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Testing Properties of E-health System Based on Arduino

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Abstract This paper deals with health functions-monitoring system for observing patient´s physical characteristics. These physical characteristics of patients are followed by sensors and the output information is broadcasted via Zigbee to PC for further processing. The tested e-health system is based on Arduino e-health kitwith Zigbee for transmitting information and a PC with Arduino and Zigbee for receiving data. Bluetooth is a well-known conventional wireless data transfer protocol, but it´s not much encouraged for long duration applications because of power consumption limitations, so Zigbee offers a better solution for such cases. Basic tasks of the system are to measure main health functions as heart rate, body temperature and body position. The tested system enables quick access to parameters of monitored biosignals, therefore identification of health risks and intervention can be provided in real time [1].

Keywords: *E-health system, Arduino, Zigbee*

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1. Introduction

The current monitoring systems used for ambient intelligence applications in home or social facilities have to be solved as mobile wireless devices in opposite to wired hospital solutions [1].

Even though the correctly connected and applied sensors the basic monitoring system requires paramedical assistant or a qualified person to continuously monitor and note down all the information manually. This kind of solution may lead to mistakes in diagnostics and analyzing or even to disaster because of human error. Our experimental system allows creating a wireless sensor network, and provides a good base for further experiments and development. Creating this kind of system allows monitoring vital functions using personal networks at patient´s homes. Applying Zigbee protocol to sensor system creates wireless sensor network suitable for transmission of data and also it allows further data treatment, visualization, and warnings. The power consumption of Zigbee is very low, and the sizes of the sensor nodes are small, therefore it is one of the best options for wireless connection. To develop and improve data collecting and data analyzing processes of above mentioned problems an e-health monitoring system based on Arduino is designed. This paper describes a laboratory sensor system that collects and transfers information about vital characteristics of patients.

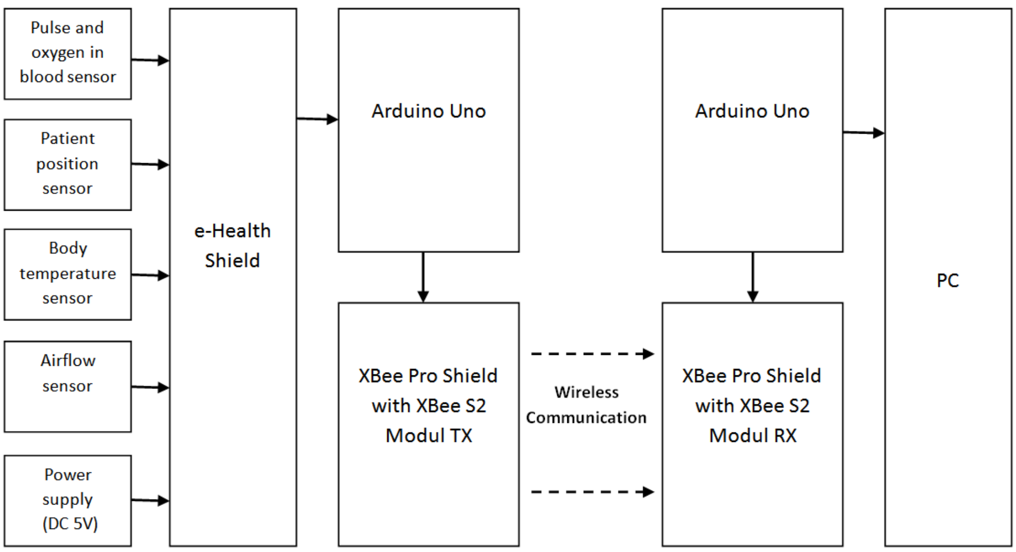

Figure 1. System architecture

2. Hardware and Software Description

Figure 1 displays the block diagram of realised hard ware solution. The system is created with an open-source platform, Arduino. The logic operations in Arduino Uno are executed by computing unit, which is an Atmel Atmega processor. The biggest benefit of this platform is that there is no fixed architecture and defined communication, the individual parts can be connected and divided freely. The devices can work either independently or with superior server. The main idea is to form a system to measure and check biosignals of human body such as heart rate, temperature, respiration and body position. The collected information is processed and sent via Zigbee protocol to a receiver computer. The receiving computer is connected to a second Zigbee module via USB wire. [2,3]

The data can be processed or transferred to a responsible person or web database for long term tracking. If the measured values hit extreme rates an alarm signal may be generated.

