Michał SIENIAWSKI, **Teodora DIMITROVA-GREKOW**, Adam KLIMOWICZ
BIALYSTOK UNIVERSITY OF TECHNOLOGY
45 A Wiejska St., 15-351 Bialystok, Poland

Low-cost Monitoring System of a Sitting Posture

Abstract

The article presents a description of sitting posture monitoring system, built on Raspberry_Pi_3b, Tact Switch buttons, a prototype board and a rubber mat. RaspberryPi connected to the sensors communicated with a personal computer. This allows on the one hand to immediately inform the seated about the appearance of no symmetry of the position on the chair and managing the time of sitting and breaks on the other. The proposed system ensures identification of the degree of incorrect seating during work and gives the opportunity to improve the user's posture, which affects many topics related to health and work efficiency. System possesses a graphical user interface. During system operation, monitoring data is collected and can be used for further research towards an optimal impact on the user to get rid of the faulty sitting habits.

Keywords: sitting position monitoring, RaspberryPi, graphical user interface, database.

1. Introduction

Over the last century, the average amount of time spent in a seated position has been significantly extended. And long-term sitting leading a sedentary lifestyle brings a number of negative health consequences [1-4]. Currently, the most popular solutions aimed at solving this problem are computer programs for measuring working time and break [5-8]. These programs are imperfect for many reasons, the biggest of which is that they are in no way able to verify if breaks are actually enforced.

A lot of research is devoted to linking the amount of seat to obesity. In particular, the number of calories burned by the so-called NEAT factor (Non Exercise Activity Thermogensis), which includes all physical activities performed during the day that are not the actual physical training [7]. The influence of sitting on the musculoskeletal system is a very important and equally often discussed subject in the research. There are unambiguous conclusions about the increased risk of acquiring muscular-skeletal disorders with the entry of personal computers into everyday life [5, 9]. Interestingly, the psychological aspects of sitting are also interesting to the correctness of posture [10]. However, over a certain number of hours of sitting during the day in front of the TV or computer, no amount of exercise can completely eliminate the negative effects [2]. And despite that an walking or simply standing could save our health [8], more and more people are at risk – sitting - group. Another way to minimize the negative effects of sitting is to use breaks [6, 7]. It was also found that the employees who behaved the correct posture while sitting performed their tasks more effectively than the employees who did not maintain the correct posture, thus it can be concluded that the attitude influences the work efficiency [11].

The studies above point, that in cases where the elimination of seating is impossible, the best strategy to minimize the negative effects of sitting is to use short and frequent breaks from sitting and maintain a correct posture while sitting, which is a very good motivation for this work.

The article presents the created computer system, which as main function possesses the ability to monitor the seated position, informing the user about the appearance of irregularities in the symmetry of the posture. In addition, the system allows optimal management of seat time and breaks.

The following tools and technologies were used to create the system: RaspberryPi_3b, Tact_Switch buttons, prototype board, cables and a rubber mat. The programming languages Python and Kotlin, the Spring framework and the MongoDB database were used for the system implementation.

2. Existing Systems

Two selected systems are described: commercial and non-commercial. Both are designed to monitor the time and posture of the user while sitting.

2.1. Dedicated non-commercial systems: CAPRIO

The CAPRIO posture recognition system (Context Aware Posture Recognition In Office) takes data about the sitting position on the pressure sensors [12]. The CAPRIO system in real time monitors the attitude of the person while sitting. If the system detects an incorrect posture, the user is warned by displaying a message on the screen and is asked to improve the attitude. The pressure sensors placed on the chair inform if the user is sitting in a chair, and if he is sitting, whether he sits correctly. Due to the fact that pressure sensors are used, the system is able to detect additional information such as increased pressure on one of the sides or backward tilt which will manifest itself as increased pressure on the backrest of the chair. The information collected from the sensors is binary. If the pressure on a given sensor does not exceed the pre-set threshold, it returns information that the sensor is inactive. However, if the pressure exceeds the set threshold, the sensor returns information that it is active.

The work points out that there is not one ideal attitude of sitting. Instead, the concept of a neutral body posture is introduced. What's more, the CAPRIO authors postulate that frequent posture changes are necessary [13]. According to them, the information flowing from the sensors on the chair is insufficient and you need another source of information on how the mouse and keyboard are. The chair and sensors connect to the computer via wireless communication. WLAN or Bluetooth can be used for this.

