AN EVOLUTIONARY PROTOTYPING FOR SMART HOME INHABITANTS WEARABLE BIOMONITORING

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Abstract: *Nowadays smart homes are becoming a rather fast progressing area for the future industrial developments. Apart of this, the new ICT smart advancing is obviously producing hidden cyber threats for the smart home inhabitants that require a special attention. This provides an inevitable necessity for exploration of possible precautionary measures for human protection. The paper describes a wearable wireless device for smart homes inhabitants' monitoring that is capable to alarm them in case of abnormal selected bio parameters values. An integration of the wearable system into an experimental test-bed smart home environment is also discussed.*

Key words: C3 Real-time and embedded systems, H1.2 Human information processing, H 3.4 Distributed systems.

Introduction

Nowadays smart homes are becoming an indispensible progressive part of our everyday lives. This concept has passed through a significant evolution for almost a century [1] and presently is addressing telemedicine, security and emergency areas, green energy and emerging technologies fans. This obviously is also and a function of the current fast ICT progress and is opening a number of threats for the technologies development perspectives and their users response. According to EU Network of Excellence SysSec Consortium Red Book recent comprehensive study [2], we are living in a digital cyber world where the interactiveness between technologies and humans is constantly evolving. As the humans' role in the problem is still a significant one, special attention to their behaviour dynamics could be a suitable information source in the ambitious task of studying the human-machine interaction process and possible resulting threats in deep.

A good starting point for the human behavior monitoring methodological framework was recently presented in [3]. As the brain activity dynamics obviously correlates in certain manner with body temperature and heart rate a wearable multimodal bio monitoring could be successfully implemented.

Today, the main part of biometric wearable devices are serving for personal measurement and monitoring, including specialized medical applications. Though quite common, these devices still lack wireless data access and especially – easy and standardized complex system integration.

The purpose of this study was to experimentally develop and test the usability of a combined pulse wave and body temperature measuring wearable device prototype, integrated into a smart home test-bed via a standardized Xbee network communication and Matlab R2011b based software analytical solution.

System Description

The wearable device prototype that was created contains two basic sensor systems (providing data for human pulse wave and body temperature dynamics), a microcontroller and an Xbee radio transceiver. All gadgets, together with the battery power supply, are embedded in a textile headband that is steadily placed (for movement artifacts minimization) on the monitored subject forehead. The device is transmitting pulse wave and temperature data to a PC for further on-line processing (see Fig. 1).