The Arduino Software for programming and X-CTU for configuring communication are used. More software details are in the following chapters. [2]

2.1. Pulse and Oxygen in Blood Sensor (SPO2)

Pulse oximetry is used for monitoring of oxygen saturation in blood.It is a non-invasive method based on measuring wavelengths of light waves sent through a thinner body part for example a fingertip or earlobe (Figure 2). The main components of this sensor are an electronic processor and a pair of light emitting diodes (LEDs) and a photodiode, in our case expanded by a display. A photodetector receives light which was not absorbed by the body part. Absorption of light is different forlow and high concentrationsof blood with oxygen (Figure 3) [4].

Figure 2. Pulse and oxygen in blood sensor with e-health shield

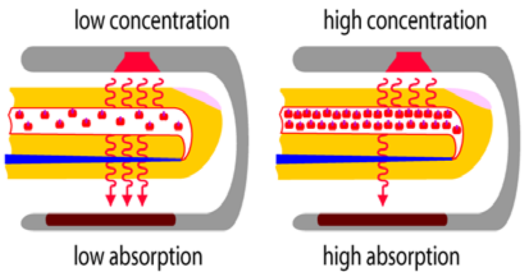

Figure 3. Light absorption

2.2. Temperature Sensor

Sensing of the body temperature is very important in medicine. The reason is that quite many diseases are followed by temperature change.

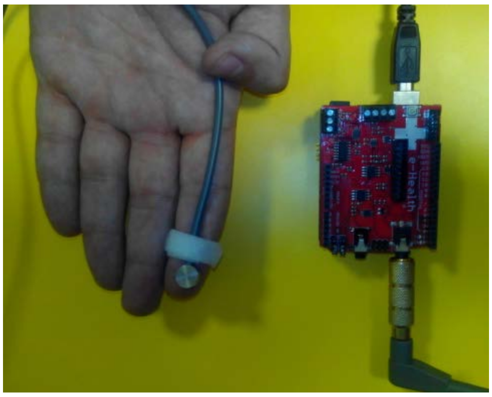

Figure 4. Temperature sensorwith e-health shield

In the same way, monitoring of illness and effects of treatment can be measured using temperature changes (Figure 5). [5]

The measured temperatures can be evaluated and warnings for medical staff can be generated in form of message or light indication. Physiological and pathological limits of temperature are shown in Table 1

Table 1. Illnesses caused by body temperature change

Hypothermy	< 35.0 °C
Normal temperature	36.5 – 37.5 °C
Hyperthermy	> 37.5 – 38.3 °C
Hyperpyrexy	> 40.0 – 41.5 °C

2.3. Body Position Sensor

This sensor uses a triaxial accelerometer which is integrated into a band. The Figure 5 shows the body position sensor and the connection to e-health shield of Arduino. This band has to be fasten on the chest of a patient.

The monitored positions are: standing/sitting. lying on chest, lying on back, lying on left side and lying on right side. In many cases it´s important to monitor body movement and position, because they can indicate health problems, for example persons with sleeping problems and during recoveries after accidents. [6]

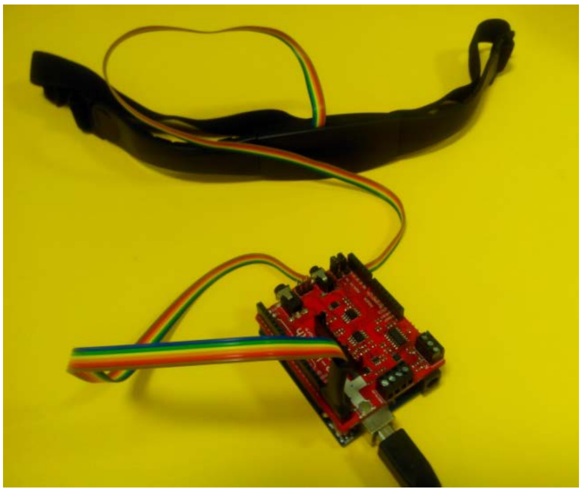

Figure 5. Body position sensor and e-health shield

2.4. Airflow Sensor

The nasal airflow sensor is used to monitor breathing of patients. The measured data can be processed or used as alarm signals in emergency cases. The airflow sensor is shown on Figure 6. [7]

