WIRELESS HEALTH CARE MONITORING APPLICATION USING MOBILE DEVICES

G. Anandhi[1]

Abstract

The prime goal was to develop a reliable patient monitoring system so that the healthcare professionals can monitor their patients, who are either hospitalized or executing their normal daily life activities. The data can be transmitted through the Bluetooth, which is received by the smart phone in another location. In this work we present a mobile device based wireless healthcare monitoring system that can provide real time online information about physiological conditions of a patient. The proposed system is designed to measure and monitor important physiological data of a patient in order to accurately describe the status of her/his health and fitness The patient's temperature, heart beat rate, muscles, blood pressure, blood glucose level, and ECG data are monitored, displayed, and stored by our system.

Keywords : ZigBee, remote healthcare, mobile device, patient monitoring, LabView, Machine-to-machine(M2M)

Introduction

One of the most promising applications of information technology is healthcare and wellness management. Continuous or even occasional recording of biomedical signals is particularly critical for the diagnosis and treatment of cardiovascular diseases [1–4]. For example, continuous recording of an electrocardiogram (ECG) or photoplethysmogram (PPG) by a wearable sensor provides a realistic view of a patient's heart condition by tracking such factors as high blood pressure, stress [5–6], anxiety, diabetes and depression [7–8], during normal daily routines. Automated analysis brings several benefits, such as decreased healthcare costs, by increasing health observability, collaboration among doctors and doctor-to-patient efficiency [9–11].

Moreover, continuous monitoring serves to increase early detection of abnormal health conditions and diseases, offering a way of improving patients' quality of life [12–13].

In this paper we present a smartphone based wireless healthcare monitoring system (WHMS), which can provide real time online information about medical status of a patient. The proposed system consists of sensors, a data acquisition unit, smartphone, and the LabVIEW program. The system is able to display, record, and send patient's physiological data. The LabVIEW program assists monitoring and displaying the data.

[1] Assistant Professor, YMT College of Management, Kharghar- Navi Mumbai & Research Scholar, VELS University, Chennai

The patient's temperature, heart beat rate, muscles, blood pressure, blood glucose level, and ECG data can be monitored by our present system.

Related Works

Real time mobile healthcare system for monitoring the elderly patients from indoor or outdoor locations has been presented in [1]. A bio-signal sensor and a smartphone are the main components of the system. The data collected by the bio-signal sensor are transmitted to an intelligent server via GPRS/UMTS network. A smart shirt has been designed in [2] . The shirt can measure electrocardiogram (ECG) and acceleration signals for continuous and real time health monitoring of a patient. The shirt mainly consists of sensors and conductive fabrics to get the body signal. The measured body signals are transmitted to a base station and server PC via IEEE 802.15.4 network.

The wearable devices consume low power and they are small enough to fit into a shirt. Windows Mobile based system for monitoring body parameters has been presented in [3]. The proposed system consists of a body sensor network that is used to measure and collect physiological data. Bluetooth has been used to transmit data from the sensor network to a mobile device. The experimental results show that the proposed system is able to monitor the physiological data of patients under mobility condition. A complete wireless body area network (WBAN) system has been designed in [4]. To increase the operating range multi-hopping technique has been used and a medical gateway wireless board has been used in this regard. This gateway has been used to connect the sensor nodes to a local area network or the Internet.