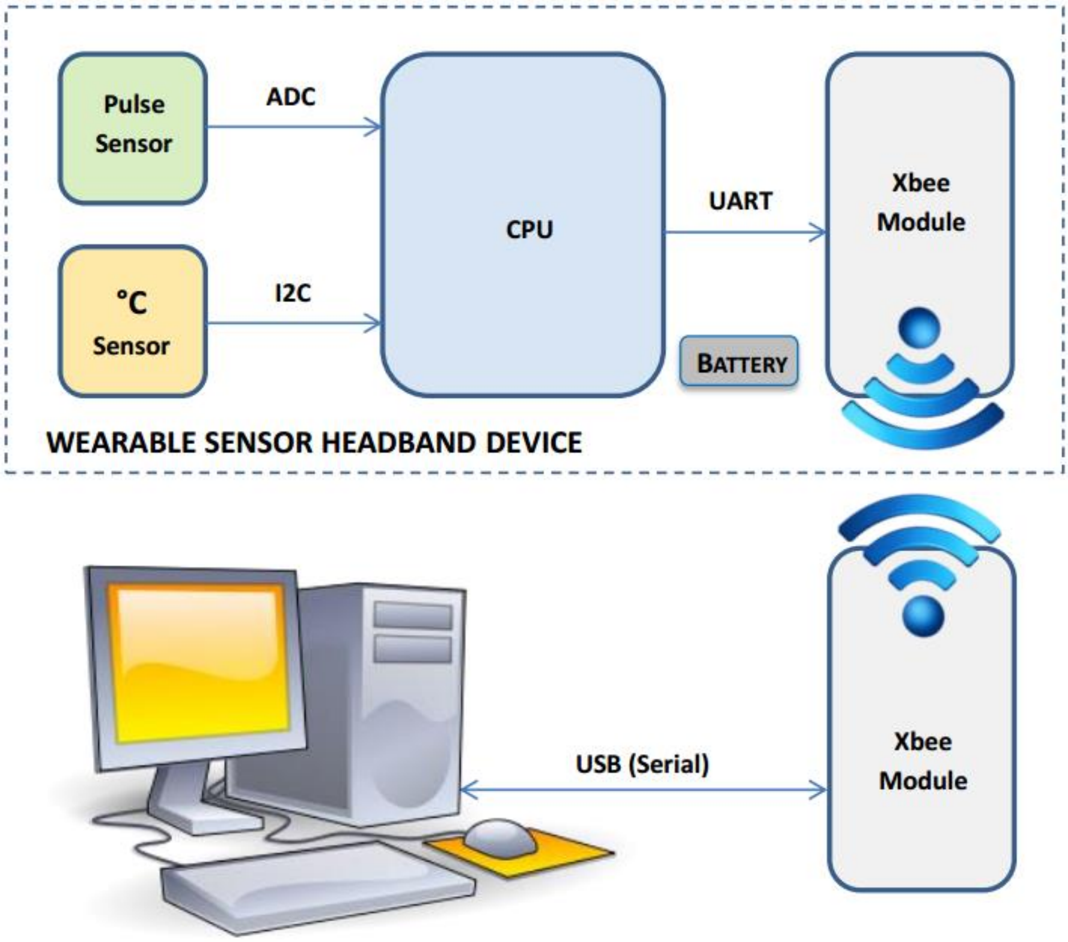

Fig.1. Principal representation of the wearable headband device work.

The pulse wave sensor

The pulse wave sensor (see Fig. 2) that was used is the Pulse Sensor Amped [4]. It contains a LED couple designed for the green spectrum area (λ = 512 – 565 nm), combined with build-in amplification and noise cancellation circuits, incorporated in a small plastic plate (16 x 16 mm diameter and 3 mm thickness).

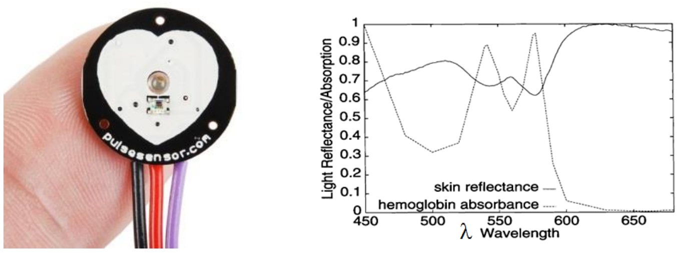

Fig .2. General view of the pulse wave optical sensor (left) and the relevant ratio of skin reflectance vs hemoglobin absorption according to λ (right).

Our choice was due to two facts: (i) the selected solution provides an optimal required necessity of parameters and price, combined with multiple mounting options (ear lobe, fingertip and thus possible easy integration into headband device prototype); (ii) the selected green light spectrum is suitable enough for accurate measurement of the pulse wave, providing future capabilities for enrichment of the device capabilities for measuring the relative concentration of oxygen in the blood hemoglobin [5] (see Fig. 2).

The key principle that the presented pulse wave sensor is based on is the reflection of light in accordance with the tissue blood volume. Thus, the transmitted light intensity varies with the pulsing of the blood from the heartbeat. This variation with time is referred to be a photoplethysmographic signal. The reflection originates from the nonhomogeneity in the optical path, i. e. at the interface between materials with different refractive indices. As the light passes through the skin and into the underlying tissue, some is reflected, some is scattered and some is absorbed, depending on what it encounters. Blood absorbs light more readily than surrounding tissue, so if there’s more blood in the area, less light will come back to the sensor. With each heartbeat, blood surges through arteries and veins and then ebbs, meaning blood volume first increases, then decreases. The change of reflected light is converted to voltage, which is then measured for obtaining a pulse rate curve. The pulse sensor transmits data to the microcontroller through an ADC channel.