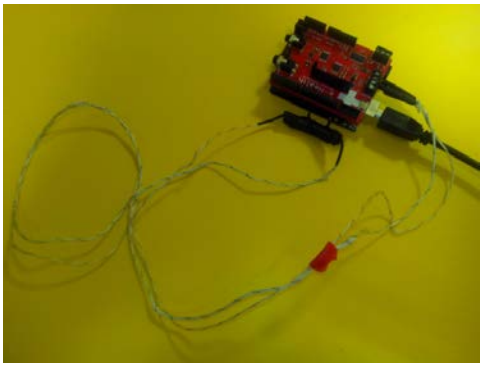

Figure 6. Nasal airflow sensor and e-health shield

2.5. Software

For programming of e-health sensor system the official Arduino Software was used. Part of the program and source code is shown below on the Figure 7.

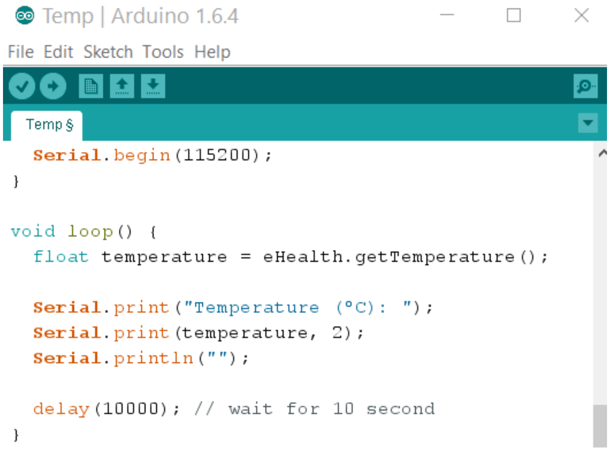

Figure 7. Arduino software

This programming language is based on programming language Wiring, where is no need for using the complicated Assembler. This programming platform was created in Java. The flowchart of the process is shown on Figure 8.

