High-tech garment for people with disabilities using IoT technology

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Abstract. The article is devoted to the development of a high-tech garment using IoT technology for people with disorders of the musculoskeletal system. In particular, the results of creating a prototype of a heat-protective product with the function of monitoring physiological indicators of the organism of a person with disabilities are presented. The aim of the work was to develop and scientifically substantiate a system for monitoring physiological parameters of a person with a disability used in a heat-protective product adapted for being in a wheelchair. The relevance of the research is due to the high demand for specialized clothing with a heat-shielding function for people with disorders of the musculoskeletal system, with the ability to track physiological parameters of the body. In the course of solving the problem, an analysis of scientific papers on this topic was carried out. Modern methods of developing algorithms for fuzzy logic, circuit design, modeling and mathematical statistics have been used. In the process of doing the work, a justification for the use of IoT technology in integration with the garment product is given. The software for the smartphone has been developed to monitor physiological parameters of a human body with disabilities. The scientific development was tested in laboratory conditions, which, in turn, confirmed the effectiveness of the proposed idea. The results obtained in the course of the conducted research can be used in everyday life by people with disabilities, thereby improving their quality of life.

1 Introduction

In the modern world, the issue of adaptation of people with disabilities to social life conditions is important. Providing people with disabilities with special clothing [1] is no less important than creating an accessible urban environment, public transport or communication devices adapted to the characteristics of the body. The integration of IoT technology with various devices («smart» watches, home appliances, cars, «smart» homes) has made it possible to use sensors to collect data and then respond appropriately to users actions. First of all, the use of this technology is effective in monitoring the general state of the human health. The presented research is devoted to the development of a high-tech garment using IoT technology for people with musculoskeletal disorders with the ability to monitor such

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body parameters as blood pressure, heart rate, pulse rate, and blood oxygen level. The sensors are placed in a heat-shielding product adapted to the anatomical features of a person with a disability. Data from the sensors is transmitted to a mobile application for a smart phone.

The issues of designing special clothing with extended functionality – «smart clothes», including monitoring of physiological parameters of the human body, are touched upon in the works of M. Jacobsen, S. Rezayi, J. Liu, M. Weenk, D. L. T. Wong and other scientists who specialize in this branch of science [2-6]. Much of the work is devoted to the continuous monitoring of physiological parameters of the body of elderly people by means of sensors [2, 4-6]. The paper [3] describes a development that allows monitoring of the patient's body condition in emergency situations in an ambulance. A number of studies are devoted to various assistive devices designed for people with disabilities [7, 8]. But, despite a wide range of research in this area, the problem of designing special clothing with the function of monitoring vital body parameters for people with disorders of the musculoskeletal system who use wheelchairs in everyday life has not been sufficiently studied. Thus, the relevance of research work is determined by the need to design heat-protective products that can not only provide thermal comfort in the cold season, but also to constantly monitor the indicators of the human body with disabilities. This segment of clothing can be equated to the class of "smart clothes", i.e. clothing with integrated electronics controlled through a developed mobile application for control and monitoring of vital body indicators.

In connection with the current situation, the authors consider it possible to present the results of their research within the framework of achieving the task – to develop high-tech sewing products using IoT technology for people with musculoskeletal disorders.

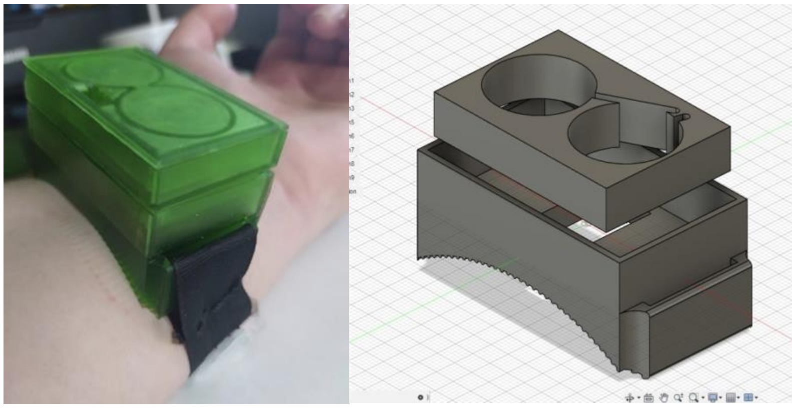
2 Methodology, methods for developing a high-tech product for people with disorders of the musculoskeletal system