An undeniable drawback of this approach is the neglect of information about the symmetry of the posture. Also additional system weakness are requirements concerning the user. The limitation is also that the system is firmly connected to a specific chair.

2.2. DARMA - commercial system

Darma is a system that consists of a chair cushion (Fig. 1b), which automatically solves the last disadvantage of the previously presented CAPRIO. Cushion containing sensors and applications for mobile operating systems: iOS and Android. This pillow is placed on a chair to sit on it. However, data is sent to the phone via Bluetooth [14].

a) b)

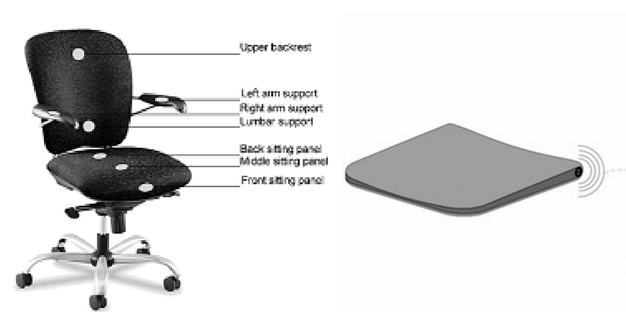

Fig. 1. a) System CAPRIO [13]; b) part of system Darma [14]

The system has to control the posture while sitting and manage stress by monitoring the seating time. The sensors built into the pillow in real time monitor the posture while sitting. When an incorrect posture is detected, the cushion activates light vibrations and a notification appears on the phone to remind you to improve your posture. The vibrations are also used to notify breaks according to pre-selected settings. The intensity of the vibrations is configurable, which makes it possible to distinguish vibrations with an incorrect posture from the vibration of the start of the break. During breaks on the phone screen, individually selected stretching exercises are shown. They are chosen based on the history of the seat so that they minimize potential problems of the musculoskeletal system that may occur from the style of a person's seat. The application is able to generate reports with seat statistics, both day and week. What's more, the cushion monitors heart rate and breathing frequency, which plays a key role in the analysis of stress levels. All this information is available for inspection from the phone application level. The main drawback is the high cost.

3. A Low-Cost Proposition

To ensure correct operation, transparent structure and easy development of the system, our system was designed in the "three layers" convention. The architecture of the system is shown in Fig. 2. The individual layers are presented with appropriate blocks (seen from the left to right): Hardware, Server, Client.

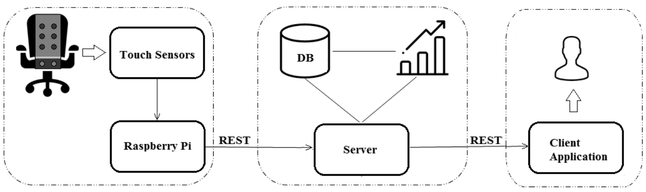

Fig. 2. Project architecture

3.1. Hardware part

The hardware part is responsible for reading the status of the buttons and then sending this information to the server using a wireless connection. It consists of a rubber mat, buttons (playing the role of touch sensors), cables, a prototype board and Raspberry Pi.

The location of the touch sensors has been inspired from the CAPRIO system described above. Serving as position detectors, the Tact_Switch buttons significantly reduce the cost of the system and even in a minimalistic configuration, which, however, takes into account the symmetry of the posture of the sitting person. This precisely eliminates the main defect of CAPRIO, providing information about the symmetry of the user's position.

System check made using Raspberry Pi version three, and software written in Python - the recommended language for changing and saving the state of ports on Raspberry Pi.

3.2. Server part

The server part consists of a server listening for incoming REST requests and a database management system. Its task is to issue a REST service with two methods: one for recording new measurements and one for reading measurements from the database.

As the database management system, MongoDB was chosen. The planned use of the current database also in future research means that the algorithm of data processing and analysis is to be independent of the positioning of the sensors on the chair and their number. Bearing in mind the above requirement, the data structure is as follows:

- date and time of measurement - used during the measurement search, acts as the key of the record,
- position evaluation as a floating point number - it will allow you to later evaluate items not only in binary but also with values between. However, total values have now been used.

The Spring MVC library serves the task of creating REST websites using annotations. In addition, to further reduce the amount of code required for writing by the programmer, the Spring Data library will be used, the task of which is to automate communication with the database.

3.3. The client part

The client part consists of an application and a graphical user interface. The main tasks are:

- periodic interrogation of the server for the last measurement of the position,
- measuring the time of sitting,
- displaying statistics, after querying the server for data.