To solve the problem of false alerts some machine learning approaches have been proposed in [5]. In these approaches data generated by the wearable sensors are combined with clinical observations to provide early warning of serious physiological changes in the patients. Cloud computing has been incorporated in a healthcare system in [6]. The authors have proposed a cloud based intelligent healthcare monitoring system (CIHMS) for providing medical feedback to a patient through cloud. The proposed system can obtain adequate data related to patient's disease and deliver the data to a remote location by using cloud computing devices. Although mobile devices are always considered a promising tool to monitor and manage patients' own health status, these devices have some inherent limitations in computation or data intensive tasks. A new hybrid mobile cloud computational solution has been proposed in [7] to overcome these limitations. To monitor the health of a pregnant woman with preeclampsia a novel health monitoring system has been proposed in [8]. The proposed system also uses an Oximeter connected to a smartphone to measure oxygen saturation level of the patient in order to predict her risk level. Remote healthcare system for monitoring electrocardiographic and temperature data has been presented in [9]. The system consists of three modules namely (i) a hardware module, (ii) Bluetooth module, and (iii) display module. The hardware module is used for data acquisition. The Bluetooth module is used for data transmission. Finally, the data are displayed by using the display module. The acquired clinical data are sent to a database server by using GPRS or WiFi. Mobile device based healthcare system for monitoring the patients with Alzheimer's disease has been developed and presented in [10]. A novel 6LoWPAN based ubiquitous healthcare system has been presented in [11]. The authors have used LabVIEW program to provide the connectivity. The whole system was tested by using an ECG simulator. An ambulatory system for monitoring the physical rehabilitation patients has been reported in [12]. The system consists of (i) a multi-sensor based monitoring device, (ii) a mobile phone with client application, (iii) a service-oriented-architecture based server solution, and (iv) application. Real time ubiquitous healthcare system for monitoring ECG signals by using mobile device has been presented in [13]. By using this system the user can monitor his ECG signal. The performance of the proposed system has been evaluated against the MIT-BIH normal arrhythmia database. A pervasive healthcare system enabling self-management for chronic patients has been introduced in [14]. The proposed system consists of (i) patient health monitoring system, (ii) status logging, and (iii) social sharing of the recorded information. The system has been implemented by (i) a mobile device, (ii) a wearable multi-sensing device, (iii) a serviceoriented architecture for communication, and (iv) microblogging services. Wireless electrocardiogram (ECG) monitoring system based on Bluetooth Low Energy (BLE) technology has been reported in [15]. The system consists of (i) a single-chip ECG signal acquisition module, (ii) a Bluetooth module, and (iii) a smartphone. The system is able to acquire ECG signals through two-lead electrocardiogram (ECG) sensor. The system is also able to transmit the ECG data via the Bluetooth wireless link to a smartphone for further processing and displaying the ECG signals. Breathing rate monitoring (BREMON) system has been proposed in [16]. A system to monitor the blood pressure of a hypertensive patient using mobile technologies has been proposed in [17]. The system is also able to communicate with a server via Internet. The server is used for storing and displaying patient data graphically. In order to monitor the breathing disease called Obstructive Sleep Apnea Syndrome (OSAS), occurs due to sleep disorder, has been introduced in [18]. This disease not only interrupts normal sleep pattern but also causes hypoxemia and hypercapnia. In this work a smartphone based wireless e-health system has been introduced for monitoring a patient with OASAS

Fig. 1. Wearable health sensors with a PCB board: (a) shirt ECG sensor. (b) wrist PPG sensor

ECG signals are recorded as electrical activity of the heart over time, while PPG signals are measured as changes in light absorption to monitor blood volumes within peripheral skin tissue. Wearable health sensors were designed to enable the measurement of biomedical signals. The PPG sensor was designed to obtain PPG waveforms and oxygen saturation data from the patient's finger by calculating the ratio of red and infrared light on the device surface, which varies depending on how much light is absorbed by tissue. This PPG sensor contains analog signal processing, amplifiers, filters and analog-to-digital converters (ADC). After emulator testing, the server program sends received data wirelessly to the patient's Android mobile device. Various algorithms are combined into mobile application software created with the Java Android language to handle all server processes. Query processes handle communication between the server and the Android mobile device for a graphic real-time display of biomedical signals on the screen. The mobile monitoring program was implemented and tested on an Android mobile phone (Samsung Galaxy S, Korea) [64] running a 1 GHz ARM processor (Cortex A8, Hummingbird) and Android operating system (OS) version 2.3.6.

LabVIEW based patient monitoring system consider two techniques (see Figure 2) to implement the system. In the first technique we connect the sensors attached with the patient's body to a transmitter unit associated with a ZigBee or GSM network. The transmitter transmits the data wirelessly to a receiver that is also associated with a ZigBee or GSM network. receiver is connected directly to the USB port of a local monitoring unit (which is a Laptop with LabVIEW software in it. The local monitoring unit displays the final data.

