Wearable sensors network for health monitoring using e-Health platform

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Abstract—**In this paper we have proposed to present a wearable system for automatic recording of the main physiological parameters of the human body: body temperature, galvanic skin response, respiration rate, blood pressure, pulse, blood oxygen content, blood glucose content, electrocardiogram (ECG), electromyography(EMG), and patient position. To realize this system, we have developed a program that can read and automatically save in a file, the data from specialized sensors. The results can be later interpreted, by comparing them with known normal values and thus offering the possibility for a primary health status diagnosis by specialized personnel. The data received from the wearable sensors is taken by an interface circuit, provided with signal conditioning (filtering, amplification, etc). A microcontroller controls the data acquisition. In this applications we used an Arduino Uno standard development platform. The data are transferred to a PC, using serial communication port of Arduino platform and a communications shield. The whole process of health assessment is commissioned by a program developed by us in the Python programming language. The program provides automatic recording of the aforementioned parameters in a predetermined sequence, or only certain parameters are registered.**

I. INTRODUCTION

In our modern world, millions of people die every year due to lack of information about their health. The rising costs in the healthcare system could be reduced, if it would give more attention to disease prevention through regular assessment of health status and their treatment in the early stages. Many researchers are trying to develop technologies to improve the quality of human life. Flexible technologies that are easy to access, such as mobile phones, intelligent clothing, smart watches, head bands, shoes and belts, will be very helpful in the future in monitoring and treating disease. They could help medical personnel with more relevant information and establishing a better medication to patients. These technologies, due to their attractiveness are accepted by more and more people and medical centers expect to begin to use technology to improve their services. Today's sensors networks can provide real-time data or collect and retain data until the synchronization with other systems. Multiple sensors fusion technology is still new and developing, but could offer many benefits for healthcare applications. Sensor fusion data can provide improved measurement accuracy and at the same time provide more results in less time. By recording data on specialized Web sites, medical personnel can easily monitor their patients in real time, or even to examine the results and to compare them between certain days or hours. By comparing the results of different days on a web diagram, usually doctors can diagnose and recommend accurate medication for the patient disease. In this way the workload of medical personnel could be reduced only by offering new tools that they could use to make patients' lives easier and better.

A modern medical system that could replace some of the existent medical equipment and facilitate the work of medical personnel should include:

- fixed or portable device used for fusion of multiple sensors to provide wireless connectivity;
- be a single device that can be attached to any patient for easier use;
- stored information on a website and allow to be accessed by medical personnel;
- allow remote patient monitoring;
- measurements to be displayed in real time;
- saving data and create a database;
- allow to generate of statistics to analyze data;
- be able to detect emergencies and alerting medical personnel.

Our developed system reflected this trend, to help gather information to assess health and provide information to properly trained personnel in diagnosing patients. We can use this information, to monitor in real time the state of a patient, or to get sensitive data in order to be subsequently analyses for medical diagnosis.

II. SENSORS FOR THE MEASUREMENT OF PHYSIOLOGICAL PARAMETERS OF THE HUMAN BODY

The human body can be viewed as an electric or electromagnetic signal generator or electric generator indirectly by collecting signals using transducers. Collection and signal acquisition on the surface or inside the body is called electrography and the resulting waveform, electrogram. Basic unit of human body is the cell. Living cells in the human body meet the most varied roles. Some of these, like neurons, nerve fibers and muscle fiber receptors responding to stimulation by an action potential. The activity of a cell can be monitored in the cell membrane by ion- exchange which takes place between the cell and its exterior and the concentration of ions inside and outside the cell. Bioelectric signal source is coupled directly to the collecting electrodes, the signal picked up by the electrodes is then amplified, processed and rendered in the appropriate time evolution phenomena. Voltages and currents overlap useful signal source can cause irreversible chemical reactions or biological signal can burn tissues. In the design and construction of medical instruments we must take the first steps to limit electric currents to prevent the patient. In the measurement of biopotentials are used instrumentation amplifiers. Instrumentation amplifiers are differential amplifiers that are characterized by outstanding performance approaching that of the most of the ideal amplifier.

For galvanic isolation (chemical) between input and output amplifier are used floating amplifiers (insulating), but the signal is transferred as far as possible without distortion. Insulating property of an amplifier to separate two masses is expressed by a factor of rejection of isolation as high (100 ... 160dB). Signal transmission through the barrier of insulation is achieved by magnetic or optical coupling. Magnetic coupling is used for applications requiring linear amplification when the optical coupling in linear frequency response. As we present in abstract, our sensors network allows us to measure following physiological parameters:

a) Body temperature measurement

Direct body temperature measurement is based on the use of a transducer contact like: thermocouple, thermistor or an active semiconductor device. In our case is a thermistor based sensor. Measuring circuit is a resistive bridge dc supplied, as show in Fig.1.