Kotlin language was chosen, TornadoFX library for graphic interface and Feign library for easy REST communication from the client side. Using the annotations added to the interface methods that have the HTTP method and the path to the resource, the library creates an object that can communicate with the resource. Communication takes place in the JSON format. It is required to provide a library that supports serialization when sending and deserialization when receiving objects. We used GSON.

The application retrieves data on the latest readings from the database of the current position while sitting. The default period is set to 0.9 seconds. There is also a ***Summary Window*** on the client side: the main program window that presents the most important information from the user's perspective:

- assessment of the current position and final visualization,
- time remaining until the end of a break or work,
- navigation to the ***Statistics window***,
- navigation to the ***Settings***.

A ***Break configuration*** window allows to customize the program to the individual needs as: counting time, calculating the remaining time until the end of the currently pending break or working, or calculating the value on the progress bar. Settings can be assigned by a physician or physiotherapist.

The system also includes the following statistics and graphs:

- *sitting time*; setting options: *beginning* and *end* of the range (Fig. 3); allows to have a general overview of the work mode and is the basis for appropriate preventive recommendations.

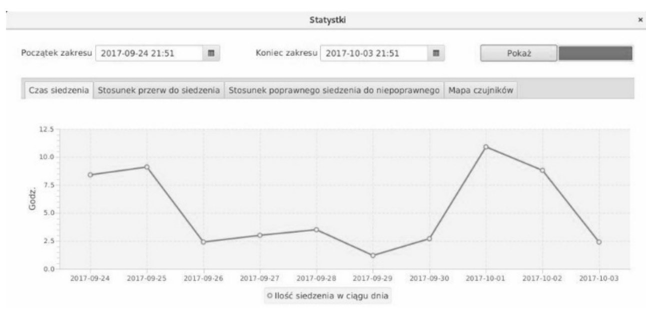

Fig. 3. Diagram of the daily sitting time

- *relationship between the correct time and incorrect sitting time*; setting options: *beginning* and *end* of the range (Fig. 4); the diagram is very good feedback not only about the current state, but above all about the changes in the habits of the seated person; it can be used in research on the most effective impact on the user, which is the object of further considerations of this project,
- *relationship between break time to sitting time*; setting options: *start* and *end* of range; is an effective supplement to information about seating time; its visualization is also a pie chart, and the collected data further enrich the database of further searches for optimal conditions for safe work in the sitting mode.

- *map of sensors* on a chair with an indication of which ones are most often touched by the body of a seated person. Options: *start* and *end* of range (Fig. 5); hence is the easiest way to see what are the most significant irregularities of the posture of a seated person.

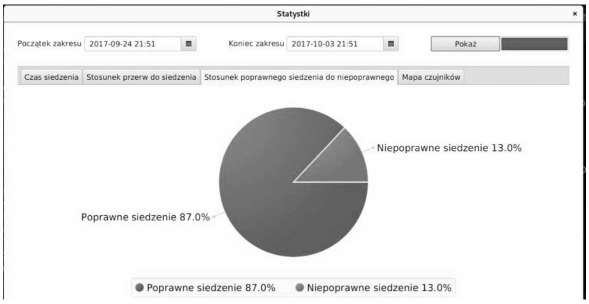

Fig. 4. The correct time vs. incorrectly time sitting

The current version has adopted a colorful transmission of information about the load of individual sensors, because it allows a qualitative analysis. The numbers, e.g. percentages of normalized time for each button, would have less substantive weight.

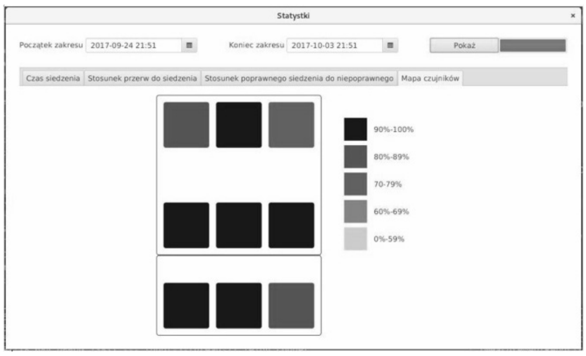

Fig. 5. Map of the sensors

4. Conclusions

Long-term sitting at the computer or generalizing a sedentary lifestyle brings a number of negative health consequences, both physical and mental. Obesity, problems with cardiovascular, bone or muscle systems can be particularly frequent problems.