In early studies [9] the authors developed a heat-protective product for people with musculoskeletal disorders, fully corresponding to the anatomical features of the figure in the sitting position, equipped with additional heating sources. The space under clothing temperature is monitored when the product is in use by transmitting data from the temperature sensors to a smartphone app via Bluetooth.

According to the results of the analysis of literary sources [10-15], the authors formulated the task of improving the previously designed product, namely, expanding its functionality by obtaining data on blood pressure, heart rate, pulse, oxygen level in the blood.

2.1 Development of a system for monitoring the physiological parameters of a person with disabilities

Thus, in accordance with the stated technical characteristics of the developed high-tech product, in addition to creating additional thermal comfort, the wearing process should be accompanied by constant control and monitoring of vital indicators of the human body with disabilities. In order to control and monitor such indicators of the human body with disabilities as blood pressure, heart rate, pulse, an additional device has been developed according to the type of cuff (worn on a person's wrist), presented in accordance with Figure 1.



a b

Fig.1. Device for control and monitoring of vital indicators a – device for control and monitoring of blood pressure, heart rate, pulse (inside view) b – device case model

Fixation of the device on the wrist is carried out with the help of Velcro tape. The case for this device was made on a 3D printer using sketches (Figure 1, b), made in the 3D object modeling software. The lower part of the case, in which the sensor for reading information (physiological parameters) is installed, corresponds to the anatomical shape of the human wrist, with grooved coating (anti-slip), for reliable fixation during wearing. There are holes for batteries in the upper part of the case (Figure 1, b). For winter wear, this device can be placed in a sleeve muff.

The algorithm for processing the oxygen content in the blood is based on the use of the principles of object-oriented programming; the SpO2Calculator class is fully responsible for data analysis.

The heart rate processing algorithm is based on reading the values of red and IR LEDs (Figure 2), pre-filtering them to remove constant signal components and accumulating a window of samples for conversion into beats per minute.

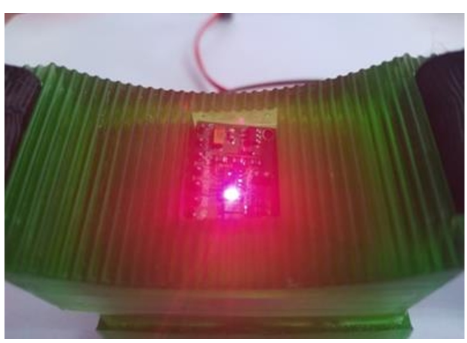


Fig.2. Location of the IR LED sensor that reads the readings

The technique for measuring blood pressure is the method of «N.S. Korotkov tones», recognized by the World Health Organization.

2.2 Smartphone software Development

The developed software is necessary to fully inform people with disabilities (users) and the attending physician about the state of their body indicators using a web application built by using SPA technology.

This system is self-sufficient, as it does not interact with other information systems of this type.

The user should be able to view readings such as:

- the temperature of each of the heating element sensors, as well as an overview of the overall temperature (temperature of under clothing space);

- statistics for a certain period of time on the temperature received from each temperature sensor and an overall graph showing all sensors;

- heart rate sensors in real time;

- statistics in the form of graphs for heart rate and blood oxygenation. Each parameter is in a separate graph;

- the state (off or on) in which the heating elements are located.

In case of critical parameter changes, the user should be informed by both light and sound signals, which indicate that the user or the attending physician urgently needs to connect to the application and check the status of the sensors and eliminate existing problems. For instance, it is necessary to finish a walk when the weather deteriorates. The interface of the main screen after downloading the Thermobag application is shown in Figure 3.

