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Continuous Vital Signs Monitoring using Smartphones

Nazrul Anuar Nayan, Faizatul Azwa Azami

Department of Electrical, Electronic and System Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, Bangi, Selangor, Malaysia

nazrul@ukm.edu.my

Abstract

World Health Organization (WHO) estimates that 347 million people worldwide have diabetes. Close observation of the vital signs has shown to be an effective way on reducing the severity of the disease. In this paper, the design and development of a vital signs monitoring system using smartphones are proposed. The biomedical sensors used in this study are a glucometer, blood pressure, pulse oxymeter, electromyography, and temperature sensors. These sensors are connected to Arduino UNO microcontroller. RN-XV Wifly module is used to transmit the vital signs data to a smartphone. The vital signs data from the biomedical sensors are processed using Arduino software and verified using a serial monitor. The result shows that vital signs can be displayed at a real time on the smartphones which can also be accessed by physicians and family members. From this development, a low-cost and reliable monitoring system has been proposed which can clearly benefit many people and improve the country's health system.

Keywords: vital signs, health monitoring, Arduino, diabetes, mobile apps

Introduction

WHO estimates that 347 million people worldwide have diabetes, 90% of whom have type 2 diabetes which is largely caused by excess body weight and physical inactivity. Lack of access to diagnosis and management of diabetes can have serious consequences including heart disease and stroke (WHO, 2014). Close observation of the vital signs has shown to be an effective way on reducing the severity of those diseases. Telemonitoring of vital signs and symptoms facilitate early detection of deterioration and reduce readmission rates and length of hospital stay in patients with heart failure (Louis Amala et al., 2003). Vital signs are the information from different physiological signals. These signals are observed to determine the status of the basic functions of the human body, such as the temperature, pulse rate, blood pressure (BP), and respiratory rate. The introduction and development of wireless technology in the biomedical field has resulted in a stiff competition among different wireless technologies in recent years. Today, different wireless communication technologies are widely available such as ZigBee, Bluetooth and Wi-Fi modules. These technologies have penetrated daily human life with their outstanding performance and popularity, as evidenced by their use in many fields. The usage of smartphones worldwide has created innovations for many systems.

In this study, a smartphone is used in the proposed system to facilitate vital signs monitoring. We perform the following processes: i) design of the layout of the continuous vital signs monitoring system, ii) integration and configuration of the system sensors and modules, iii) development of the programming for the Arduino microcontroller and RN-XV Wifly, and iv) human testing of the prototype.

Development of Health Monitoring

Wireless medical data transmission is driven by the need to perform remote analysis of physiological data, assuming that the system is effectively implemented. Several systems for nonhospital wireless health monitoring have been established (Alaoui et al., 2003). A survey by Roine et al. (2001) on "telemedicine" literature between 1990 and 2000 found 50 studies to be suitable for consideration; 34 of these studies were assessed clinical outcomes and 16 were assessed economic benefits.

Vital signs such as BP, electrocardiography (ECG), peripheral oxygen saturation (SpO_2), and blood glucose, are monitored to evaluate the health status of patients. BP, respiratory rate, ECG, and SpO_2 are the parameters that need constant monitoring at home. The other parameters that can be monitored using wireless technology are blood glucose, weight, physical activity, and sleep quality (Clifton et al., 2013). A health monitoring system provides results through detection devices and can thus help prevent the onset of severe health conditions. This system uses context awareness, which is defined as the ability to determine the current situation and to react smoothly and proactively (Preuveneers et al., 2013).

Telemedicine is introduced because of the need to reduce costs. Spending in the healthcare sector consumes the wealth of developed countries. Mobile healthcare not only helps manage diseases but also provides an inexpensive way of addressing issues related to positive symptoms. Approximately 60 telemedicine projects are in progress in the United Kingdom Health Service (Clifton et al., 2012). Although small in scale, these projects have shown positive results. The lack of trained healthcare specialists in developing countries is also a factor that emphasizes the need for mobile health (m-health) as an alternative solution.

The use of smartphones nowadays has increased the interest in conducting research on telemedicine systems. The latest estimates indicate that up to 90% of the world's population uses mobile phones, and the number of mobile phone users is approaching the global human population (Clifton et al., 2013). Smartphone applications (apps) have features that are suitable for various systems, thus making smartphones suitable devices for m-health apps. The m-health applications have great potential in the public healthcare and health education sector as they can be developed using mobile devices as a platform (Liu et al., 2011).