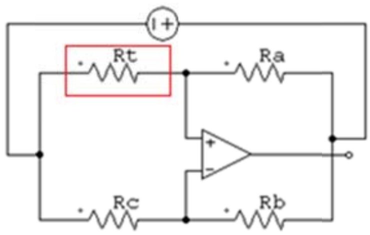

Fig.1. Measuring circuit for temperature sensor.

b) Skin resistance measurement(GSR)

Galvanic skin response (GSR) is a measure of sweat gland secretion in response to emotional stimuli (1mV, 5Hz). Skin resistance measurement is done by measuring the electric resistance between two fingers of one of the hands. This measurement can detect the emotional state of the patient.

c) Airflow measurement

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 apnea and hypoxemia. The nasal airflow sensor is a device used to measure the breathing rate in a patient in need of respiratory help or person. This device consists of a flexible thread which fits behind the ears, and a set of two prongs which are placed in the nostrils. Breathing is measured by these prongs. Monitoring respiratory rate, which's upper and lower alarm limits can be set by the user, it is very useful especially in departments of surgery and newborn. The signal produced by capacitive transducer is amplified by an amplifier, which can detect useful signal pulses coming from patient movement, coughing etc. A peak detector transforms the analog signal pulse type "breath", which is transmitted to central processing unit.

d) Blood pressure measurement

Blood pressure is 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. Blood pressure is recorded as two numbers—the systolic pressure (as the heart beats) over the diastolic pressure (as the heart relaxes between beats). Pressure transducers used in the medicine is based on: a) The direct measurement of blood pressure in the blood vessel; b)Indirect measurement by measuring a fluid or air pressure to the blood pressure. In all methods one or two cuffs are placed around an arm, usually forearm cuff which is inflated to a pressure higher than the systolic pressure and then gradually degonflate feeling the changes in blood flow. Monitoring blood pressure at home is important for many people, especially if you have high blood pressure. Blood pressure does not stay the same all the time, because it is affected by various factors including breathing, body position or emotional state. To measure blood pressure it is best when you are relaxed and sitting or lying down. In our case it is used a LUCAS NOVA sensor type, which is a bridge type sensor, to measure blood pressure.

e) Determination of blood glucose (glycemia)

Fast, precise and automatic determination of glucose is of great importance both for diabetics as well as in cases of coma with unspecified causes. Measurement and precise control of blood glucose to administer insulin in time help maintain a near normal state of activity of the patient, especially in cases of unstable diabetes. The operation principle of a device for measuring blood glucose is based on colorimetric effects that occur with colored reflection of light on a surface. Specific transducer senses the color change of a reactive band, on which a drop of blood is applying, depending on the amount of glucose present. Knowing the correlation of color-concentration, the signal from the transducer is processed and displayed directly as the concentration of glucose in the blood.
The medical device for determining the approximate concentration of glucose in the blood is called glucometer. Glucometer measures blood glucose in mg / dl or mmol / l.

f) Pulse and Oxygen in Blood (SPO2)

Pulse oximetry is a noninvasive method of indicating the arterial oxygen saturation of functional hemoglobin.
Pulse oximetry combines spectrophotometry which measures the concentration of hemoglobin (absorption of light is a

function of the degree of oxygenation of the blood) and optical plethysmography to measure pulsatile changes in arterial blood volume (pulsatile changes in light transmission through tissue are due to changes in arterial blood volume in tissues). The measurement principle is based on optical sensors, placed at the finger, ear lobe, as well as the forearm, with one of two sources of emission of red light having a wavelength of 660 nm and an infrared wavelength 950 nm as well as at least one photodetector. Infrared absorption coefficient of oxyhemoglobin is larger than the reduced hemoglobin. The sensor measures the report of light pulsating / no pulsating light at wavelengths in the red and infrared and implement the percentage of oxygen saturation. A pulse oximeter sensor is useful in any setting where a patient's oxygenation is unstable, including intensive care, operating, recovery, emergency and hospital ward settings, pilots in unpressurized aircraft, for assessment of any patient's oxygenation, and determining the effectiveness of or need for supplemental oxygen. Acceptable normal ranges for patients are from 95 to 99 percent, those with a hypoxic drive problem would expect values to be between 88 to 94 percent, values of 100 percent can indicate carbon monoxide poisoning.