The monitoring system of the sitting position proposed here can be very easily implemented, and moreover the cost of its implementation would not exceed five hundred PLN. The current form allows both: immediate use and further research for the optimal interface. The future final solution could merge the server and client part into one application, making the system compact and battery powered,

The system can be further developed in many independent directions, such as switching buttons to pressure sensors, adapted location of sensors and intelligent matching to the user based on machine learning procedure implemented into the system.

This paper is supported by the S/WI/3/2018.

5. References

[1] Wilmot E.G., Edwardson C.L., Achana F.A.: Sedentary time in adults and the association with diabetes, cardiovascular disease and death, J. Diabetologia. Vol. 56(4) , pp. 942-953 (2013).
[2] Ekelund U., Steene-Johannessen J., Brown W.: Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality, J. The Lancent, Vol. 388, pp. 1302–1310 (2016).
[3] Christian von Loeffelholz: The Role of Non-exercise Activity Thermogenesis in Human Obesity, Med Sci Sports Exerc, Vol. 45(7): pp. 1386-1393 (2013).
[4] Villablanca P.A., Alegria J.R., Mookadam F.: Nonexercise activity thermogenesis in obesity management, Mayo Clinic Proceedings Vol. 90(4), pp. 509-519 (2015).
[5] Biswas A., Faulkner E.: Sedentary Time and Its Association With Risk for Disease Incidence, Mortality, and Hospitalization in Adults: A Systematic Review and Meta-analysis, J. Ann Intern Med. Vol. 162, pp. 123-132 (2015).
[6] Dunstan D., Kingwell B., Larsen R.: Breaking Up Prolonged Sitting Reduces Postprandial Glucose and Insulin Responses, Diabetes Care. Vol. 35(5): pp. 976–998 (2012).
[7] Stephens B., Granados K., Zderic T.: Effects of 1 day of inactivity on insulin action in healthy men and women, Metabolism, Vol. 60(7):, pp.941-949 (2012).
[8] Duvivier B.M., Schaper N.C., Bremers M.A.: Minimal intensity physical activity of longer duration improves insulin, PLoS One. Vol. 9(8), pp.105-135 (2014).
[9] Ortiz-Hernández L., Tamez-González S., Martínez-Alcántara S.: Computer use increases the risk of musculoskeletal disorders among newspaper office workers, Archives of Medical Research. Vol 34(4),pp. 331-342 (2003).
[10] Grabmeier J., Study: Body Posture Affects Confidence In Your Own Thoughts, The Ohio State University News, October 05, 2009, https://news.osu.edu/news /2009/10/05/posture/, stage 26.03.2018.
[11] Robertson M.M.: Health and Performance Consequences of Office Ergonomic Interventions Among Computer Workers. LNCS, vol 4566. Springer, Berlin, Heidelberg (2007).
[12] OSHA., Computer Workstations eTool, https://www.osha.gov/ SLTC/etools/computerworkstations/, last stage 26.03.2018.
[13] Haveman S., Kant G.: Smart monitoring of worker posture in an office environment, 2008.
[14] Darma. http://darma.co/Darma_Cushion.html, last stage 22.03.2018.

Received: 12.10.2017 Paper reviewed Accepted: 01.12.2017

Michał SIENIAWSKI, Eng.

Graduated Faculty of Computer science at Bialystok University of Technology, in 2018. Since 2016 works as technical analyst. His research interests include computer graphics, computer networks and data warehouse.

e-mail: m.sieniawski@pb.student.edu.pl

Teodora DIMITROVA-GREKOW, PhD

Graduated Faculty of Electronics Sofia University of Technology, Bulgaria in 1991. Postgraduate studies and doctoral thesis - Electronics and Automation at Technical University in Vienna in 1997. She is an assistant professor at the Department of Computer Science at the Technical University of Bialystok. Her research interests include synthesis of programmable systems, robotics, mechatronics, analysis and signal processing.

e-mail: t.grekow@pb.edu.pl

Adam KLIMOWICZ, PhD

He graduated from the Institute of Computer Science at the Bialystok University of Technology. He defended his doctoral dissertation in 2007 at the Faculty of Computer Science at the Bialystok University of Technology, where he holds the position of assistant professor. His scientific interests include design of embedded systems and methods of synthesis of combinational and sequential circuits based on CPLD/FPGA devices and microcontrollers. Co-author of the ZUBR package for supporting the design process of digital systems.

e-mail: a.klimowicz@pb.edu.pl