A Wearable Internet of Things Device for Bio-signals Real Time Monitoring of Elderly People

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Abstract**—Monitoring of elderly health in real time could be vital in the event of emergency medical incidents and could possibly result in saving a person's life. Researchers are focusing on the field of monitoring vital signs in real time via biosensors with non-invasive methods, followed by processing and assessment of the acquired data. Due to Internet of Things technology, vital signs could be gathered and distributed in real time to multiple users simultaneously. The main indicators of vital signs involve measurements of skin temperature, heart rate, blood pressure respiration rate, oxygen saturation, PH level, calories, etc. In this paper, we present a novel approach of a wearable device fabricated in a flexible substrate that can measure such bioindicators and notify caregivers in order to assist an elderly person in a potential emergency situation. In this paper a wearable vital sign monitoring wearable device is presented in order to monitor the physiological state in real time.**

Keywords- Internet of Things; homecare elderly; elderly care; wearable monitoring; health monitoring system.

I. INTRODUCTION

Recent technological advances that brought about the Internet of Things revolution that we are experiencing today [1], can provide efficient and innovative solutions to issues related to elderly care, taking in the average life expectancy [2]. Elderly care facilities are investing in human resources to provide high quality treatment to elderly people in need, which in many cases is a must for people with continuous medical treatment. Caregivers must spend multiple hours measuring and recording vital signs of people with high probability of human errors through this process. The cost for such an institution is highly raised due to the numerous personnel needed and the fees for the boarders are raised proportionally. Towards this direction, researches have been carried out in order to integrate wearable technology in the continuous monitoring and precision measuring of the user's vital indicators [3].

Wearables have been a growing technology in recent decades. More and more are getting involved in our daily life in the forms of smartwatches, bands, Virtual Reality glasses, etc. This technology provides an easy-to-access method to precise recording of vital signs with low cost [4].

In addition, measuring and monitoring by a sensor device could provide stable, long term, continues medical records without requiring personnel and expensive medical equipment; moreover, it provides extended freedom of movement to the user. These medical records could be stored in cloud services 24/7 and prove to be a useful tool for future state of health analysis or even for early diagnosis of potentially harmful diseases.

The paper is organized as follows. Section II describes recent advances on wearable systems and devices. Section III presents in the first part the wearable device fabricated for the purpose of this research and in the second part the monitoring system designed for the same reason. Section IV presents the results of the measurements and the corresponding procedure. Finally, conclusions and future research directions are drawn in Section IV.

II. BACKGROUND

Several research groups have already fabricated wearable devices for continuous real time monitoring of vital signs with non- invasive technics.

Duran-Vega et al. [5] created a system for monitoring and storing vital signs called "Abuelometro" to assist in an elderly care facility. Using the Hexiwear biometric [6] wearable device, a platform was fabricated, able to monitor skin temperature, heart rate and oxygen saturation in real time, as well as additional data, such as exercise time, sleep time, meal time etc. Relatives and caregivers could have access to that information and would be notified in case of an emergency condition.

Kumar et al. [7] demonstrated a wearable device measuring blood vessel change via an optical device in real time using the Photoplethysmography method. The system is separated in 4 main parts, the sensor device, the gateway the smartphone app and the cloud server. The device communicates with MiWi and BLE protocols to a smartphone app through a gateway and the data are uploaded to the cloud where they stored and visualized.

Cohen et al. [8] demonstrated a ring sensor device able to measure blood pressure and heart rate using transmission Photoplethysmography technique. In their device, an LDR and a LED were used to observe the pulses using transmission Photoplethysmography while a microcontroller was reading the change in the LDR resistance. The accuracy of the device prediction exceeds over 90% compared to an average real for both systolic and diastolic pressure.

Zheng et al. [9] demonstrated a cuff-less wearable system using pulse arrival time measurements for monitoring blood pressure in order to obtain and diagnose hypertension.

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Wearable contained of optical Photoplethysmography sensor parted from a led and a photodiode and two pieces of Electrocardiography patches sewed on the inner side of the armband. The receiving signal is amplified and filtered before it reaches the microcontroller. After that, data can be stored and transmitted via Bluetooth to a smartphone app. The system was tested on both healthy and hypertense subjects.

