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A smart computer mouse with biometric sensors for unobtrusive office work-related stress monitoring

Thelma Androutsou, *Graduate Student member, IEEE,* Spyridon Angelopoulos, Ioannis Kouris, Evangelos Hristoforou, *Member IEEE* and Dimitrios Koutsouris, *Senior Member, IEEE*

Abstract— **Health disorders related to the prolonged exposure to stress are very common among office workers. The need for an automated and unobtrusive method of detecting and monitoring occupational stress is imperative and intensifies in the current conditions, where the pandemic COVID-19 causes changes in the working norms globally. In this study, we present a smart computer mouse with biometric sensors integrated in such a way that its structure and functionality remain unaffected. Photoplethysmography (PPG) signal is collected from user's thumb by a PPG sensor placed on the side wall of the mouse, while galvanic skin response (GSR) is measured from the palm through two electrodes placed on the top surface of the mouse. Biosignals are processed by a microcontroller and can be transferred wirelessly over Wi-Fi connection. Both the sensors and the microcontroller have been placed inside the mouse, enabling its plug and play use, without any additional equipment. The proposed module has been developed as part of a system that infers about the stress levels of office workers, based on their interactions with the computer and its peripheral devices.**

I. INTRODUCTION

According to the World Health Organization, work-related stress is the response people may present when work demands and pressures are not matched to their knowledge and abilities, which challenges their coping mechanisms [1]. Stress, along with depression and anxiety, are the second most frequently occurring work-related health problems in Europe, leading to a large increase in absenteeism and presenteeism rates [2]. Occupational stress is a major problem of modern societies and is gaining importance due to the COVID-19 pandemic, which has brought about enormous changes in the social, economic and labor sectors. Most of the office workers have been working remotely for over a year in order to minimize the spread of the pandemic. However, remote working is a challenge because of workplace isolation, family disturbance, peer absence and lack of organization [3]. Combined with COVID-19 related stress, this condition can adversely affect the mental health and stress levels of employees and therefore needs careful and systematic monitoring [4].

To enhance the work-life wellness of workers, especially in the current period of global health crisis, it is imperative to adopt a system of continuous monitoring and detection of occupational stress. The field of Affective Computing has extensively studied the possibility of automatic detection of emotions and stress, through the collection and analysis of sensor data. Physiological measures, such as heart rate and galvanic skin response, are the most frequently used in research works, as they can be quite effective and indicative of a person's emotional state [2], [5], [6]. Behavioral responses, mainly including changes in facial expressions, body posture and speech variation, have also proven to efficiently detect stress and emotional states and can be measured in a more unobtrusive way than physiological measurements [7], [8]. Considering the rapidly increasing use of information and communication technologies in the daily life of office workers, many studies have examined the interaction patterns with the computer as possible indicators of their stress levels [9]–[11]. The results are quite significant as they show that mouse and keyboard dynamics information can measure the affective state of the user non-intrusively and without the need of expensive extra equipment [12]. Although information on stress can be obtained using a variety of modalities, the research studies that present the most accurate results are usually those that use a combination of different measurements. Their methods are based on the multimodal nature of stress and integrate features extracted from physiological, psychological and behavioral data, achieving high performance in stress detection and prediction [13]–[16].

In this paper, we present a computer mouse that collects biometric data from the user through a multi-sensor module design on its surface and transmits them wirelessly over Wi-Fi connection with the use of an embedded development board. This smart biometric mouse has been developed as part of a system that aims to detect and predict the stress levels of office workers, based on their interaction with the computer and its peripheral devices. There have been only a few studies that have proposed such systems. In [17], a PPG sensor was placed in a PC mouse and collected signals from the user's thumb. The acquired PPG signal was transferred wirelessly via a Bluetooth module and a robust algorithm for the detection of its peaks was proposed. In [18], PPG surfaces were implemented on the left and right side of an ordinary wired mouse and the inter beat intervals detected during the conducted experiment were highly correlated to those of a conventional point sensor. Lin et al. proposed a multi-PPG sensor that is placed on the top surface of the mouse and makes use of the user's palm, with the aim to increase the contact area and the probability of signal detection [19]. A weighted average method was used to adjust the weight of the