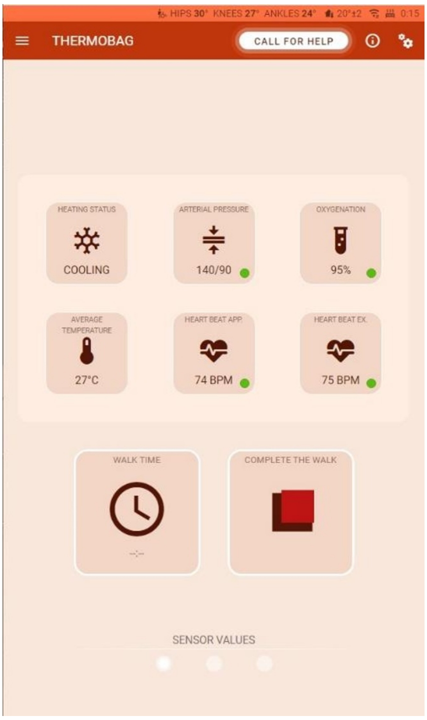


Fig. 3. Main screen after loading

Figure 4 shows the temperature map screen in 3D. The 3D temperature map consists of a central 3D scene, in which a 3D model is located, the departments (local areas of the lower extremities) on which change depending on the temperature coming from the sensors. The 3D model itself is divided into 3 segments: hips, knees, foots.

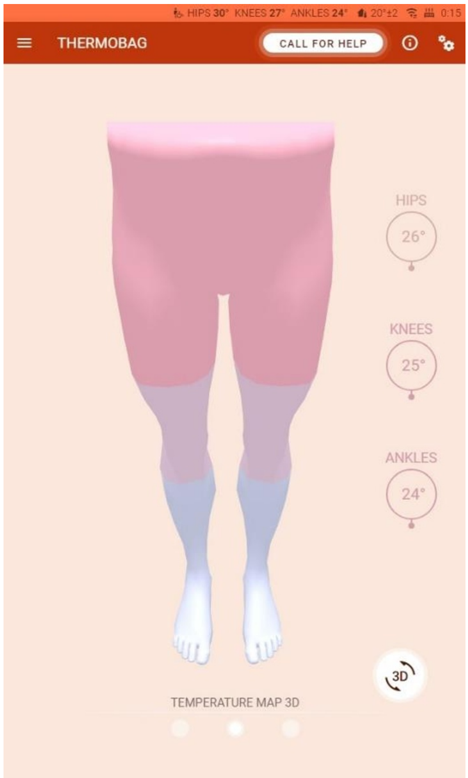


Fig.4. Temperature map screen in 3D view

When developing the software, all possible aspects of operation in all its states, including critical ones, have been considered. Each indicator is also provided with an abundance of additional information in the form of graphs that can be downloaded.

An important element can be a button to call for help in critical situations, while critical situations are provided with brief instructions and rules of conduct in them to minimize harm to the user's health.

3 Approbation of high tech sewing products for people with musculoskeletal disorders

To test a prototype, the technique described in [9] was used. The test conditions are presented in accordance with Table 1.

Table 1. Conditions for the experiment.

Gender of participants in the experiment	Male
Age, years	45-60
Disease	Paraplegia of the lower limbs Congenital dislocation of the hip Consequences of road traffic accidents

Disability group	2
Disability experience, years	over 10
Environmental conditions during the experiment	
t of air, ºC	0, minus 5, minus 10, minus 15
Air humidity, %	60-65
wind velocity, m/s	0,2-0,4

The prototype of the product was tested by 6 men, in laboratory conditions under simulation of different air temperatures (0°C, minus 5°C, minus 10°C, minus 15°C). The tests were carried out in laboratory conditions under simulated temperature conditions with 6 men involved. During the testing, software was used to monitor their physiological parameters. In Figure 5, as an example, an application interface element is shown – a graph of blood pressure of one of the subjects participating in the tests.

