

SENSOR-BASED PLATFORM E-HEALTH CONNECTION WITH MATLAB

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Abstract

Arduino is an open-source platform, which consists of development boards with microcontrollers ATMEL and development environment Arduino IDE. For Arduino boards there are several extensions in the form of shields. One such shield is the extension for biometrics and medical applications e-Health. This article discusses the sensor e-Health platform connection with MATLAB programming environment.

1 Introduction

e-Health is a form of modern technology in medicine [1,2]. Medicine at e-Health use electronics and information technology. Popular e-Health area is information systems for storing medical records of patients. Another interesting area is telemedicine, which diagnoses and treats various diseases remotely. The modern mobile devices are used in m-Health to obtain the available patient data and provide such data to doctors or scientists. With the development of low cost electronic devices at present a platform for the biological data collection from users are formed.

Computer type SBC (single-board computer) contains all the computer components on a single board. SBC is equipped with a microprocessor, memory and some input-output interfaces. Usually it is a modular system, which is why SBC can be extended. The typical SBC representatives are low-cost platforms as Arduino, Raspberry Pi, BeagleBoard and many others [3-5]. For collecting biological data e-Health sensor platform was created. It represents extension of the Arduino and Raspberry Pi that allows measuring the biological data in the real time [6]. This article describes the e-Health Sensor Platform from the Cooking Hacks Company and its link with MATLAB programming environment.

2 e-Health Sensor Platform

In 2013 the Cooking Hacks Company has created a new version of a platform extension for Arduino and Raspberry Pi. Extension e-Health Sensor Shield V2.0 allows connecting the sensor platform on Arduino and Raspberry Pi device for users who want to measure biometric and medical variables in the real time [6]. Platform programming is easily performed using libraries written in C++. The obtained data is afterwards sent using one of the wireless technologies such as Wi-Fi, 3G, GPRS, Bluetooth, 802.15.4 and ZigBee depending on the application. Data can be sent to the Cloud server and visualized on a computer or other device. Currently platform comprises 10 non-invasive sensors, which are shown in the Fig. 1.



Figure 1: e-Health Sensor Platform [6]

2.1 Pulse and Oxygen in Blood (SPO2)

Pulse oximetry is a noninvasive method of indicating the arterial oxygen saturation of functional hemoglobin. Oxygen saturation is defined as the measurement of the amount of oxygen dissolved in blood, based on the detection of Hemoglobin and Deoxyhemoglobin. Two different light wavelengths are used to measure the actual difference in the absorption spectra of HbO₂ and Hb. The bloodstream is affected by the concentration of HbO₂ and Hb, and their absorption coefficients are measured using two wavelengths 660 nm (red light spectra) and 940 nm (infrared light spectra). Deoxygenated and oxygenated hemoglobin absorb different wavelengths. Deoxygenated hemoglobin (Hb) has a higher absorption at 660 nm and oxygenated hemoglobin (HbO₂) has a higher absorption at 940 nm. Then a photo-detector perceives the non-absorbed light from the LEDs to calculate the arterial oxygen saturation.



Figure 2: Pulse and Oxygen in Blood sensor [6]

2.2 Electrocardiogram (ECG)

The electrocardiogram (ECG or EKG) is a diagnostic tool that is routinely used to assess the electrical and muscular functions of the heart. Electrocardiogram Sensor (ECG) has grown to be one of the most commonly used medical tests in modern medicine. Its utility in the diagnosis of a myriad of cardiac pathologies ranging from myocardial ischemia and infarction to syncope and palpitations has been invaluable to clinicians for decades. The accuracy of the ECG depends on the condition being tested. A heart problem may not always show up on the ECG. Some heart conditions never produce any specific ECG changes. ECG leads are attached to the body while the patient lies flat on a bed or table.



Figure 3: Electrocardiogram [6]

2.3 Airflow: Breathing

Abnormal respiratory rates and changes in respiratory rate are a broad indicator of major physiological instability, and in many cases, respiratory rate is one of the earliest indicators of this instability. Therefore, it is critical to monitor respiratory rate as an indicator of patient status. AirFlow sensor can provide an early warning of hypoxemia and apnea. The nasal / mouth airflow sensor is a device used to measure the breathing rate in a patient in need of respiratory help or person.

