A Heart Rate Monitoring Application Using Wireless Sensor Network System Based on Bluetooth With Matlab GUI

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Abstract:
Wireless sensor networks (WSNs) are growing into a widespread technology due to the improvement of low-power and low-cost wireless technology. There are a wide variety of applications, ranging from personal healthcare to military applications and environmental monitoring, for WSNs. Bluetooth, ZigBee, HomeRF, IrDA and other multifarious wireless technologies could be used for communication between sensors. WSN architecture supports diversified network topologies like star, mesh and hybrid star-mesh network. In this work, a heart rate monitoring system is designed with using Bluetooth based WSN. Pulse-Oximeter(SPO2) data, which is received from the patients, forwarded wirelessly through Arduino to the personal computer (PC) using HC-05 Bluetooth module also processed on PC. Graphical User Interface (GUI) is designed using with MATLAB program to use this design without programming knowledge which also able to observe the measurements of the pulse of the heart rate, simultaneously.

Keywords: Wireless sensor network (WSN), Bluetooth, Pulse-oximeter (SPO2), Arduino, Matlab gui

I. Introduction
In today’s world Wireless Sensor Network (WSN) technology is very important subject that is worked on quite a number. WSN technology has lots of extensive usage area such as military, healthcare, industrial and many more. Information can transferred one place to another or stored in the memory via WSN’s and therefore, they become popular in the sense of its reliability, righteousness, low cost and energy efficiency. There are several technologies under the topic of Wireless Sensor Network such as Bluetooth (IEEE802.15.1), ZigBee (IEEE802.15.4), HomeRF, IrDA and Wireless Body Area Network, WBAN (IEEE802.15.6). Bluetooth is a wireless personal area network standard which is developed to provide short distance application of transferring data. Generally, it supports the data transmission in range of 10 meter long and in 2.4 GHz frequency range. Bluetooth has extensive usage area such as home, vehicles, small office and many others. There are many applications which uses bluetooth for data transferring. For example, Setton, Guigner and Labidi studied about Bluetooth sensors for wireless home and hospital healthcare monitoring [1]. In this study, adaptable and modular low power platform was improved for health and life-style monitoring. The bluetooth enabled sensors was used by way of network based services in hospitals or at home. MSP430 microcontroller manages low power, signal processing, data storage, LCD display and wireless communication which was used for discrete measurement of blood pressure or continuous monitoring of health conditions of the patients for instance ECG and pulse oximeter. Data was transferred through the Internet using TCP IP or UDP protocols, and exhibited as web services. Lastly, the construction of real time continuous vital signs monitoring is applied to cardiovascular disease in a hospital and for home rehabilitation were presented. In another application, Dayoğlu designed a bluetooth based wireless communication system prototype to be capable of measuring around greenhouse [2]. The system was comprising of a host computer, serial port adapter and two wireless communication units. Designed system was programmed to control wireless units, data transferring and recording to host computer, and real-time monitoring with respect to instruction sent from host computer placed outside greenhouse. In experimental studies, air and soil temperatures and relative humidity data was measured at the top and bottom of crops and numerical datas scrutinized. Another Wireless Sensor Network technology is ZigBee which is also known as Low-Rate Wireless Personal Area Network (LR-WPAN) is preferred because of the abilities which are low power consumption, cost efficiency, easy installation incase of small size data transmission needed. ZigBee used technologies are choosen in the applications due to reliability, supporting supernumerary nodes, fast and easy setting, long battery life, security, etc. There are various applications using with ZigBee. For example, Singh and Sing used wireless sensor network technology to monitor Heartbeat of human in real time [3]. Zigbee was used at 2.4 GHz as RF transmitter and receiver using RF communication protocols. Heartbeat sensor node detected and transmitted the changes in the human heartbeat to send the computing unit which is stored data and drewed the datas simultaneously. In the other application, Obaid at al. (2014) used ZigBee technology and its application in wireless home automation systems [4]. In this study, the main purpose was automatically control and monitor the household electrical appliances. Similar to this study, Hou et al. (2008) studied about Intelligent Home Security [5]. In this research, real time observation of the home security systems was involved based on several sensors, the Zigbee and GSM network. The experimental result displayed in the system which has remote observations ability to guarantee home safety with high availability and reliability. HomeRF is wireless access standard technology depending on Wireless Local Area...
Network (WLAN) that is used at home and small workplaces in 2.4 GHz frequency range and in 50 meter long. Lastly, IrDA is a wireless communication technology which works in infrared frequencies via directional light beam. IrDa is a suitable technology for the short distance and in medium which the line of sight between the receiver and transmitter. Infrared technology is generally used for the communication and control of telecontrol equipments. There are some studies on these issues, such as [6] and [7]. In this study, a heart rate monitoring application using wireless sensor network system based on Bluetooth and the designed graphical user interface are explained. The rest of this paper is organized as follows. Section 2 provides an architecture of system and the used components defined. Section 3 describes the reading datas from pulse oximeter with MATLAB program. Finally, Section 4 concludes the paper.