g) Measurement of cardiac activity

The electrocardiogram (ECG or EKG) is a diagnostic tool that is routinely used to assess the electrical and muscular functions of the heart. Heart may be regarded as consisting of an electrical system that generates rhythmic impulses contract, a mechanical system that responds to these impulses by rhythmic contractions. Sinoatrial node of the heart acts as a local oscillator with natural frequency of oscillation of 70 beats / minute. The sinoatrial node is coupled to the body's nervous system so that the oscillation frequency can change from case to case, depending on the needs of the body. In the frontal plane are using measurements in three directions, forming an equilateral triangle, called Einthoven triangle, .ECG is a representation of these signals and it is composed of deflections (waves), segments and intervals, illustrated in Fig.2, where:

-P- wave: atria depolarization;
-PQ-wave: atria depolarization;
-QRS: ventricular depolarization;
- ST segment: isoelectric line;
-T-wave: ventricular depolarization.

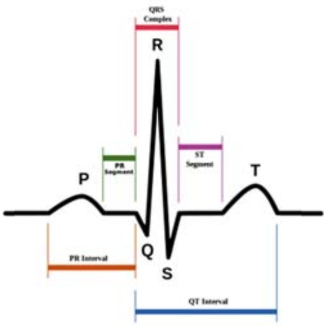

Fig.2. ECG normal signal representation [1].

The Electrocardiogram Sensor (ECG) has grown to be one of the most commonly used medical tests in modern medicine. Its utility in the diagnosis of cardiac pathologies ranging from myocardial ischemia and infarction to syncope and palpitations has been invaluable to clinicians for decades.

h) Measurement of muscles activity

Electromyography (EMG) is a technique for evaluating and recording the electrical activity produced by muscles. EMG is performed using an instrument called electromyograph, and the result of record is called electromyogram. An electomyograph 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, and recruitment order or to analyze the biomechanics of human movement. EMG signals are used in many clinical and biomedical applications. EMG is a usefully diagnostics tool for identifying neuromuscular diseases, assessing low-back pain, kinesiology, and disorders of motor control. EMG signals are also used as a control signal for prosthetic devices such as prosthetic hands, arms, and lower limbs. This sensor will measure the filtered and rectified electrical activity of a muscle, depending the amount of activity in the selected muscle.

i) Measurement of patient position

The patient position sensor is an accelerometer, and it monitors five different patient positions (standing/sitting, supine, prone, left and right lateral recumbent.) In many cases, it is necessary to monitor the body positions and movements made because of their relationships, we can detect 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 is very useful to detect fainting or falling of elderly people or persons with disabilities.

In our system, we measure the following physiological parameters of the human body: body temperature, skin resistance, respiratory rate, blood pressure, pulse, oxygen in blood (SPO2), blood glucose(glycemia), electrocardiogram (ECG), electromyogram(EMG) and patient position. The data received from the sensors are taken by an interface circuit, provided with signal conditioning (filtering, amplification, calibration, etc). Data acquisition is controlled by a microcontroller using an Arduino standard development platform. The data can be transferred in two different ways to a PC: in a wired way using serial communication port of Arduino platform and in a wireless way using a communications shield added to Arduino and a ZigBee module. This information can be used to monitor in real time the state of a patient or to get sensitive data in order to be subsequently analysed for medical diagnosis. If real time image diagnosis is needed a camera can be attached to the 3G module in order to send photos and videos of the patient to a medical diagnosis center. To implement the proposed system we used e-Health platform from Libelium Company, the biometric shield for Arduino and Raspberry Pi, Platform V2.0. The structure of the system that we used is shown in Fig. 3.