Gao et al. [10] demonstrated a wearable device capable of performing perspiration analysis by sampling human sweat and measuring sweat metabolites such as glucose and lactose and electrolytes such as potassium and sodium ions. The device was placed in a flexible substrate in order to achieve contact with human body and a skin temperature sensor was used in order to monitor thermal shift. A microcontroller was implemented for gathering all the measurements and sending the corresponding data to a smartphone app via a Bluetooth module. The aim of the researchers was to monitor the physiological state of an athlete in real time.

The devices mentioned above are using Internet of Things technology to gather data from the biosensor in order to determine and present the physiological state of the user. Despite vital signs, it is common to monitor information such as environmental conditions, the kinetic changes, or the time and duration of the measurements taken from the user. Research is continuing in the integration of new biosensor to wearable systems in order to improve the quality of the measurements and the variety of vital signs collected.

III. WEARABLE DEVICE

In this section an overview of our approach and the corresponding monitoring system will be presented.

A. *Overview of the present approach*

The wearable device fabricated for the purposes of this research consisted of both vital sign and environmental sensors. The criteria for choosing the sensors are driven by the main specifications of the device, which can be analyzed as follows: At least two user's vital signs of the user must be monitored, non-invasive methods must be implemented, and the device should be flexible and easily fit. Furthermore, the final device should be low cost and expandable.

A schematic indicating the main parts of the proposed device is illustrated in Figure 1. The device implements a microcontroller (atmega328p) in order to collect measurements, perform calculations and send data via a Wi-Fi module to a MQTT server in real time. The device is powered by 2 Li-po batteries of 400mAh in series.

All data collected by the microcontroller are processed and send in real time to the Wi-Fi module placed in the flexible substrate. The Wi-Fi module (esp8266) is constantly connected to the internet and posting the measurement received by the MCU to a MQTT cloud server. The measurements are shortly stored on the server and posted to all the subscribers.

In order to build the device, a commercial Kapton substrate was chosen since it provides stability in high temperatures and can be commonly found in many thicknesses and covering metal layers. A Vishay PT100 thermistor (100-ohm PTS SMD flat chip temperature dependent resistor) was integrated in the above-mentioned substrate for skin temperature monitoring. A simple passive linear circuit of a voltage divider was used for this purpose, with a resistor and a thermistor in series, and the output was connected to an ADC channel of the microcontroller. The voltage divider transfer function was used for the calculation of the thermistor resistance value.

The person's heartbeat (also referred as 'pulse') can commonly be measured on the wrist or neck. The pulse of a person is measured by counting the number of heart beats in one minute. Beats per minute measurements were calculated using a non-invasive, optical sensor, using the Photoplethysmography method [11] to determine the heart rate of the user. Specifically, the HRM-2511E optical sensor was utilized, which is a transmissive sensor with a phototransistor output, emitting at 950nm. The sensor system consists of an infrared LED and a photodiode pair in a transmissive topology (LED is placed opposite of the photodiode, with the finger in between). A proportion of light passes through the finger to the photodiode is absorbed by the hemoglobin (a protein in red blood cells carrying oxygen) resulting to a pulsation relevant to the heart rate. The corresponding principle of operation is presented in Figure 2a (depicted by [12]). The recorded signal of the photodiode after been filtered by a high pass - low pass filter and amplified, ends up to the ADC channel of the microcontroller.

Additionally, a 3-axis accelerometer (ADXL362) with a 12-bit output resolution was used for precise monitoring of the person's movements. An environmental sensor (HIH6130) was used to measure humidity and environmental temperature in order to acquire data regarding the user's background conditions. All the parts of the system were fabricated on a flexible substrate (Polyimide), so that the device could easily fit on a person's wrist.