II. System Architecture

Architecture of wireless sensor network systems consists 5 parts simply, as shown in Figure 1. These parts are wireless communication standard, wireless module, sensor, microcontroller and graphical user interface (GUI). Wireless communication standard is used to between wireless modules and base stations. Software runs over wireless module that reads the received signal from sensor and sends to the base station during this process. Measurement results are observed with GUI.

Fig. 1. System architecture of the heath pulse measurement

1.1. Wireless Communication Standard (IEEE 802.15.1&2 / Bluetooth)

Bluetooth is a wireless personal area network standard that has more power than IEEE 802.11x standard. It is developed to provide short distance application of transferring data, for example, between PCs and mobile phones. It supports communication between 7 nodes and a base station with star topology, as shown in Figure 2. Star topology is a network connection type that provides receiving and sending data to several nodes from base station. In this topology nodes can transfer data only to base station. Nodes cannot transfer the data between each other. The advantage of this topology is power consumption which can keep under control for each node.

Fig. 2. Star topology.

III. Wireless Module (HC-05 Bluetooth Module)

HC-05 Bluetooth module (as shown below figure) is a compatible device with Arduino, as shown in Figure 3. It is an easy to use Bluetooth serial port protocol module, designed for wireless serial connection setup. Serial port Bluetooth module is capable of 3Mbps Modulation with 2.4GHz radio transceiver and uses CMOS (Complementary Metal Oxide Semiconductor) technology and with AFH (Adaptive Frequency Hopping Feature).

Fig. 3. HC-05 module.

Technical specifications of HC-05 Bluetooth module are split in half as hardware features and software features. As a hardware features, it is capable of 5V Input/Output operation, up to +4dBm RF transmit power, PIO (Pin Input and Output) control and UART (Universal Asynchronous Receiver and Transmitter) communication protocol with programmable baud rate. As a software features, configuration parameters of HC-05 Bluetooth module are 9600 baud rate, 8 data bits, 1 stop bit and no parity. PIO8 and PIO9 can be connected to blue and red led separately. When master and slave are paired, red and blue led blinks ½ time/s in interval, while disconnected only blue led blinks at ½ time/s. It permits pairing device to connect as default. Auto-pairing PINCODE is “1234” as default. There is a special command series as named “AT” in Arduino software to change internal setting of HC-05 Bluetooth module which are baudrate, name of the device and pin modes. The following algorithm is loaded to Arduino. Afterwards, Arduino communicates with HC-05 device with Rx and Tx pins successfully.
Algorithm 1:
1- SETUP
2- Open Serial Communication
3- Set Baudrate to 9600
4- Get the Analog data
5- END SETUP
6- OPEN MAIN LOOP
7- Declare an integer variable called sumval
8- Declare an integer variable called i
9- Declare an integer variable called maxsize
10- Set maxsize to 5 for counter loop
11- Set sumval to 0 as a first value
12- FOR i=1 to maxsize LOOP
13- Add sumval to sumval+ Analogdata/maxsize
14- END LOOP
15- Add sumval to sumval times 0.26
16- Add sumval to 3 for calibration process
17- Print sumval
18- END MAIN LOOP

Thus HC-05 module is programmed and configuration is done. Pin connections between Arduino and HC-05 module is shown below figure (Figure 4).

![Arduino Uno](image)

**Fig. 4. HC-05 module and Arduino pin connection [8].**

**Microcontroller Unit (Arduino UNO)**

Arduino is an open source production platform that is enable to design circuits easily. Programming language of Arduino is similar to C. There are several types of Arduino board exists which can be choosen to the requirements of the project and also plenty of modules are available to extend the usage. One of the Arduino board is Arduino Uno, which has Atmega 328 microcontroller and contains both analog and digital input/output pins, as shown in Figure 5. Implementation of the circuit is moded with using these pins and microcontroller is programmed via computer. After that, reading and writing analog and digital data is possible. There are several types of Arduino board exists which can be choosen based on the requirements of the projects and also plenty of modules exists to extend the usage of Arduino.

![Arduino Uno](image)

**Fig. 5. Arduino Uno.**

Arduino Uno is used for communication between sensor and Bluetooth module. Received analog signal is converted to the digital signal. For this purpose, analog to digital converter unit is used. The Atmega controllers used on the Arduino board contain an onboard 6 channel analog-to-digital (A/D) converter. The Arduino board contains a 6 channel, 10-bit analog to digital converter. This states that it will map input voltages between 0 and 5 volts into integer values which are between 0 and 1023. This yields a resolution between readings of 5 volts /1024 units or, .0049 volts (4.9 mV) per unit. In this study, A0 pin is used for taking analog data from the analog output of the sensor to Arduino. 5V and GND pins are used also to energize the sensor. Rx and TX pins are used for providing the serial communication between HC-05. In the light of these informations, code is written for converting the analog sensor value coming from pulse oximeter to digital signal. Then the digital value is made sense according to actual pulse value that is read from sensor, and displayed on LCD screen. Theoretically; 5 volts is divided into 1024 integer. Received sensor values are averaged. It is observed “370” as an analog value on the serial monitor for equaled to “98” as an actual sensor pulse value on the LCD screen of the sensor. Thus, averaged value must be multiply with 0.26 because of the below equation 1. Then 3 offset is added to complete the calibration.