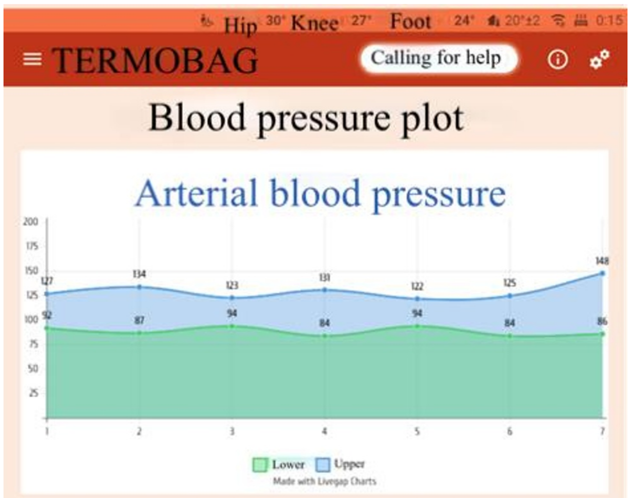


Fig.5. Blood pressure graph

The developed application made it possible to extract the received information in the form of a multimedia file and transfer the data to the attending physician.

4 Research results

Thus, the developed high-tech garment for people with disorders of the musculoskeletal system, integrated with an application for monitoring and monitoring vital signs of the body, fully complies with the stated technical requirements. This product can be used during walks at low temperatures for up to 2 hours of autonomous operation (a longer stay for a person with a disability in sub-zero temperatures is not recommended).

5 Conclusion

Thus, the developed high-tech sewing product with the use of IoT technology for people with disorders of the musculoskeletal system fully meets the stated technical requirements.

It should be noted that the use of IoT technology in integration with specialized products for people with disabilities is the most successful solution due to such problems as the lack of retained intelligence or the inability to make adequate decisions on one or another environmental impact (for example, exposure to cold). The developed product helps to accelerate the process of integration of people with disabilities into society, increasing the process of rehabilitation.

References

1. L.G. Babenko, et. al., IOP Conf. Ser.: Mater. Sci. Eng, **680**, 12-31 (2019) doi: 10.1088/1757-899X/680/1/012031
2. M. Jacobsen, et. al., J. Diabetes Sci. Technol. **15** (1), 34-43 (2021) doi: 10.1177/1932296820904947
3. R. Sorayya, et. al., J. of Sensors **2021** (2021) doi: 10.1155/2021/8820740
4. J. Liu, et.al., Sensors **20**, 4009 (2020) doi: 10.3390/s20144009
5. M. Weenk, et.al., J. Med. Internet Res. **22** (6), 15471 (2020) doi: 10.2196/15471
6. D.L.T. Wong, et.al, IEEE Sensors J. **99** (2019) doi: 10.1109/JSEN.2019.2942099
7. X. Qu, et.al., J. Phys. Mater. **4**, 034015 (2021) doi: 10.1088/2515-7639/ac0092
8. M.A.D. Brodie, et.al., Physiol. Meas, **36**, 857 (2015) doi: 10.1088/0967-3334/36/5/857
9. L.G. Babenko, N.Yu. Saveliefa, IOP Conf. Ser.: Mater. Sci. Eng, **1155** (0120912021) doi: 10.1088/1757-899X/1155/1/012091
10. Y. Koyama, M. Nishiyama, K. Watanabe, IEEE Sensors J. **18**, 6175–6180 (2018) doi: 10.1109/JSEN.2018.2847333
11. X. Yang, et.al., IEEE Sensors J. **15**, 757-761 (2015) doi: 10.3390/s17040890
12. M. Alrige, S. Chatterjee, International Conference on Design Science Research in Information Systems (2015) doi: 10.1007/978-3-319-18714-3_43
13. J. Wannenburg, R. Malekian, IEEE Sensors J. **15**, 6839-6852 (2015) doi: 10.1109/JSEN.2015.2464773
14. L. Dziuda, et.al., Scientific Reports, **9**, 1-11 (2019) doi: 10.1038/s41598-019-40737-w
15. B. Bouziane, E. Moez, et.al., Building and Environment, **203**, 108056 (2021) doi: 10.1016/j.buildenv.2021.108056