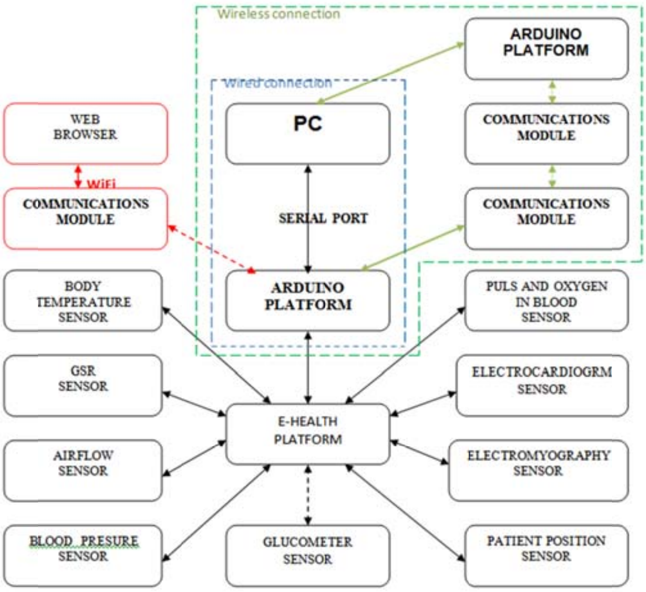

Fig.3. System structure

The data of physiological parameters gathered can be wirelessly sent, using any of the 6 connectivity options available: Wi-Fi, 3G, GPRS, Bluetooth, 802.15.4 and ZigBee depending on the application. A camera can be attached to the 3G module if we want to send photos and videos of the patient to a medical diagnosis center in real time, for image diagnosis.

III. SYSTEM SOFTWARE

To automate data acquisition from the sensors, we developed a program in Python programming language. The program allows recording data from the nine sensors, in a predetermined sequence or choosing the desired parameter(s) from the menu. By using the Python programming language, we can achieve an interactive scenario with the patient and measuring and recording parameters requested by them in the desired order. Next program sequence presents the blood pressure and temperature reading functions (Fig.4).

```
import time
import serial
import array
import sys

def e_health_read():
    ser = serial.Serial(15,115200,timeout=1)
    time.sleep(5)
    ser.write(array.array('B', [0x54]).tostring()) # send T for temperature reading
    time.sleep(2)
    f=open("D:\eHealth\Input.txt", "w")
    li1=[]
    li2=[]
    i=1
    while i<2:
    ser.write(array.array('B', [0x53]).tostring()) # send S for START the reading
    time.sleep(2)
    temp = ser.read(5)
    time.sleep(2)
    print "Temp : " + temp
    print
    li1.append(str(temp))
    i += 1
    ser.write(array.array('B', [0x42]).tostring()) # send B for STOP the reading and return to previous menu
    ser.write(array.array('B', [0x42]).tostring()) # send B for STOP the reading and return to main menu
    time.sleep(2)
    ser.write(array.array('B', [0x4E]).tostring()) # send N for Blood Pressure reading
    print ("BP")
    time.sleep(3)
    ser.write(array.array('B', [0x53]).tostring()) # send S for START the reading
```

Fig.4: Blood pressure and temperature reading program sequence.

For each of the nine sensors used by us, besides the necessary calibrations, we also modified the applications offered by the producing company of Arduino controller. Software changes were needed to optimize data acquisition from sensors. In figure 5 is shown the sequence for reading data from the airflow sensor and the skin resistance sensor.

```
void airFlowBucle(void) {
  while (state == 0) {
    while (Serial.available()>0){
      serialByte=Serial.read();
         if ((serialByte=='V') || (serialByte == 'v')){
                serialByte=Serial.read();
                Serial.println(eHealth.getAirFlow());
                delay(50);
      return;
         }
      }
    }
}
/*==============================================================================

/*==============================================================================
void skinSensorBucle(void) {
  while (state == 0) {
     while (Serial.available()>0){
       serialByte=Serial.read();
          if ((serialByte=='S') || (serialByte == 's')){
                serialByte=Serial.read();
                float conductance = eHealth.getSkinConductance();
                long resistance = eHealth.getSkinResistance();
                float conductanceVoltage = eHealth.getSkinConductanceVoltage();
```

Fig.5. Reading data from the airflow sensor and the skin resistance sensor.

IV. EXPERIMENTAL MEASUREMENTS

Automated system for recording physiological parameters proposed by us, as shown in Figure 6, is fully functional. It allowed the recording of data in files on a computer using the serial port of the Arduino Uno platform.

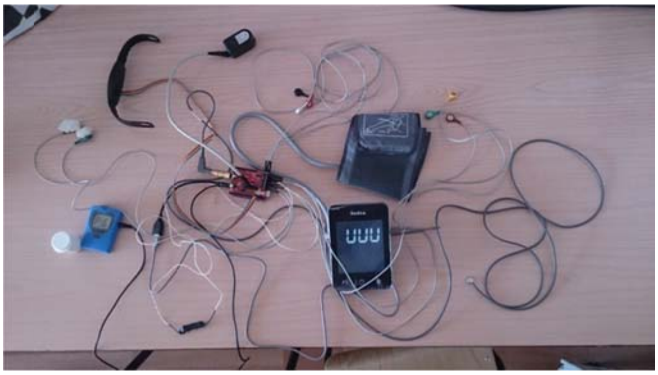

Fig.6. Experimental platform.

