Contact-communicative approach to research and development the smart prosthesis for the transradial amputees

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Abstract. The article is devoted to further researches and developments of the smart prosthesis for transradial amputees. Describes the solutions of thematically related tasks to increase the effectiveness of the amputee's interaction with the external subject-spatial and social environment. One of the tasks is to study the behavior of experimental resistive pressure sensors protective materials in order to optimize sensor contact. Another task is to provide with the help of conductive materials the effect of "digital touch" with the aim of creating the amputee through the agency of the screen-compatible prosthesis conditions for active social communication.

1. Introduction
This research work, which is the next stage in the creation of a smart prosthesis, that solution compared in its functions human hand with, was conducted on two directions: protection of resistive pressure sensors acting as receptors and the creation the system for the transradial amputee interaction with projection-capacitive (PC) touch screen devices [1].

The article is conceptual in its nature and is based on the idea of an artificial hand as a mediator providing a wealth of connections between the amputee and the outside world. We emphasized this circumstance earlier, giving the smart prosthesis the "agent" status [3].

2. System approach and complexity - basic principles of smart prosthesis R&D
Recall that the device we are developing is a complex object consisting of two elements - an artificial part of the hand equipped with sensors and a vibration bracelet, connected by wireless transmission of information. At the moment, this complex is supplemented with a conductive structure that allows the amputee to operate with projection-capacitive screens. This design model can be called two-part or binary (figure 1). This is that we meant under the general term 'smart prosthesis' from beginning. Thus, the spatial separation of the smart prosthesis does not negate its integral consideration.
The principle of integrity is preserved even when attention is paid to particular components and processes. In this case, the only correct approach is to consider them in the ‘artificial organ – human’ system. For example, sensing, as a rule, implies the placement of sensors on the palmar part of a myoelectric prosthesis, immediately puts before researchers a number of questions related to the peculiarities of operation. To answer them the biomechatronics theoretical and practical basis is used. This knowledge suggests imitating the most important functions of the human hand using high-tech quasi-organismic elements.

3. The protective aspect of sensorization

Equipping the smart prosthesis working model with resistive pressure sensors (FSRs) necessitates protection by their own outer shell from adverse factors. It is known that the human skin main function is to protect the body, including the receptor system. To a greater extent this applies to the stratum corneum of the epidermis [2]. As applied to the smart prosthesis, the task is to provide the sensors with a local protective layer similar to the epidermis, but at the same time, by its physicochemical properties, it is resistant to mechanical damage, including abrasion. The second task is to preserve the parameters of the sensors declared by the manufacturer or their minimum deviation from the established norms during operation with the applied protective coating.

During the work, a hardware complex was used, including an STM32F429 microcontroller from STMicroelectronics and an FSR 400 sensor from Iterlink Electronics (figure 2).

The parameters study of the output voltage $V_{out}$ of the silicon protection of resistive pressure sensors with increasing applied forces was carried out using plates of different hardness and thickness provided by Medsil JSC (figure 3).
Figure 3. The graph of the output voltage $V_{out}$ of silicone plates at a pressure from 50 to 700 g.

As a result of experiments, have been identified silicone plates that are suitable for stable tactile forces transmission. The threshold parameters of the actuation and the ranges of the distribution of forces are determined in accordance with the metrological sensors properties, as well as the effect of the conductive materials thickness on the transmitted signals.

4. The phenomenon of screen-compatible prosthesis

One of the transradial amputees problems interacting with the surrounding object environment is the impossibility of operating with the screens of communication devices work on projection-capacitive principle. These include mobile phones, tablets and some types of laptops. The reason for this is the dielectric material from which modern hand prostheses are made, in particular the artificial hands fingers.

To date, it is known about several realized attempts to implement the idea of successful interaction of amputees with PC screens. The largest and most famous of them is the creation and promotion of the i-limb quantum hand prosthesis on the world market by the British firm Touch Bionics [3].

Other notable businesses include Point Design, a US-based company that specializes in prosthetics for amputees who have lost fingers. The most noteworthy is the Point Digit II prosthesis, equipped with titanium fingers with conductive pads [4].

The noted shortage of ready-made proposals for screen-compatible prostheses is combined with a shortage of ideas at the professional level. A rare exception is a patent obtained in the USA by Macduff Charles, who developed a finger prosthesis capable of controlling gadgets equipped with PC screens [5].

In order to compensate for the lack of affordable touch screen-compatible prostheses on the market, individual users are trying to make their own removable prostheses for operating with smartphones using a 3-D printer [6].

Attempts to adapt prostheses to work with a PC screen are made on an individual basis in various ways. One of them is the use of conductive silicone buttons Digits invented by biochemist Brian Shy, usually attached to winter gloves [7]. Another way is to use conductive adhesive foam buttons by Gordon Adkins [ibid.].

As for scientific research in the open press dedicated to touchscreen-compatible prostheses, they are rare [8]. While noting this, we express our confidence that such research is needed. This is confirmed by the above facts of an independent solution of the existing problem.

5. The touchscreen-compatible finger cot concept and its implementation

The idea of creating a touchscreen-compatible finger cot arose on the basis of awareness of the modern mobile phones rapidly expanding capabilities, the contact zone of which and the control
platform of which are and, probably, will be in the near future, the projection-capacitive screens. This idea organically fit into the overall vision of the smart prosthesis we are developing as a communication system that provides the amputee with the outside world in digitalization conditions. And not only with a subject, but also with a social environment, in which the latest mobile phones have become a necessary condition for comfortable integration of a person into the structure of not only interpersonal, but social relations [9-10].

Based on international experience, it is clear that for successful interaction with such screens, it is necessary to have a conductive element as part of the artificial prosthesis finger. The choice of the finger was due to the placement of resistive pressure sensors on the thumb, index and middle fingers. For ergonomic reasons, the ring finger was preferred. In addition, its proximity to the sensor-equipped middle finger allows to adjust the pressing force on the touchscreen.

At the first stage of creating the finger cot laboratory prototype, we tested three samples of conductive silicones. The minimum electrical resistivity was shown sample of the Russian company RT-Technologies based on the silver nanocomponent. During the design of the prototype, a conductive three-component adhesive by RT-Technologies was also used.

![Conductive finger cot experimental prototype](image)

It is planned for further research to use the finger coat experimental sample with higher electrical conductivity manufactured by RT-Technologies using injection moulding.

6. Conclusions
As a result of the experiments was identified possibilities introducing innovative products in the field of prosthetics, providing transradial amputees with:
- long-term tactile contact with the external object environment in the presence of silicone-protected resistive pressure sensors;
- successful social communication through the use of screen-compatible conductive silicones.

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