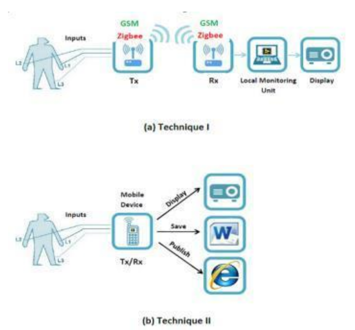

Figure 2. Investigated Techniques

In the second technique as shown in Figure 2(b) we connect the sensors attached with the patient's body to a mobile device. The mobile device acquires the data from the sensors and sends them to a processor, which is running the LabVIEW software in it. The processor receives the data and performs the necessary analysis. It can display the data in an organized Graphical User Interface (GUI). The processor also saves the data in a worksheet associated with the Microsoft Excel program. Finally, it can publish the data in the Internet so that the healthcare professionals can monitor them from a remote location at any time. In this proposed system we minimize the hardware by combining transmitter, receiver, and local monitoring unit in one device. We implement this work by using hardware and software in such a way so that it can be easily accessed by different systems and devices. We made the system flexible enough to accommodate more options as per user demand in future.

System Implementation

Figure 3. The biometric shield

The Yocto-Knob device supports easy reading of 5 input buttons, contacts, switches or potentiometers (knobs) from USB. It is a kind of analog-to-digital converter (ADC). We can use it to read any analog resistive sensor including photodiodes. On the device, five tiny LEDs constantly show the value of the five inputs. Five micro switches connected in parallel to the inputs simplify a design. This device can be connected directly to an Ethernet network using a YoctoHub-Ethernet or to a Wi-Fi network using a YoctoHub-Wireless. Android application called Valarm Pro v1.1.0 provides support for the Yocto-Knob sensor. We can use these sensors to trigger alerts and/or record the conditions of a variety of stuff one might need to monitor without any programming. The Valarm Pro application integrates Yoctopuce sensors to monitor, record, and broadcast alerts based on environmental and weather parameters such as CO2, VOCs (Volatile Organic Compounds), ambient temperature, relative humidity, barometric pressure, ambient light, electrical resistance, water Levels, and flood alerts. The Valarm Pro currently integrates with the Yocto-Meteo, Yocto-Temperature, Yocto-Light, Yocto-Knob, Yocto-VOC, and Yocto-CO2. The e-Health Sensor Shield V2.0, as shown in Figure 3, allows Arduino and Raspberry Pi users to perform biometric and medical applications where physiological data monitoring is needed. Ten different sensors can be connected to this e-Health Sensor Shield including pulse, oxygen in blood (SPO2), airflow (breathing), body temperature, electrocardiogram (ECG), glucometer, galvanic skin response (GSR-sweating), blood pressure (sphygmomanometer), patient position (accelerometer), and muscle/electromyography sensor (EMG). The biometric information collected by the sensors can be used to monitor the real time health status of a patient in order to be subsequently analyzed for medical diagnosis. The information can be wirelessly sent by using any of the six connectivity options available including Wi-Fi, 3G, GPRS, Bluetooth, 802.15.4, and ZigBee depending on the application. If a real time image diagnosis is needed, a camera can also be attached to the 3G module in order to send photos and videos of a patient to a medical diagnosis center. Data can be sent to the Cloud in order to perform permanent storage and visualization in real time by sending the data directly to a laptop or smartphone. IPhone and Android applications have been designed in order to easily monitor the patient's information.

System Components

A.ECG Electrodes

An ECG electrode is a device attached to the skin on certain parts of a patient's body during an electrocardiogram procedure. It detects electrical impulses produced each time the heart beats. The number and placement of electrodes on the body can vary, but the function remains the same. The electricity that an electrode detects is transmitted via this wire to a machine, which translates the electricity into wavy lines recorded on a piece of paper. The ECG records, in a great detail, are used to diagnose a very broad range of heart conditions. An ECG electrode is usually composed of a small metal plate surrounded by an adhesive pad, which is coated with a conducting gel that transmits the electrical signal.

B. The LM35 Temperature Sensor

The LM35 series are precision integrated circuit LM35 temperature sensors, whose output voltage is linearly proportional to the temperature in Celsius (Centigrade). The LM35 sensor thus has an advantage over linear temperature sensors, calibrated in °Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient centigrade scaling. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy.

C. Blood Pressure Sensor

Blood pressure sensor is a device that measures the pressure of the blood in the arteries as it is pumped around the body by the heart. When our heart beats, it contracts and pushes blood through the arteries to the rest of our body. This force creates pressure on the arteries.

D. Blood Glucose Sensor

Blood glucose sensor is a medical device for determining the approximate concentration of glucose in the blood. A small drop of blood, obtained by pricking the skin with a lancet, is placed on a disposable test strip that the meter reads and uses to calculate the blood glucose level.