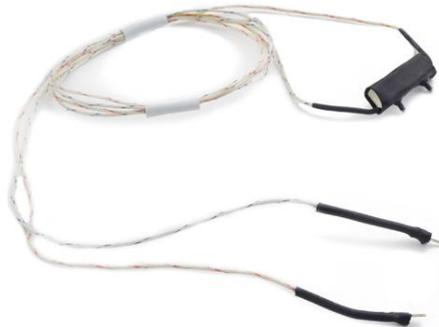


Figure 4: Airflow sensor [6]

2.4 Body Temperature

Body temperature depends upon the place in the body at which the measurement is made, and the time of day and level of activity of the person. Different parts of the body have different temperatures. The commonly accepted average core body temperature (taken internally) is 37.0°C. In healthy adults, body temperature fluctuates about 0.5°C throughout the day, with lower temperatures in the morning and higher temperatures in the late afternoon and evening, as the body's needs and activities change.



Figure 5: Temperature sensor [6]

2.5 Blood Pressure

Blood pressure is the pressure of the blood in the arteries as it is pumped around the body by the heart. When your heart beats, it contracts and pushes blood through the arteries to the rest of your body. This force creates pressure on the arteries. Blood pressure is recorded as two numbers—the systolic pressure (as the heart beats) over the diastolic pressure (as the heart relaxes between beats).



Figure 6: Blood pressure sensor [6]

2.6 Patient Position and Falls

The Patient Position Sensor (Accelerometer) monitors five different patient positions (standing/sitting, supine, prone, left and right). In many cases, it is necessary to monitor the body positions and movements made because of their relationships to particular diseases (i.e., sleep apnea and restless legs syndrome). Analyzing movements during sleep also helps in determining sleep quality and irregular sleeping patterns. The body position sensor could help also to detect fainting or falling of elderly people or persons with disabilities.



Figure 7: Patient position sensor [6]

2.7 Galvanic Skin Response (GSR)

Skin conductance, also known as galvanic skin response (GSR) is a method of measuring the electrical conductance of the skin, which varies with its moisture level. This is of interest because the sweat glands are controlled by the sympathetic nervous system, so moments of strong emotion, change the electrical resistance of the skin. Skin conductance is used as an indication of psychological or physiological arousal. The Galvanic Skin Response Sensor (GSR - Sweating) measures the electrical conductance between 2 points, and is essentially a type of ohmmeter.



Figure 8: Galvanic skin response sensor [6]

2.8 Glucometer

Glucometer 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. The meter then displays the level in mg/dl or mmol/l. Despite widely variable intervals between meals or the occasional consumption of meals with a substantial carbohydrate load, human blood glucose levels tend to remain within the normal range. However, shortly after eating, the blood glucose level may rise, in non-diabetics, temporarily up to 7.8 mmol/L (140 mg/dL) or a bit more.



Figure 9: Glucometer [6]

2.9 Electromyogram (EMG)

An electromyogram (EMG) measures the electrical activity of muscles at rest and during contraction. Electromyography (EMG) is a technique for evaluating and recording the electrical activity produced by skeletal muscles. EMG is performed using an instrument called an electromyograph, to produce a record called an electromyogram. An electromyograph detects the electrical potential generated by muscle cells when these cells are electrically or neurologically activated. The signals can be analyzed to detect medical abnormalities, activation level, recruitment order or to analyze the biomechanics of human or animal movement.



Figure 10: Electromyogram [6]

3 Arduino

Arduino is an open platform based on Atmel ATmega microcontroller and Arduino IDE the graphical development environment. This platform has gained many enthusiasts and is nowadays used in several projects. Arduino is programmed using its own programming language resembling the language C. Thanks to the strong support it exists numerous third-party libraries for easier programming. On the main Arduino board a various extended boards (Shields) can be connected. Arduino is one of the two platforms supporting the e-Health Sensor Shield V2 extension. The Arduino extension connection is shown in the Fig. 11.

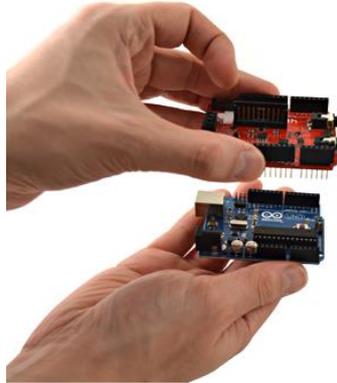


Figure 11: Platform connection [6]

Program in Arduino IDE consists of three basic parts. In the first part the library is connected to a program using the *#include* directive. In the second part device settings are programmed. This could include the serial communication settings. This section is located in the function *setup()*. The last part of the program is the function *loop()*. In the mentioned function *loop()* the main program is repeatedly performed.