\[
\text{Pulse Value} = \frac{98}{370} = 0.26(1)
\]

**IV. Sensor**

In this work, it is used an available designed circuit that is capable of measuring the pulse data from patient using with finger clip. It consist a microcontroller that is programmed with PIC and gives an analog data as an output between 0- 5V range according to pulse rates. Pulse sensor and Bluetooth module, HC-05, are connected as shown in figure 6 below. Pulse datas are received from the sensor and transferred to the Bluetooth module which communicates with Bluetooth of PC and the device received datas are observed via designed GUI.
2. Reading Data from Pulse Oximeter with MATLAB Program

MATLAB, which is numerical computation software and capable of solving engineering and scientific problems. Due to easy of use, MATLAB program is preferred for presenting data which is used in this study for measurement and visualization. In addition, programs which are written with MATLAB, can be used in different programming languages converting with MATLAB Compiler, such as C or C++ language. So, a single line of MATLAB code can run faster than other programming language code. GUIDE (Graphical User Interface Development Environment) which is a toolbox in MATLAB allows to design graphical user interface in an easy way. It consist of many tools for common controls which also allows to use of icons or other visual indicators, such as list box, push button and pop-up menu and so on. MATLAB’s benefits to medical experimentation can be farther raised via use of GUI which supplies an effective interface between the user and the programming language. A well-designed GUI is an influent tool for arrangement and inspection whole way of running a medical experiment, containing design, data acquisition and analysis [9].

2.1. Designed Interface

User interface window is developed, based on MATLAB GUI. This design has an entrance window which has initial information about versions of its interface, which is also shown in Figure 7.

When “Cont’d” button is clicked, login screen will be open. Login screen allows to user entrance to the measurement window, if the required informations are entered by user, as shown in figure 8.

In part 1 of the figure 8, when language change button which is clicked, Turkish version of same page will be shown up alternatively. In part 2, time information is shown instantaneously. When the user name, password and security code are entered correctly in to the text boxes 3, 4, 5 respectively, heart rate monitoring window is opened by clicking on the “ENTER” button in part 6. Otherwise, any of these is false, a warning screen will be shown up.

Heart rate monitoring window consists of 6 main parts as shown in figure 9. In part 1, serial port number is chosen based on the connected serial port of the computer and duration time is entered by the user. In part 2, properties of the graphic can be determined by the user which are color type, linestyle and line width. After all parameters and chooses are entered by user, tracking/reporting are performed by clicking the “Start Reading Sensor Data” button. When clicked to “Start Reading Sensor Data” button, pulse rate result is coming to part 3 simultaneously. Every second, user may be able to observe average value of the pulse oximeter and after the measurements is finished the average value is shown in part 3, also graphical representation of the measurements is drawn in part 4, at the same time. In part 5, BPM levels the controlled with LED panel according to bpm values, in which is separated into interval. Cardiac dysrhythmia, also known as irregular heartbeat, is a group of situations in which the heartbeat is irregular, faster or slower than normal range of the heartbeat. A heart rate that is
too fast (above 100 beats per minute in adults) is called tachycardia and a heart rate that is too slow (below 60 beats per minute) is called bradycardia [10]. In part 6, there are some options which can be used after measurements are obtained. If “Save Data” button is clicked, a new window will be opened to save the measurements of the heart beat, average of the heart beat, measurement time, date and information about the patient is saved in a text file. After a name can be given to that data and saved to the chosen location in the memory. When clicked to “Close Serial” button, port is closed serial communication with defined variable and then restart the communication again. If ‘Send EMAIL’ button is clicked, a new blank e-mail window will be opened and an email can be send with an attachment file. When clicked to “Save Graph” button, graphics of the measured heart beat is saved with capturing frame of the Axesfigure and then storing it. After that, it is able to convert the frame to an rgb (red-green-blue) image data matrix and write the image to specified place. In addition, ‘Hold’ button pause and “PRINT” button take a print out of graphic. “CLEAR” button resets the all measurement datas and chosen buttons. When all operations are finished, the interface can be closed by clicking the “EXIT” button.

V. Conclusion

Wireless sensor networks are an attractive research surveying area with various probable applications which are healthcare monitoring, area monitoring and environmental monitoring. In view of advantages and usage, wireless sensor networks are considerably used in academic studies as well. In this study, a wireless sensor network system based on Bluetooth with MATLAB GUI for heart rate monitoring of patients was designed for real time measurements of the heart rate. Pulse oximeter data is taken from person after that data is transferred wirelessly by way of Arduino to the PC. Bluetooth is an appropriate choice for data transmission in sensor networks. There are many advantages of using Bluetooth like low-power consumption, low-cost, flexibility, hardware usability and more. Nevertheless short-range (max. 10m) data transmission supporting and easy breaking connection is some of the deficiencies of bluetooth. Therefore, this article is a good example for further research and inspire interest new developments in this field and also decreases the workload of healthcare personal.

VI. References