T. Androutsou, I. Kouris and D. Koutsouris, are with the Biomedical Engineering Laboratory, School of Electrical and Computer Engineering, NTUA, Iroon Polytechniou 9, 15780, Greece (e-mail: tandroutsou@biomed.ntua.gr, tel:+30-2107722430)

S. Angelopoulos and E. Hristoforou are with the Laboratory of Electronic Sensors, School of Electrical and Computer Engineering, NTUA, Iroon Polytechniou 9, 15780, Greece

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signal, based on the quality of each channel. In [20], a biometric mouse that helps to evaluate user's work productivity and general emotional state was developed. The sensors placed on the mouse can measure the temperature and humidity of the hand, heart rate, skin conductance and touch intensity. These physiological measurements were combined with psychological and behavioral data to infer stress levels and make stress management recommendations.

The smart computer mouse presented in this paper is a multi-sensor comfortable and easy-to-use module that can be used as a plug and play Internet of Things (IoT) device. A PPG sensor and a GSR sensor are placed on the mouse's surfaces and their signals are controlled by a 120 MHz ARM Cortex M3 microcontroller that is integrated in the device. Data are transferred wirelessly over a Wi-Fi connection. The unobtrusive way of data collection and transfer enables the application of the suggested system easily and cost effectively in any office working environment. Moreover, it can be easily adapted to the new working norms and contribute to the detection and monitoring of the occupational stress and productivity of remote workers.

The remainder of the paper is organized as follows. Section II explains the materials and methods for designing the system and collecting the signals. The results of the system's application are presented in section III and discussed in section IV. Finally, section V gives the conclusion.

II. MATERIALS AND METHODS

The proposed system consists of a development board (Particle Photon board with a 120 MHz ARM Cortex M3 microcontroller and a Broadcom Wi-Fi chip), a PPG sensor (Pulse Sensor by World Famous Electronics LLC) and a GSR sensor (Grove-GSR sensor by Seeed), which are all packaged in a commercially available wired optical mouse.

The PPG sensor is assembled on a circular printed circuit board (PCB), having a diameter of 16 mm and a thickness of 3 mm. On the one side of the PPG sensor, there is a reverse mounted green LED, as well as the required electronic components for signal filtering and amplification. On the other side of the board, there is a Broadcom APDS-9008 ambient light sensor. The reverse mounted LED shines light into the skin through a hole on the PCB. The ambient light sensor receives the reflected signal that changes along with the blood pulse. Then, the signal is passed through a passive RC filter network to reduce its noise, followed by an operational amplifier, where it is amplified and level-shifted, in order to use half of the supply voltage (Vcc/2) as a voltage reference. As a result, the final output signal is appropriate for further processing by a microcontroller having low noise, being amplified and adjusted to the preferred [0, 5V] or [0, 3.3V] voltage range.

The GSR sensor consists of two disc-shaped electrodes and a PCB board (20 mm x 20 mm) which contains the required electronic components. When the two electrodes get in contact with the skin, a small current passes through it, making it to act as a resistor. When there is no contact with the electrodes, the output of the GSR sensor is equal to the reference voltage. On the other hand, when the two electrodes are in contact with the skin, any variation of the skin resistance, e.g. due to sweat, leads to a change of the sensor's output.

As shown in Fig. 1 both the PPG and the GSR sensors are connected to a Particle Photon development board. Its 120 MHz processor is able to process the signals at high speeds, while its 12-bit analog-to-digital converter (ADC) produces digitized signals with sufficient resolution. The main advantage of this board is that, despite its small dimensions , it houses a Wi-Fi module on-board, enabling the wireless communication with the device. The wireless connectivity is essential for the desired application, as it enables the remote data acquisition and storage, as well as the ability to send a potential update of the device's code, without dissembling the mouse or even installing any software to the user's personal computer. The small packaging was also critical, due to the limited free space inside the computer mouse.

The Particle Photon needs a supply voltage in the range of 3.6-5.5 V. This is also a critical advantage, as it allows its internal connection to mouse's power pins, which can provide a voltage of 5 V and a current up to 500 mA, through any standard USB port. This is more than sufficient, as the current consumption of the mouse is equal to 100 mA and the current requirements of the device's additional parts are equal to 85.5 mA (Particle Photon with Wi-Fi enabled: 80 mA, PPG sensor: 4 mA and GSR sensor: 1.5 mA).