As commonly used health monitoring systems are Internet-based, the use of smartphones signifies an important technology development. Health monitoring apps can be downloaded for free and are seen as low-cost systems. Mobile phones are now used with integrated health tracking devices that can interact with an external detection device (Cho et al., 2009). Moreover, smartphones are now utilized as microphones, cameras, GPS devices, and accelerometers to provide information about patient health (Celi et al., 2009).

Methodology

This section presents the basic ideas, brief description, software and hardware design of the proposed system. The scope of this health monitoring system covers medical sensing devices and wireless communication systems. The biomedical sensors, e-health board, Arduino UNO microcontroller, RN-XV Wifly module, and smartphone (Figure 1) are the important devices used in this study.

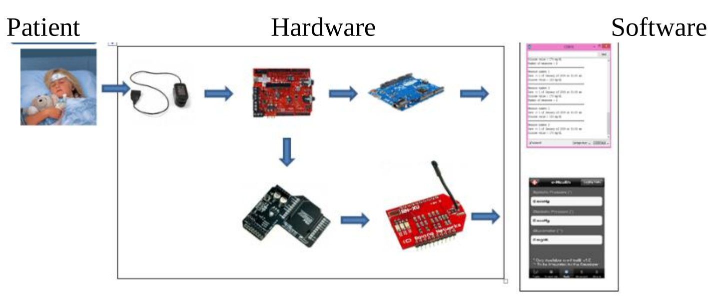

Figure 1 Proposed system architecture

A. Hardware System

The biomedical sensors (Figure 2) included in this study are i) a glucometer sensor to measure glucose in the blood, ii) a digital BP sensor to monitor the circulatory system, iii) a pulse oxymeter sensor to measure oxygen in the blood, iv) an electromyography (EMG) sensor to measure muscle activity, and v) a temperature sensor to measure body temperature.

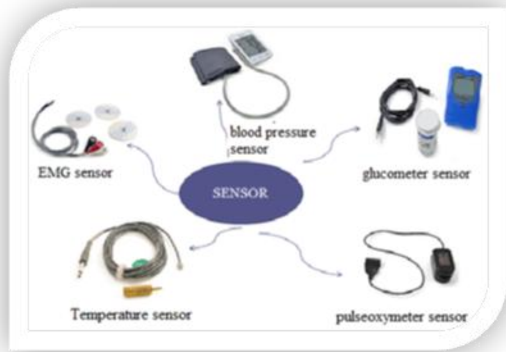

Figure 2 Biomedical sensors

The Arduino UNO microcontroller serves as the brain of the system to facilitate programming. It is a microcontroller board based on ATMega328 that comprises 14 digital pin entries (input) 6 analog production entries (output), a 16 MHz ceramic resonator, USB connection, power jack, ICSP header, and reset button. The board is equipped with the features needed to support the microcontroller by connecting it to a computer using a USB cable.

A communication device and protocol are required to transfer the vital signs data to a smartphone. The RN-XV Wifly is used as a Wi-Fi antenna to transmit the data from the Arduino software to the smartphone. The device is also loaded with firmware that can facilitate integration and decrease application development time. The RN-XV Wifly module enables wireless data transmission to the smartphone and complements the wireless health monitoring system.

B. Software System

The software used for this system are Arduino and Tera Term. Arduino is used to program Arduino UNO for the acquisition of data from biomedical sensors. It is also used to process and transmit the data to a smartphone. Aside from Arduino, Android and iOS are also used as platforms for viewing all the vital signs data.

Tera term is used to configure the RN-XV Wifly. The Tera term connection properties are shown in Figure 3. An XBee USB adapter is connected to the RN-XV Wifly to create a serial connection during the configuration. The Android and iOS configurations are set independently. The configurations of both operating systems are shown in Figures 4 and 5. The RN-XV Wifly configuration is built differently because Android smartphones and iPhones have different wireless systems. Android automatically connects to the RN-XV Wifly, whereas the iPhone can only connect manually (Figure 6).