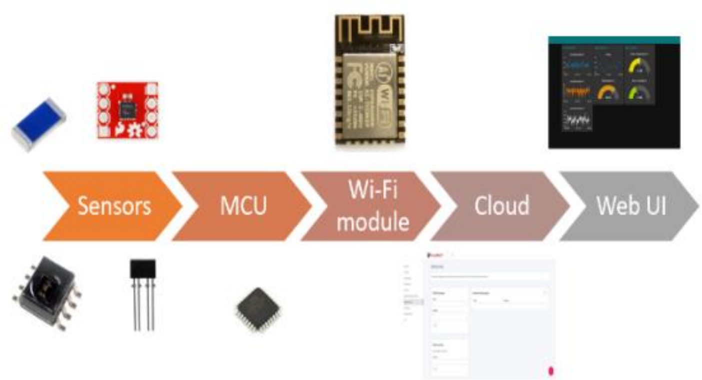

Figure 1. Schematic of the main components involved in the device.

a)

b)

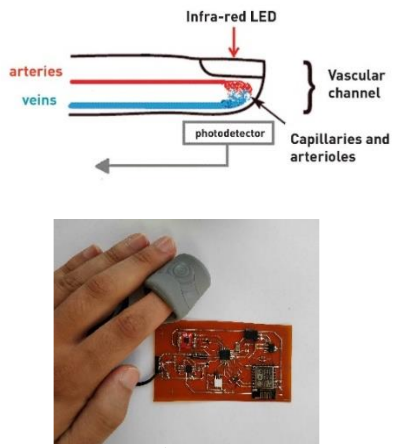

Figure 2. a) representation of the optical measuring system principle [11], b) Wearable device.

B. *Monitoring System*

A software written in C, using Arduino and public libraries was developed in order to achieve communication among the integrated ICs.

Several protocols were used for the communication of the atmega328p microcontroller with the various peripherals. More specifically UART was used for esp8266 connection, SPI was utilized for ADXL362 communication and I2C was implemented for HIH6130 connection.

Real time monitoring system is based on the MQTT protocol. The WIFI module (subscriber) is publishing data on an MQTT server (Broker). We used the MQTT cloud server of Amazon as a Broker and our device publishes data on it.

The Node-RED online platform [13] was utilized (as a Subscriber), to receive the data acquired by the server. A custom user interface called FRED was created for the data transferring, visualization and storage. More specifically, we develop an interface to visualize the sensor readings, create a user's archive, and alert the caregivers regarding the user condition, when potential danger situation is detected. In this way, relatives and caregivers could monitor vital signs of elder people and become alert to act in case of an emergency.

Figure 3 shows a typical representation of the device output when it is connected to a user.

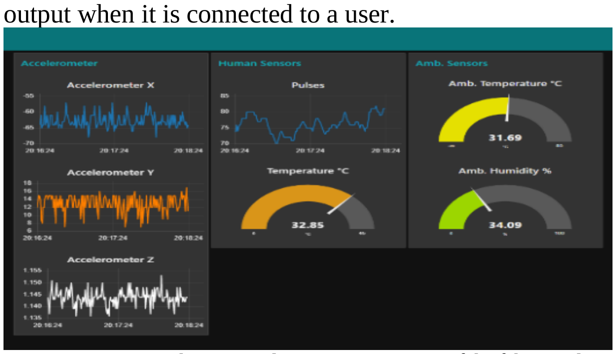

Figure 3. UI FRED, showing real time measurements of the fabricated Internet of Things wearable device.

IV. RESULTS

In order to demonstrate the validity of the proposed device, commercial systems were utilized for reference purposes. In our case, the optical sensor's measurements were compared to a commercial band, a Xiaomi Mi smart band integrated with a 3-axis accelerometer sensor, a 3-axis gyroscope, a Photoplethysmography heart rate sensor and a Bluetooth 5 BLE module. The temperature sensor measurements were compared to a digital infrared thermometer, Mastech MS6522B, simultaneously in four different daily routine tasks. During Sleep, at Lunch time, at Rest time and during casually exercise. For both test scenarios, a series of measurements were taken, up to 1 minute, and the final result was the average for each task. This process was repeated 3 times, over 3 different days to improve the reliability of the corresponding evaluation.

Table 1 and Table 2 present the results for the optical sensor and skin temperature evaluation, while Figure 4 illustrates the corresponding raw data of the accelerometers' signals in all axis.