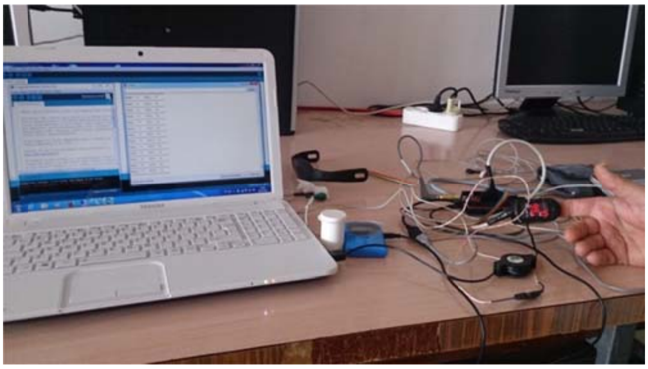

Fig.7. Experimental measurements performed by us.

Experimental measurements performed by us (see Figure 7) for the nine sensors allowed adjustment software applications for the Arduino platform. Some of experimental data performed, recorded and processed by us for the nine sensors are represented as follow: pulsioximeter sensor (Fig. 8), GSR sensor (Figure 9),) and ECG sensor (Figure 10).

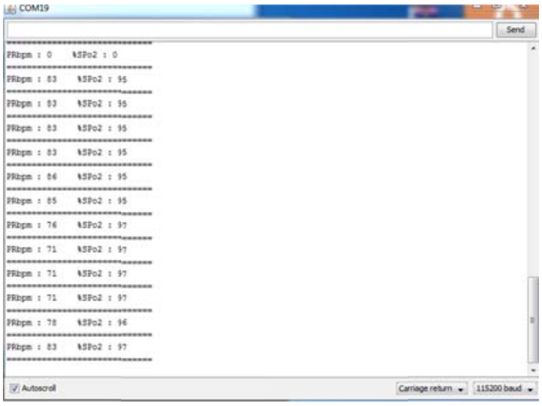

Fig.8. Data aquisition for pulsioximeter

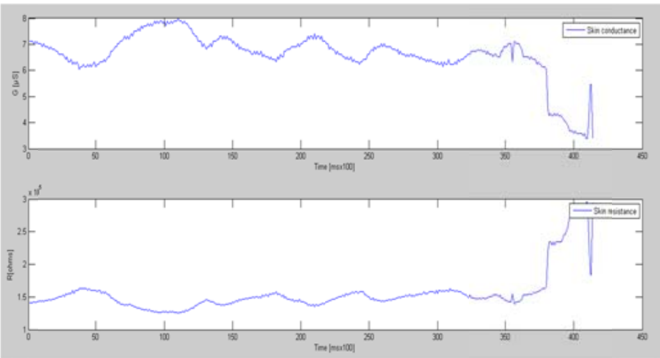

Fig. 9. Data sequence obtained using GSR sensor.

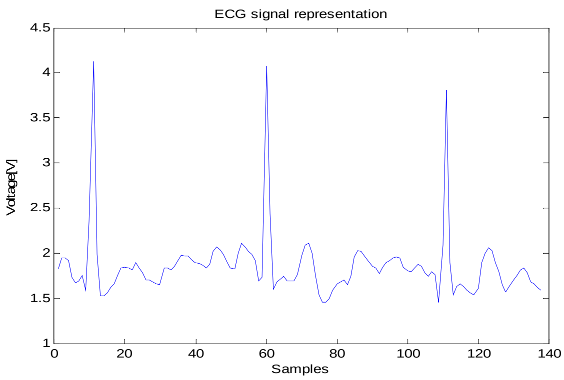

Fig.10: ECG signal representation

The analysis of experimental data measured with the temperature sensor give us information from the difference between the temperature of a finger and body temperature. From the data measured with GSR sensor, we determine an emotion, and from data measured with ECG sensor we can represent ECG wave.

V. CONCLUSIONS

In this paper we present an automated system, fully functional, for measurement of physiological parameters of the human body.

Our presented system allows recording data from the nine sensors in files for storage and further processing or real-time tracking of the parameters provided by sensors.

The system is open, being able to add new sensors by modifying the interface and software properly. Some sensors require an initial calibration to increase the accuracy of data reading, and after some preliminary measurements, to modify the Arduino microcontroller software parameters.

By using the Python programming language we can achieve an interactive scenario with the patient and measuring and recording parameters requested by them in the desired order. If we attach a Wi-Fi module to Arduino platform, data can be sent to a web browser and accessed through mobile terminals such Android tablet or Smartphone.

The system can also become portable if we add a WiFi module and a power accumulator for it.

ACKNOWLEDGMENT:

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