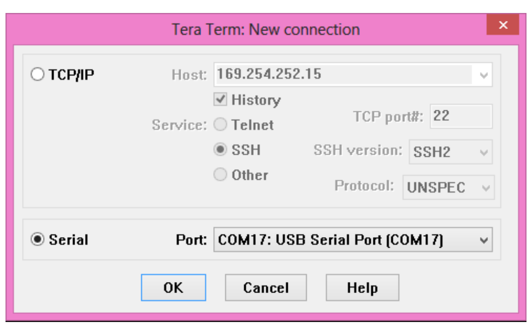

Figure 3 Tera term connection

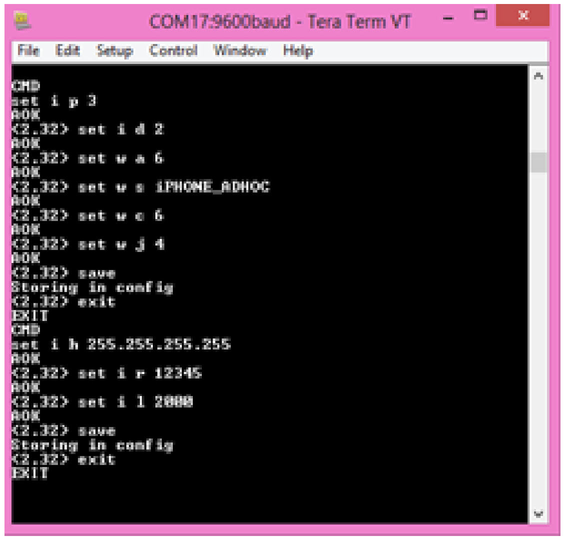

Figure 4 RN-XV Wifly configuration for iPhone

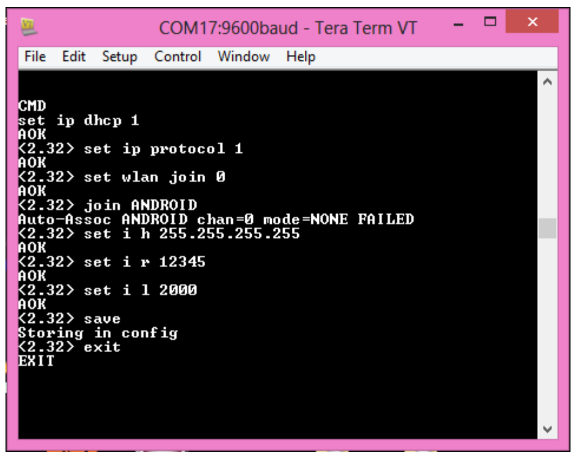

Figure 5 RN-XV Wifly configuration for Android

Figure 6 Signal from RN-XV Wifly in iOS

Results and Discussion

Results are obtained using Arduino and a smartphone. The result of the glucometer sensor is shown in Figure 7, whereas the blood pressure data are shown in Figure 8. Both data include the date and time to help the doctor in monitoring the patients.

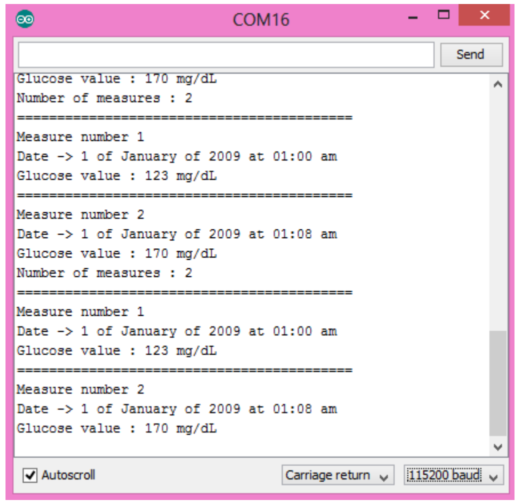

Figure 7 Glucometer data

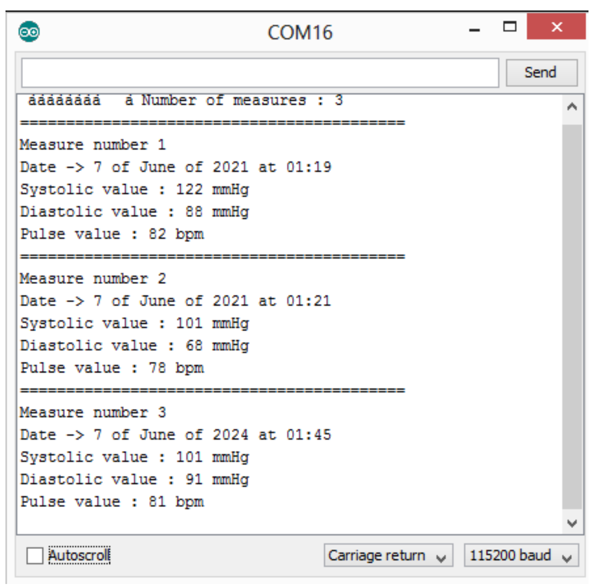

Figure 8 Blood pressure data

The result of the pulse oxymeter sensor, the EMG data, and the temperature data are shown in Figures 9, 10, and 11, respectively.

