemoglobin (Hb)}}$$

This module uses two LEDs (RED) and IR and photodiodes on the other side finger placed in between and based on the level of oxygen in the blood. Different absorption is carried out by the blood cells and the remaining light passes through the finger that is converted in to current by the photodiode which is then with the help of tranceinductance amplifier (OPA381) converted into the voltage and further amplified by the op-amp (OPA333).

All the above modules that provide analog data are converted into digital data using the 10 bit ADC channels of the microcontroller (MSP430G2553). The flowchart in Figure 3 explains the interaction between the bluetooth module of android and the data acquisition module.

2.2 Software: Android Application Development

The data received from the bluetooth module is utilized in the android application. This application (BIOMAPP) is designed using Android Studio. Based on the user preferences, the data is analyzed and processed in the device. The authors have used Graph View library, Google location API and SDK version 21 for the design of this application. Dropbox API is also used for storing the recorded data on the drive from where the physician can access the data. It has the following features:

- Profile based data analysis and storage.
- EEG and ECG graph (plot on the data provided by the hardware module).
- Temperature, SPO_2 and other parameter in the TEXT

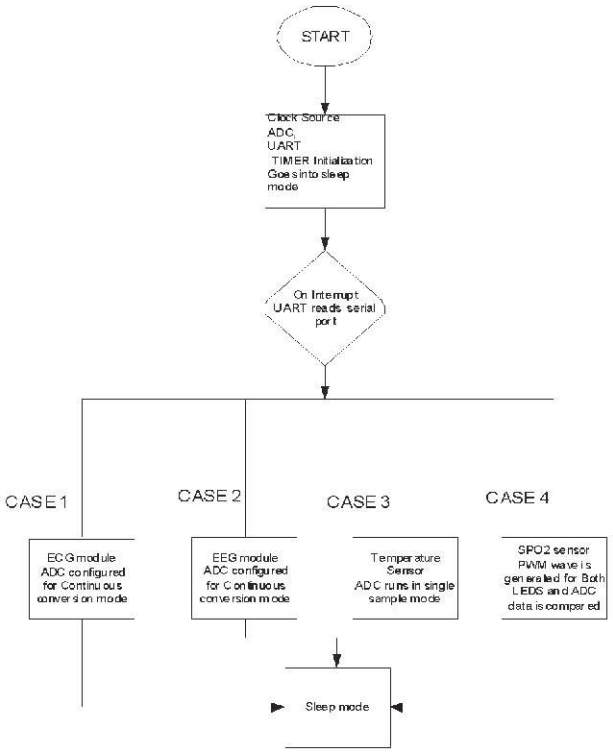


Figure 3. Program Flow in Data Acquisition Module

format.

- Text format for data storage and sharing on local disk.
- Screenshot option.
- Abnormality detection.
- Alarm and notification trigger.
- Emergency contact.
- Direct assistant of doctor on emergency.
- Rescue feature.

Different physiological parameters are measured on the device on their normal and abnormal conditions with different notifications. The alarm and rescue methods are also implemented in the application. If the condition is normal, then a simple notification is generated expressing the condition as normal and if the condition is abnormal then the emergency contacts will be called.