The key aspects for the choice of the computer mouse were a) its size (being able to enclose the microcontroller and the required electronics and cabling), b) its design (consisting of quite flat surfaces in order to easily incorporate the sensors in the most unobtrusive manner for the user), c) its way of communication with the PC (being wired, provides enough power for both the sensors and the mouse) and d) its low cost.

The Particle Photon board and the GSR sensor's board were placed inside the mouse. A hole was made at the side wall of the mouse, to place the PPG sensor at the area where the user's thumb rests. Similarly, two holes were made at the top surface of the mouse, where the two GSR sensor's

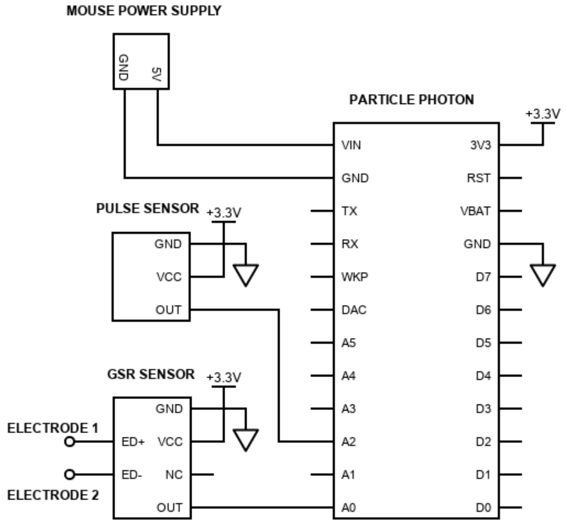

Figure 1. The schematic diagram of the proposed system.

electrodes were placed, in order to get in contact with two areas of the user's palm, but also remain unaffected by the common mouse actions, such as clicking or wheel scrolling. All sensors were positioned in such manner that the use of the mouse was not hindered and the received signals were affected as little as possible. The structure of the mouse with the embedded sensors is shown in Fig. 2.

III. RESULTS

The monitoring of PPG and GSR signals as well as the analysis of their various characteristics and parameters can give us a lot of information about the emotional state and the stress levels of the user. In our solution, signal preprocessing is done on the acquired sensors' data by the microcontroller. The results can then be transmitted to a cloud service or a local server for further analysis and extraction of statistical features in the time and frequency domain.

PPG signal can measure the volumetric variations of blood circulations that are controlled by the heartbeat. Thus, several physiological measurements regarding heart rate (HR), inter-beat intervals (IBIs) and heart rate variability (HRV) that are highly correlated with stress responses can be derived from the signal analysis. In order to obtain accurate results, special emphasis should be given to locating the exact moment that each heartbeat occurs. In the present system, a method that considers the amplitude of the wave during fast rises as well as the time interval from the last recorded pulse is applied during the signal processing by the microcontroller [21].

In this way, an attempt is made to eliminate false calculations due to the existence of noise and the presence of the dicrotic notch, i.e. the brief increase in blood pressure following the closure of the aortic valve. Moreover, motion artifacts that may affect the quality of the signal during the mouse movements are reduced by the use of a Kalman filter, modifying the method described in [22].

Figure 2. The developed smart mouse with PPG and GSR sensors.

The voltage output (V_{out}) of the GSR sensor can be converted to human skin resistance (SR) measured in ohms, by adapting the (1) provided by the sensor manufacturer [23] to the specifications of the microcontroller we are using:

$$SR = ((4096 + 2 \cdot V_{out}) \cdot 10000)/(2048 - V_{out}) \quad (1)$$

Part of the preprocessed signals of GSR and PPG, as they are sent by the microcontroller can be seen in Fig. 3. The horizontal axis represents time for a period of ten minutes while the vertical axes show the transitions of SR in kΩ and HR in beats per minute, respectively.