4 Serial Communication

Data transmission between the devices can be serial or parallel. Nowadays, there are many types of communication buses, although a large number of them are not accepted because of their universality of the USB interface. Today's computers are usually not equipped with a serial port. Therefore the serial communication over USB is solved with a converter USB-to-serial. USB was designed to connect devices to a computer, but thanks to its versatility, it is also used for the communication between other devices. Through this bus, certain device can be also powered.

4.1 Serial Communication in MATLAB

In the MATLAB applications there is also an opportunity to communicate via a serial port. The communication is based on a serial object that can be created in the MATLAB workspace. The communication via serial line runs very similar as a work with files, but we do not open the file, but the serial object type by using the function *serial()*. The function includes a several parameters such as port, baud rate, and the terminator. Additional functions for working with a serial communication are for example, *fopen()*, *fwrite()*, *fread()*, *fclose()*, and many others.

4.2 Serial Communication in Arduino

ATmega328 enables the serial communication via UART chip with TTL (5V) voltage level, and its contacts are routed to the pins 0 (RX) and 1 (TX). To connect to a computer there is a FTDI USB-to-serial chip or ATMEGA8U2 that create a transmission over serial line and communicate with a computer via USB. The standard communication speed is 115 kbps. Part of the Arduino IDE development environment is *Serial.h* library, and it contains all necessary functions for the secure communication. In the Arduino program in the section *setup()*, the function *Serial.begin()* is usually called. This function initializes settings and initiates communication. For data entry the function *Serial.write()* is used and to read a single character the function *Serial.read()* is used. Work determination with the serial communication can be performed with the function *Serial.end()*.

5 The Application for Data Monitoring

After familiarize with the serial communication system in MATLAB, the application was created to visualize measured data. For each program tasks, several functions have been developed in MATLAB. Subsequently, graphical user interfaces were created. The principle of communication occurs in steps, and the first one is handshaking. After the communication port opening, the character 'a' from the Arduino is starting to be broadcasted. Subsequently, the character 'A' is sending from MATLAB. This indicates to the Arduino that it can perform the main loop. Subsequent communication takes place in the client-server mode. MATLAB sends the character 'R' and the sensor number from which it wants to read. By the type of sensor it will reply as a number or a complex structure.

5.1 Main Window

The entire application consists of 10 graphical user interfaces. One of them is the main window of the entire application through which we are connecting to the serial port and run all other interfaces using the corresponding buttons. Graphical interfaces are identical thanks to the variety of sensors, but most of them have common characteristics. The main window of the entire application is in the following figure.

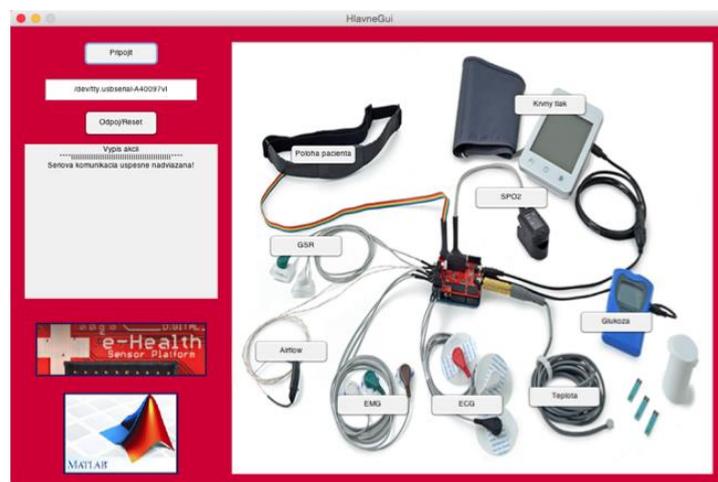


Figure 12: The main GUI

5.2 Online Data

The graphical user interface (GUI) for the online mode contains several controls. The main component of the GUI is a graph with the parameters progress. When the button *Prijat' jednu hodnotu* (Accept One Value) is pressed, values are loaded as a single-shot. Moreover, the continuous data acceptance can be selected. It loaded data from the sensor with specified sampling period. Data can be saved to a file for the further processing and afterwards they can be drawn. Controlling the chart can be performed with more options in the GUI.