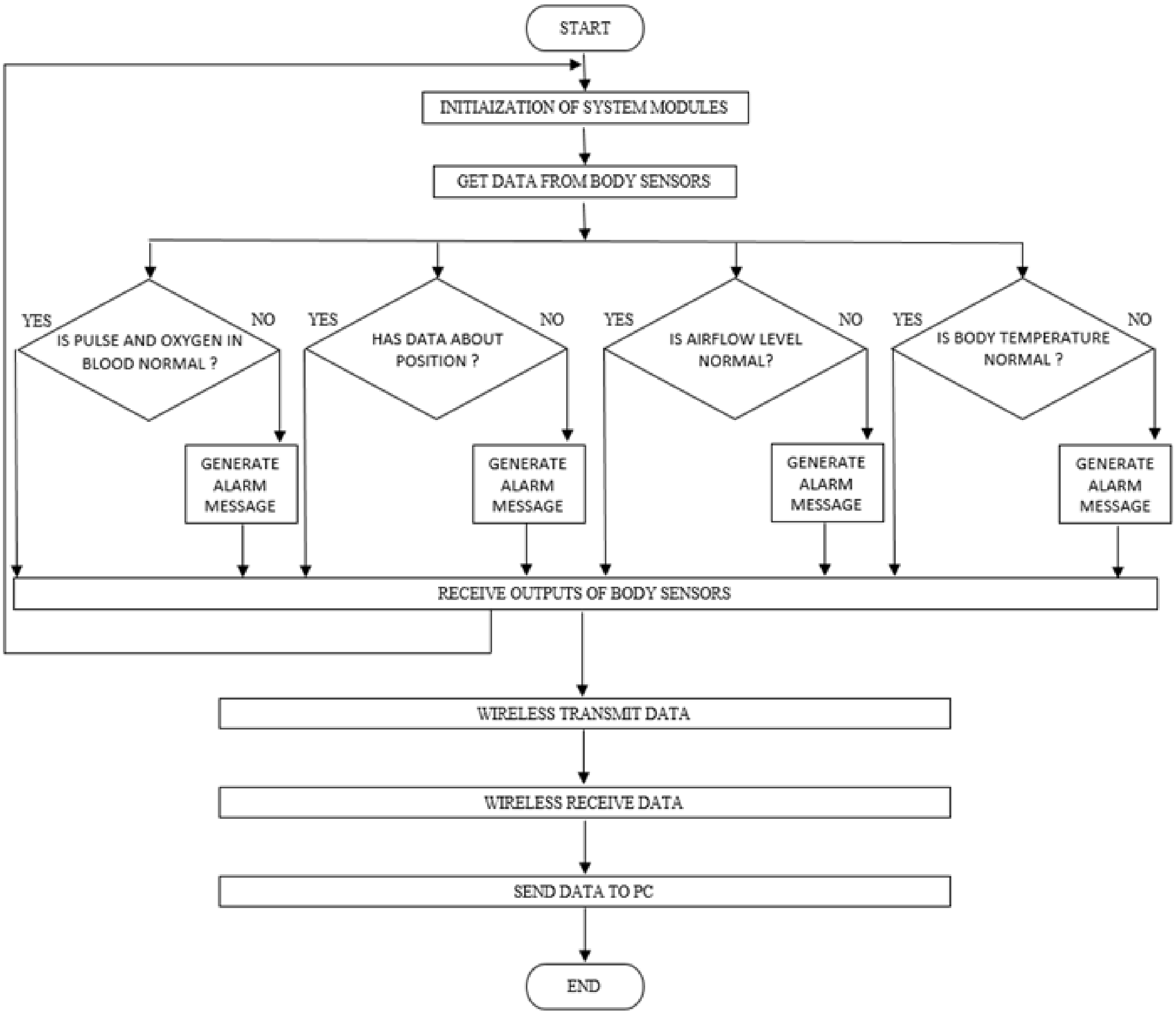

Figure 8. Flowchart of the process

After connecting the main Arduino to a power unit, the program is running continuously in a loop. It begins with initialization of connected modules. This is followed by collecting information from sensors. If the sensors are connected and work correctly, the data are sent by Zigbee to a receiver Zigbee node of another Arduino, which is connected to a PC. After data collecting, they can be processed or stored for longer monitoring. The software can be configured for extreme values or states of measured data and this can be used for generating further alarms and warnings.

3. Communication

The individual parts of e-health system are connected simply trough attributable pins. The communication between the sensors/transfer part and the receiver part is solved by Zigbee protocol. In this case we used Xbee nodes connected to Xbee Pro Shield which can be configured to use this protocol, see Figure 9. The X-CTU software was used for configuring the nodes (Figure 10). The selected characteristics are shown in Table 2. [3]

Table 2. Configured parameters

Baud rate	9600
Flow control	HARDWARE
Data Bits	8
Parity	NONE
Stop Bits	1

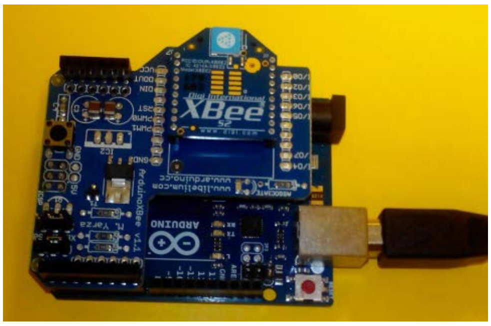

Figure 9. Xbee node and Xbee Pro Shield

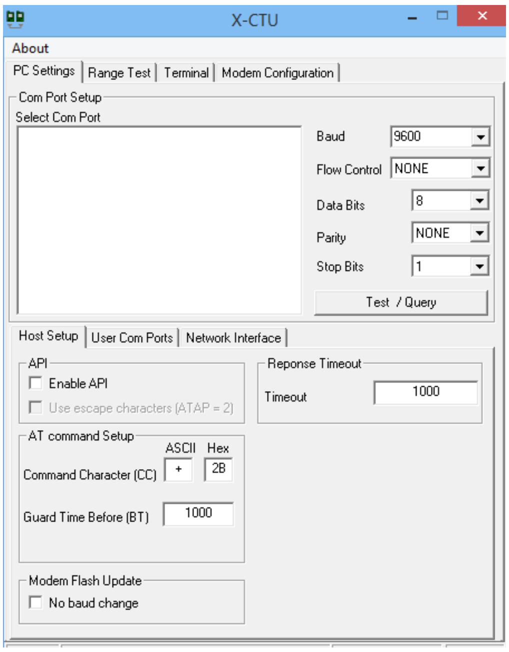

Figure 10. X-CTU software

4. Testing of Properties

We tested system functionalities (Figure 11) by the comparation of measured temperature from the body warn sensor and from the standard manual digital thermometer. Actual body position was measured with body sensor, and the displayed data was compared with real position checked visually by the operator.