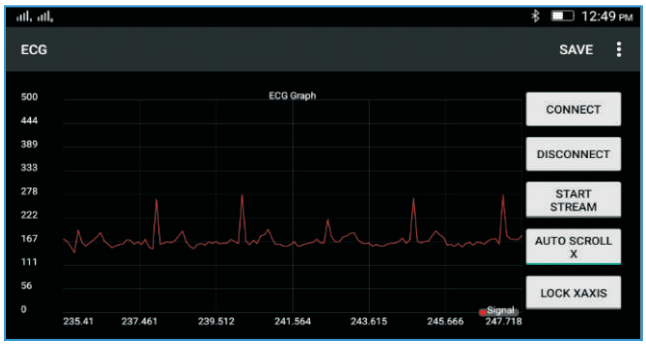
3. Results and Discussion

Figure 4 shows the outlook of the developed BIOMAPP on the screen of an android smartphone. Figure 5 shows the acquired ECG (Figure 5 (a)) and EEG (Figure 5 (b)) signals on the smartphone screen. Figure 6 shows the SpO_2 readings of two subjects. The data collection in the BIOMAPP is facilitated in two ways: each module's separate folder, as shown in Figure 7 and date-wise data collection, as shown in Figure 8. Figure 9 indicates the smartphone screen for a sample message sent to the physician when an abnormal condition is detected, albeit it's not the actual abnormal event/condition, but the facility of the android app.

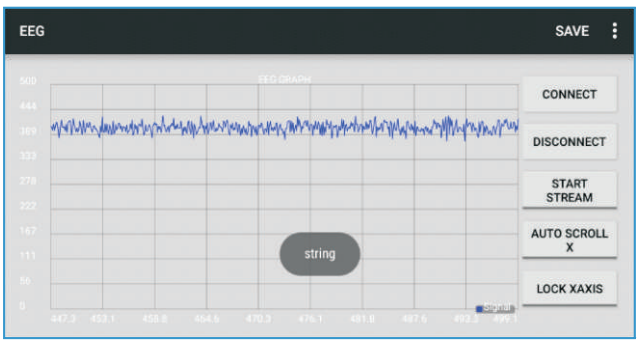
Conclusion

The authors have successfully implemented the EEG module, ECG module, SpO_2 sensor and body temperature sensor. The sensor data are acquired in the android application using the bluetooth protocol. After acquiring these data, they are stored in the android device in text format. These data are also uploaded on

Figure 4. The Biomapp Application Screenshots



(a)



(b)

Figure 5. ECG and EEG Signals Displayed on the Smartphone

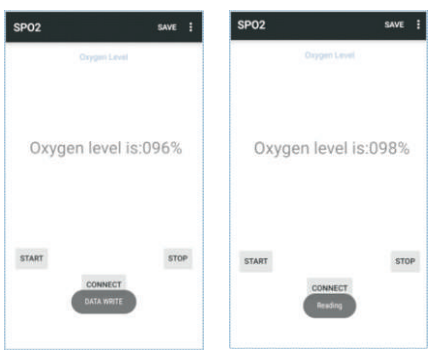


Figure 6. SpO_2 Readings of two subjects

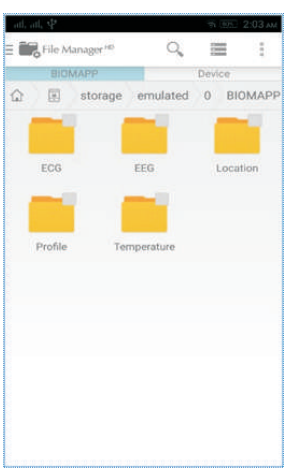


Figure 7. Folders for Different Modules

Figure 8. Date-wise Data Collection for Each Module

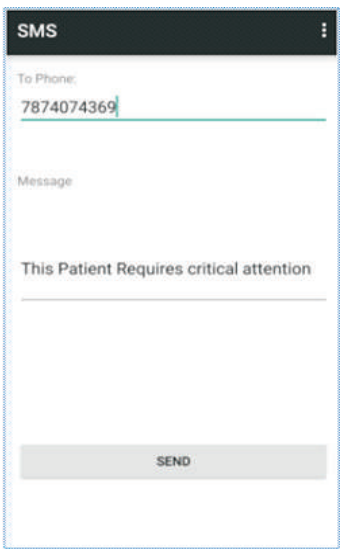


Figure 9. Alert Message to the Physician

Dropbox. A physician can analyze this data using the link shared by the patient. An alert message is also generated based on the abnormal value of the body temperature value. The alert messages are generated based on the abnormalities detected in SpO_2 data or heart rate after certain analysis, thus helping in monitoring of a patient's physiological parameters over the smartphone.

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