Additionally, further processing of the acquiring data could occur in order to extract more bio-parameters. For example, by integrating a burnt calory counter in the measurements of the 3-axis sensor stored in the UI platform via the use of open-source algorithms, we can determine calories burn. Furthermore, by processing the measuring data acquired from the optical sensor, the systolic and diastolic pressure [8] can be extracted from the average maximum and minimum bits per minute.

Although the system design was successfully performed, there were some limitations that were faced during the procedure. The main limitations were focused on the process complexity and time, Moreover, the fitting of the optical sensor was also an issue mainly in terms of device robustness.

V. CONCLUSION AND FUTURE WORK

A system for monitoring vital signs of elderly in real time was presented. The system is capable of performing real-time vital signs monitoring and transferring them to an Internet of Things platform for future medical processing and analysis. The device is low-cost and could easily be fitted to a wristband for daily use due to its flexible substrate. The main parts used for the device include several sensors, namely: a thermistor, a reflective sensor combined by an IR transmitter and a phototransistor, an environmental sensor and an accelerometer. Those parts were connected directly to the MCU, which processes and transmits the data via a Wi-Fi module to a Web server using the MQTT communication protocol and presented the results in a web UI.

The measurements took place for 4 different body states and during 3 different days. The preliminary data demonstrate the ability of the device to successfully monitor predefined biosignals and its potential to discriminate among various activities of people.

TABLE I. BAND – WEARABLE DEVICE COMPARISON MEASURING BEATS PER MINUTE .

	Days	Xiaomi Band	Wearable device
Lunch	Day- 1	78.3	79.3
	Day- 2	80.6	81
	Day- 3	79.6	79.3
Rest	Day- 1	77.3	77.6
	Day- 2	75.2	76.8
	Day- 3	72.4	72.2
Exercise	Day- 1	91.2	91.1
	Day- 2	95.5	94.2
	Day- 3	103.1	102.7
Sleep	Day- 1	68.5	68.6
	Day- 2	64.3	64.7
	Day- 3	70.1	70.4

TABLE II. DIGITAL INFRARED THERMOMETER – WEARABLE DEVICE COMPARISON MEASURING SKIN TEMPERATURE

	Days	Mastech MS6522B	Wearable device
Lunch	Day- 1	34.1	33.2
	Day- 2	33	33.3
	Day- 3	32	32.3
Rest	Day- 1	33.1	33.4
	Day- 2	32.2	32.5
	Day- 3	32.9	32.8
Exercise	Day- 1	33.3	33.3
	Day- 2	35.3	34.1
	Day- 3	34.3	33.1
Sleep	Day- 1	32.4	32.7
	Day- 2	32.8	33.2
	Day- 3	32.2	32.6

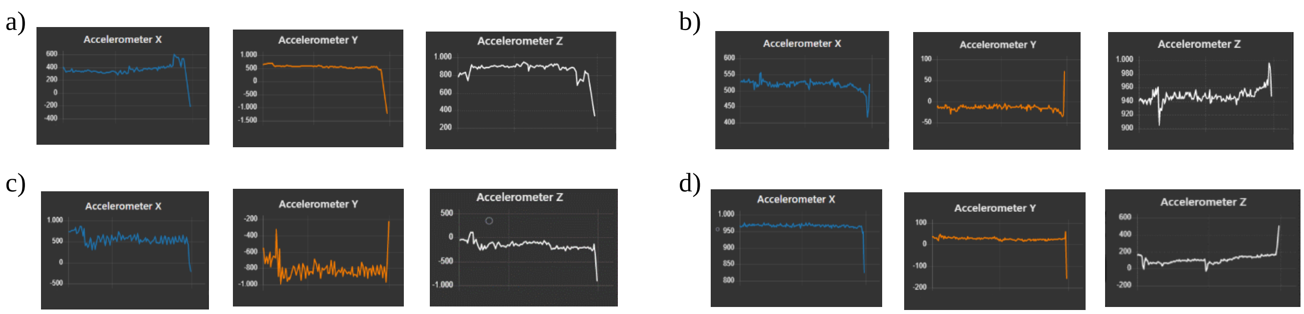

Figure 4. Visual representation of accelerometer during: a) lunch, b) rest, c) exercise, d) sleep

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