IV. DISCUSSION

By observing the presented preliminary results, we can claim that the smart mouse works effectively. No disconnections or interruptions were observed during the reception of the signals, which not only verifies the selected design and construction of the system, but also confirms the suitability of the sensors' locations. Furthermore, the ranges of the acquired results for the two biosignals are as expected

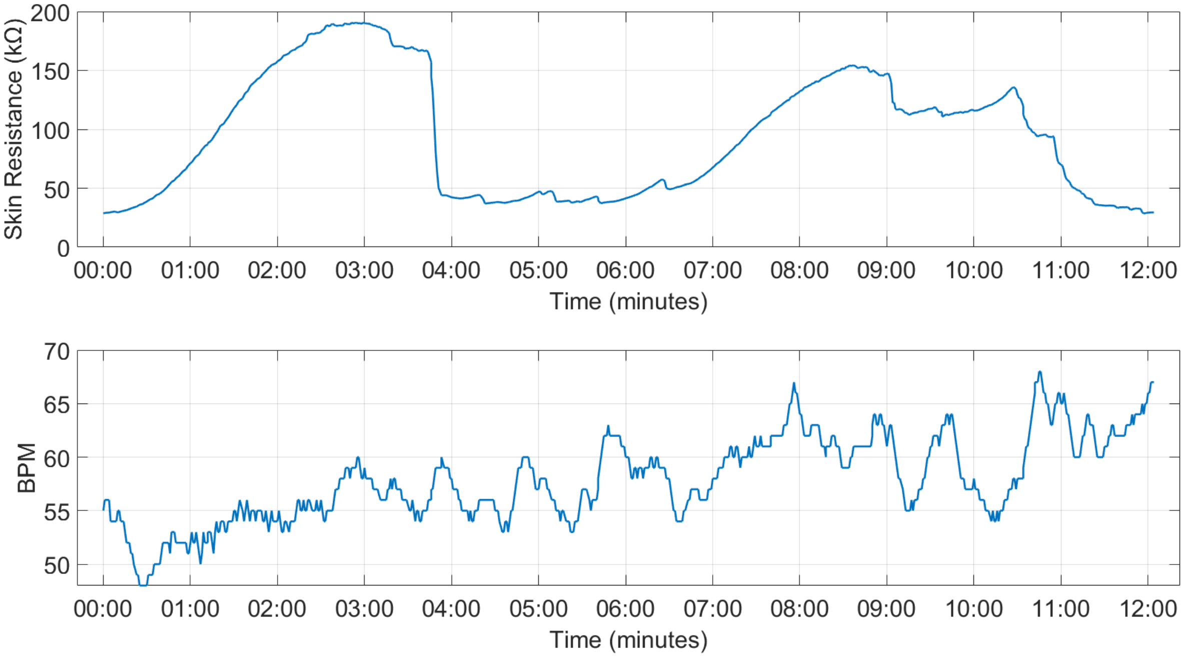

Figure 3. Skin resistance and beats per minute measurements for a time period of ten minutes.

and in line with the corresponding measurements. Therefore, we suggest that this computer mouse can be integrated into a continuous stress monitoring system in an office environment. It is worth noting that the purpose of this paper is to demonstrate the successful recording of reliable biosignals using the proposed system, therefore no experiment involving human subjects or the application of stressors was performed. The presented results are preliminary, but more will follow to verify the device as part of a larger system.

V. CONCLUSION

A smart computer mouse equipped with a multi-sensor module for work-related stress detection has been presented in this study. Signals are collected unobtrusively from the system's sensors, they are processed and filtered by the microcontroller and are transmitted wirelessly for further analysis. Future work will evaluate the performance of the proposed device, as part of a system that aims to detect and predict office work-related stress. We are planning the conduction of a lab experiment that will use known work stressors to elicit stress to the participants during their interaction with the computer and its peripherals. For this purpose, statistical features of HR, IBIs, HRV and GSR will be extracted and analyzed. We believe that this low-cost and simple to use IoT device could be served as an effective measurement tool to collect physiological signals and thus can be easily integrated into systems for early detection and monitoring of employee stress, whether in office or remote work areas.

CONFLICT OF INTEREST

The authors declare no affiliation or involvement in an organization or entity with a financial or non-financial interest in the subject matter or materials discussed in this manuscript.

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