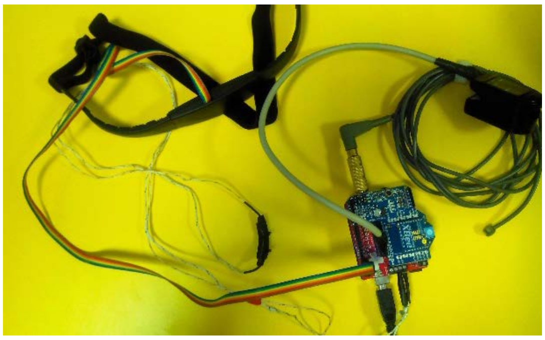

Figure 11. E-health system with sensors and Xbee module

For analyzing and evaluating the received data from sensors we provided 50 measurements of temperature and body position. The testing conditions during the measuring were constant:

- Temperature T= 21 °C
- Atmospheric pressure P_a= 101,325k Pa.

The Table 3 shows results from 10 measurements from sensors and their comparation with reference devices.

Table 3. Measured values of temperature and body positions

No.	Temp.Sensor[°C]	Therm. [° C]	Real Body Position	Body Pos. Sensor
1.	35,76	36,0	Standing	Fowler´s
2.	35,82	36,0	Standing	Fowler´s
3.	35,88	36,0	Standing	Fowler´s
4.	35,78	36,0	Supine	Supine
5.	35,8	36,0	Supine	Supine
6.	35,92	36,0	Sitting	Fowler´s
7.	36,12	36,0	Sitting	Fowler´s
8.	35,95	36,2	LLR *	LLR
9.	35,85	36,2	LLR	LLR
10.	36	36,2	LLR	LLR

*LLR- Left Lateral Recumbent

The graph on Figure 12 shows difference between received data from e-health system and from digital thermometer.

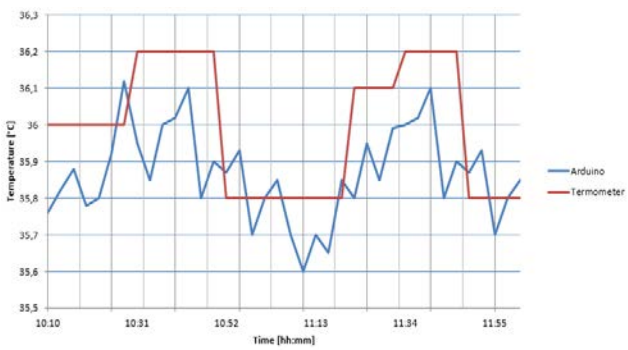

Figure 12. Measured temperatures

Average measured temperatures, the average temperature difference and faulty body positions are shown in Table 4.

Table 4. Average results of measurement

Avg. temp. sensor [°C]	35,87
Avg. thermometer [°C]	35,99
Avg. difference	0,13
Total Body position measurements/False Body position detection	50/5

5. Results

In this paper we described the laboratory system built for monitoring of physiological parameters such as pulse and oxygen in blood, body position, air flow, and body temperature. Two parameters were also tested and compared with referential devices. The system uses the Arduino control and processing unit expanded by the sensor and communication shields, e-health sensors, and Xbee node.

We will continue with further development of the system and experimental testing of data processing using web-based platforms, and reliability of wireless sensor networks.

Experiments proved that the temperature sensor works accurately for standard monitoring of body temperature. However, the body position sensor showed faulty results, which could be caused by non exact positions of the subject during experiments. Some disadvantage of body position sensor was observed, it couldn´t recognize difference between standing and sitting position. We plan to solve that problem by adding another sensor to the system, which can help to recognize the real body position.

Acknowledgement

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