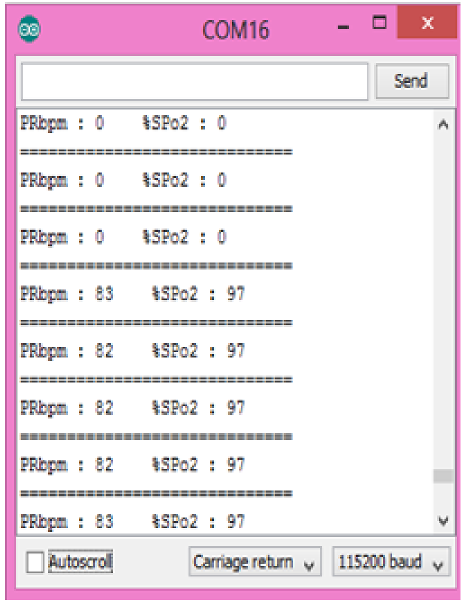

Figure 9 Pulse oxymeter data

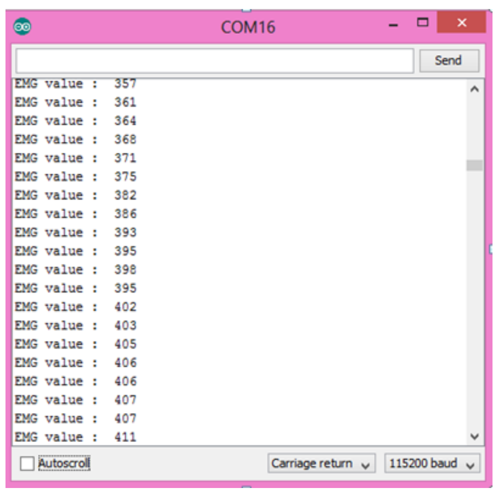

Figure 10 EMG data

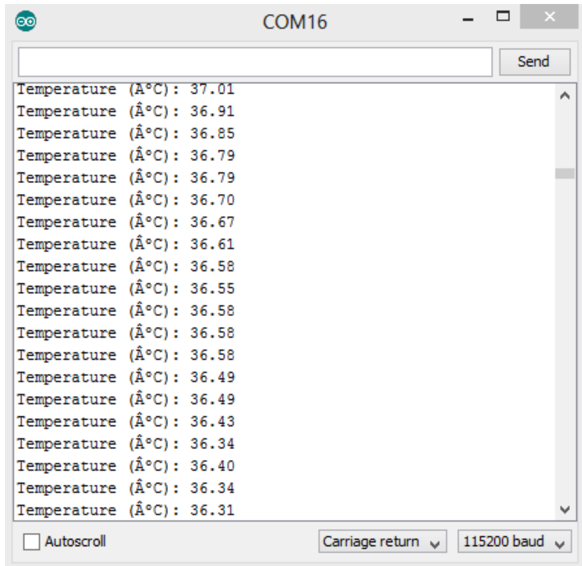

Figure 11 Temperature data

The data are successfully transmitted to the smartphone app using the RN-XV Wifly (Figures 12 and 13). Figure 12 shows the data obtained using an Android app, whereas Figure 13 shows the data obtained using an iOS app.

Figure 12 Vital signs data in an Android smartphone

Figure 13 Vital signs data in an iPhone

Conclusions

This study designs and proposes hardware and software that are capable of continuously monitoring vital signs in real time. The results of this work suggest that a low-cost RN-XV Wifly is important in the data communication between microcontrollers and smartphones. Besides its low cost, the RN-XV Wifly module features the high networking capacity, stability, and security of a wireless communication network. A successful interaction among the Arduino UNO microcontroller, the e-health board, the biomedical sensors, and the RN-XV Wifly was achieved. The prototype has been tested with human users, and excellent results have been obtained. The system app can be downloaded from both Google Play and the iTunes App Store. The system can be further enhanced by adding a cloud database to store the acquired data. The proposed system can provide economic benefits, such as lower health costs and increased efficiencies. However, many trials must be conducted to prove the telemedicine efficiency of the system. This need arises because of the fact that successful vital signs monitoring using wireless technology depends on several factors, such as human intermediaries who control and use the data, human factors, and data transmission.

Acknowledgment

This work is supported by Universiti Kebangsaan Malaysia ETP-2013-078 research grant.

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