Temperature sensor

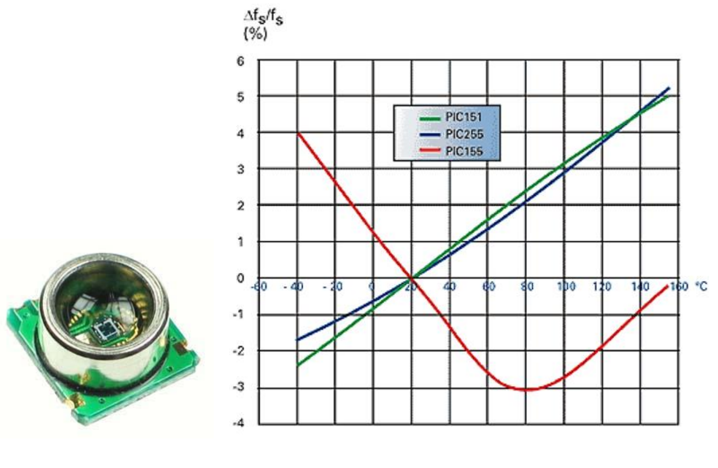

Fig .3. General view of the temperature sensor (left) and the temperature dependence of the resonant frequency Δf_s and the longitudinal oscillation f_s for three popular piezoceramic materials (right)

We have selected HP03D temperature sensor, Futurlec [6] (see Fig. 3). The physical principle of our sensor is based on the property of piezoelectric ceramics to change resonant frequency with temperature variation [7], [8]. The temperature sensor is a low power, low voltage (from 2.2 to 3.6 V) device with automatic power down switching. The sensor is calibrated and transmits 16 bit temperature data through I2C serial interface. It is able to pick up correct temperature in range from -30° C to +80° C with accuracy of one tenth of degree. The temperature data is read from the microprocessor via I2C interface every 20 sec and send wirelessly (via Xbee) to the PC USB port receiver. The temperature sensor is equipped with metal cap, which must be in contact with the human forehead skin in order to provide correct temperature values.

Microcontroller
For an embedded microcontroller we have selected MSP 430G2553, Texas Instruments [9] as a low consumption microprocessor with simultaneous 12 bit ADC, UART and I2C communication interfaces and supply voltage in range 1.8 V to 3.6 V, matching the voltage supply requirements of the pulse sensor, temperature sensor and the wireless radio module.

Wireless radio module
We based our radio communication network on the Xbee standard. Since the sensory module was placed very close to the human head it was important to reduce the radio transmission power as much as possible. We have selected Xbee Series 1, Sparkfun [10], with maximum possible radio emission power - 1mW. As the pulse wave analog signal falls in extreme low frequency range we need to sample and transmit no more than 500 samples per second.
In order to send the temperature and pulse wave signal to PC we have used two XBee radio modules – transmitter and receiver. The communication baud rate was 38400 bauds.
The combined sensory device is powered by 3.6 V, 550 mAh NiMH battery with total consumption of approximately 50 mA. After powering on, the device is automatically sending, continuous pulse wave and temperature data to the PC USB Xbee receiver.

Biometric parameters description

Pulse wave rate
The hearth rate and hearth rate variability are important feature related to human emotional state and health condition [11], [12], [13]. Since the pulse wave is not a single point event but rather a complex waveform with

specific morphology, when measuring the hearth rate we must define the single point within the pulse waveform. In addition the pulse wave morphology can vary slightly in time, which makes crucial the correct choice of criteria for definition of pulse wave event moment. The normal frequency range of the input signal is 0.5 Hz to 5 Hz. So the noise elements are cancelled by using low pass filter of cut off frequency 5 Hz [14]. In the scientific literature are described different approaches to indicate the exact moment of pulse wave arrival. Conventionally, the 25% or 50% point of the maximum value on the pulse waveform is taken to indicate the arrival of the pulse wave [15], [16] defined the arrival of the pulse wave as the peak value of the differentiated signal, which corresponds to the steepest part of the ascent of the plethysmography obtained signal. For our calculations we used the last approach namely as maximum amplitude of the pulse wave gradient. Another group of authors [17], [18] draw attention to frequency analysis of heart rate variability, which may add significant information to human cardiovascular state. Considering the latter data we have chosen the pulse wave rate, pulse wave rate variability and the frequency power spectrum of pulse wave rate variability as feedback parameters, which trigger the alarming event.

Body skin temperature

The body temperature is also an important indicator, which is characterizing the overall human health condition especially in young children and infants [19], [20]. The ability for body temperature monitoring is useful not only in case of disease but also for non-invasive and accurate measurements of body temperature in a continuous fashion over weeks in realistic environments. This can substantially improve the quality of data available to medical researchers such as psychophysiologists and chronobiologists.