E. Microsoft Pro Tablet

A tablet computer is a mobile computer with display, circuitry, and battery in a single unit. Tablets are equipped with cameras, microphone, accelerometer, and touch screen with finger or stylus gestures replacing computer mouse and keyboard. Tablets include physical buttons to control basic features such as speaker volume, power, and ports for network communications and to charge the battery. An on-screen pop-up virtual keyboard is usually used for typing.

Why Zigbee And Labview Combination?

The ZigBee technology was introduced by the ZigBee Alliance [19,20]. This technology has evolved based on a standardized set of solutions called ‘layers'.

The IEEE 802.15.4 standard defines the characteristics of the physical and Medium Access Control (MAC) layers for Wireless Personal Area Network (WPAN). Taking this standard as a “chassis” the ZigBee Alliance has defined the upper layers in the ZigBee standard. We choose ZigBee wireless technology because it has been optimally designed to provide some advantages namely low cost, low power, easy implementation, reliable, and high security. One of our design considerations was to maximize the operating life of our system. The transmission range of ZigBee is greater than Bluetooth, but it less compared to other technologies. Still, it is remarkable for a low power solution. While implementing any wireless health monitoring system we need to consider security issue. The ZigBee technology provides enough security for our system. The security has been ensured via several steps namely key establishment, key transport, frame protection, and device authorization. Another major advantage of our system is that we used LabVIEW software to design the front panel. It is an excellent integrating platform for acquiring, processing, and transmitting the physiological data.

The LabVIEW software also includes a number of advanced mathematical blocks for functions such as integration, filter, and other specialized capabilities. By using the LabVIEW we can automatically store the physiological data of patients in spread sheet, which was one of the key features for us.

System Operations

The system operating procedure is as follows:

1. We place three electrodes of ECG on the patient’s body (i.e., right hand, left hand and right leg as shown in Figure 4).
2. We connect the Arduino Shield with a temperature sensor, a blood pressure sensor, and a blood glucose level sensor.

3. From the Arduino shield we connect a wireless node (as a transmitter) and the USB port of the tablet (as a receiver) or the smartphone that has LabVIEW software running on it to take the reading of the physiological data from the patients' body. The data are then processed and displayed on LabVIEW front panel by using Data Dashboard application.
4. The data are also saved according to the time and presented in a report format. In addition some personal details of the patient are also recorded.

After completing all the procedure the collected data can be used to monitor (in real time) the state of a patient or to get sensitive information in order to be subsequently analyzed for medical diagnosis. Biometric information gathered can be wirelessly sent using any of the six connectivity options available namely Wi-Fi, 3G, GPRS, Bluetooth, 802.15.4, and ZigBee depending on the application. In our work we use ZigBee. If real time image diagnosis is needed, the system can also be equipped with a camera attached to the 3G module. Data is sent to the Cloud in order to perform permanent storage or to visualize in real time by sending the data directly to a laptop or a smartphone. The iPhone and Android applications have been designed in order to easily see the patient's information. There are also buttons for ECG signal, heart rate, blood pressure, QRS interval, and body temperature. These buttons will change their color depending on the health status of a patient. For example, the button will change color from 'gray' (as originally set) to 'green' if the monitored data are within the normal range. The button will change color from 'gray' to 'blue' if the monitored data are abnormally low. Similarly, the button will change color from 'gray' to 'red' if the monitored data are abnormally high. By tracking the colors of the buttons the patient will be easily aware of her/his health status. In addition to some personal information of the patient and timing data the report presents the monitored physiological data. It is depicted in the report that the heart of the patient is in normal condition. The other data including blood pressure and body temperature are also in the normal range.

Figure 4. ECG Electrodes placements

Conclusion

A smartphone based health monitoring system has been presented in this work. By using the system the healthcare professionals can monitor, diagnose, and advice their patients all the time. The physiological data are stored and published online. Hence, the healthcare professional can monitor their patients from a remote location at any time. Our system is simple. It is just few wires connected to a small kit with a smartphone. The system is very power efficient. Only the smartphone or the tablet needs to be charged enough to do the test. It is easy to use, fast, accurate,high efficiency, and safe (without any danger of electric shocks). In contrast to other conventional medical equipment the system has the ability to save data for future reference. Finally, the reliability and validity of our system have been ensured via field tests. The field tests show that our system can produce medical data that are similar to those produced by the existing medical equipment.

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