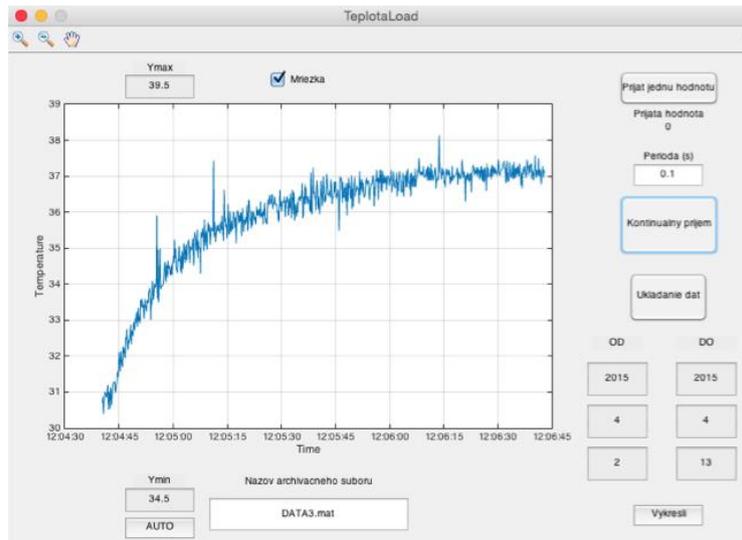


Figure 13: Online data - Temperature

5.3 Offline Data

Windows for offline sensor types (glucose, pressure) look like the online mode, but do not have keys to load the data once or continuously. Direct communication is not possible because the independent data reading used the serial communication. Data is therefore stored in Arduino EEPROM. Data can be loaded also from the archive file. The example of data display for offline mode is in following figure.

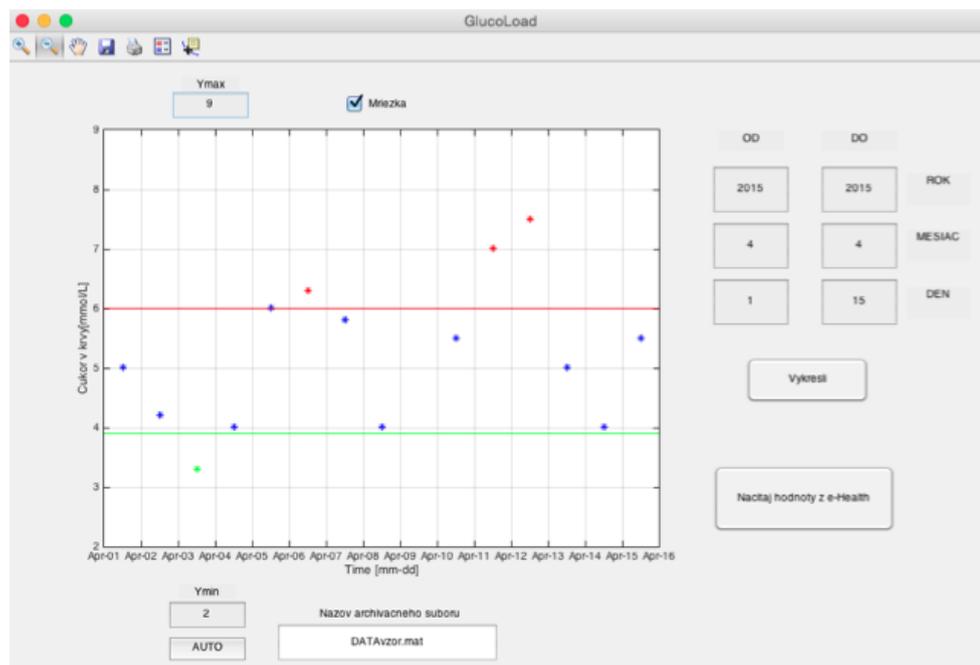


Figure 14: Offline data – Glucose

6 Conclusion

The use of information and communication technologies in medicine brings many advantages not only for patients but also for doctors. e-Health is already considered in the world as one of the strategic areas. It is expected that in the future it will be one of the routine of our lives. With the approach of low-cost hardware new opportunities were created for the development of e-Health solutions. One of them is the e-Health Sensor Platform from the Cooking Hacks Company and contains 10 non-invasive sensors. Using MATLAB programming environment, the application for displaying and storing data from sensors via serial communication was created. Archived data can be analyzed, using other available functions of MATLAB, by experienced user.

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