Software for data acquisition and analysis

The software for data acquisition, analysis and decision making was developed under Matlab R2011b platform. After connecting the receiving radio to the PC USB port the software starts to reserve, store and analyze in real time the incoming pulse wave and temperature data. For pulse wave visualization and analysis we are sending 500 values per second. The temperature values are send ones each 20 seconds appending the pulse wave array, preceding the instructions indicating temperature data. For better observer perception the pulse wave data are refreshed on the computer screen every 5 seconds.

The software extracts the following features: (1) temporary pulse wave rate for the current 5 seconds; (2) pulse wave rate for the last 1 minute; (3)

variation of pulse wave rate for the last 1 minute; (4) the frequency power spectrum of pulse wave curve stored in the last 1 minute; (5) current temperature value; (6) correlation coefficient of mean pulse rate for the last 1 minute and the mean temperature value for the last 1 minute; (7) correlation coefficient of pulse rate variation for the last 1 minute and the mean temperature value for the last 1 minute;

The software is also recording each monitoring session allowing also a later offline data processing.

Currently, the developed software is able to trigger alarm events based on user predefined boundary parameters.

A screen shot of data acquisition software work is depicted in Fig. 4:

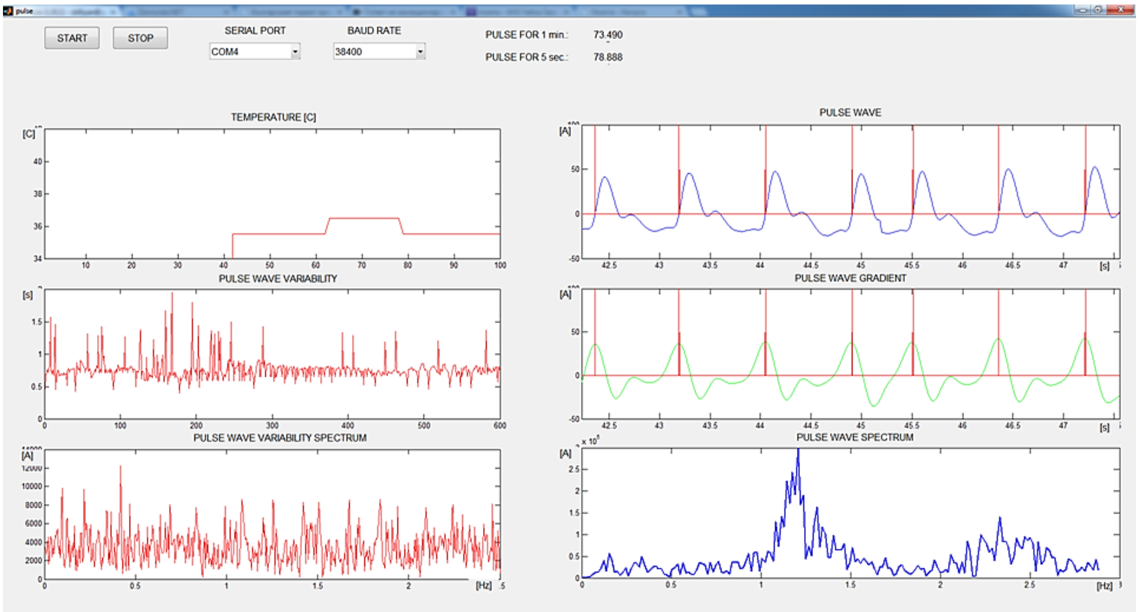

Fig.4. A screen shot of data acquisition software work.

Discussion

Evidently the nowadays digital world with its fast progressing Web 3.0 and the upcoming Web 4.0/Web 5.0 human-machine interaction requires special attention to both technologies and human factor.

So, as most important components of the present digital world we could consider: the environment of living, i.e. smart homes/cities and environment of communication: web based social networks and smart devices.

As a key player in this world the human factor still requires special attention and monitoring with suitable equipment for the behaviour and emotions dynamic changes.

One of the possible solutions for this is the wearable wireless equipment that together with technologies observation could validate and provoke understanding of present and future cyber threats in the digital era.

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