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New biomedical interface for artificial limbs: review

One of the existing and urgent problems of humanity is maintaining healthy body and its competence. The state of a human body and proper functionality of its systems generally influence the life quality and human welfare, not only physical but mental. Therefore, primary task is solving problems of healthcare and developing new treatment and diagnostics methods of existing pathologies and diseases in many countries.

According to the Department of Labor and Social Security of Russian Federation the number of disabled people has increased to 12.8 millions – it is about 9.2% of all Russian population. Only about 1.75 million people are working-aged. But only 0.508 million people are involved in labor activity [1]. Due to the program of United Nations Organization this number is about 650 million people – 10% of the world population [2].

In addition, people of different disability groups are experiencing great difficulties in socialization because of their disadvantages during the whole life. It dramatically reduces their level of life quality and wounds them mentally. To improve their lives and integrate them into our society is one of the problems which every country and the whole world try to solve.

One of the ways to solve the problem of socialization and improve the life quality is developing prostheses, which can replace lost limbs. Prostheses allow disabled person to fade accent on current invalid disabilities and decrease discomfort, which a person experiences. Also, it can help to adapt to the real world.

There is a great deal of different kinds of prostheses and its classifications. Due to the simplest and general classification prostheses can be divided into two groups: cosmetic and functional.

Cosmetic prostheses have a long history which starts from the times of the ancient Egyptians. It has long been used to disguise disfigurements and injuries, but it has minimally restored functions of locomotor apparatus of a lost or damaged fragment. With evolution of modern technology it is now possible to create lifelike limbs and fragments of face, eyes, ears, which significantly improve life of disabled people.

Cosmetic prostheses production is widespread throughout the world. In Russia more than 70 orthopedic workshops are involved in production of cosmetic prostheses of different limbs and parts. Generally, each workshop is connected with the region to supply it with new prosthesis.

Cosmetic prostheses functional analogs are designed to restore lost functions of locomotor apparatus or organ. These devices can be enhanced by cosmetic lifelike design for the better appearance and disguising. Such combination is the most appropriate for patients. Functional prostheses can be classified into 3 types by their control methods and functions:

Body-powered prosthetic device is controlled by cables connecting prosthesis executive parts with healthy limb or other place on human body, which moving performs action in the prosthesis.

Joint prosthesis is designed to replace lost or severely damaged joints in limbs.

Electrophysiological robotic prosthesis is designed to replace lost parts of locomotor apparatus. It is a robotic device controlled by electrophysiological interface.

An electrophysiological robotic prosthesis represents great interest for prosthetics. Research in this sphere allows developing devices fully replacing lost fragments of locomotor apparatus in the future with minimal discomfort and maximum ability to control. Electrophysiological prostheses contain electrophysiological interface, which is used as an informative parameter electrophysiological body signal to control electronics of a prosthesis device.

Scientists divide electrophysiological interfaces into different groups. One of the common classifications is a group of interfaces by the type of signals. Due to this classification interfaces can be divided into 3 types: electromyographic biointerface, brain computer interface, neural interface.

The main distinction of a brain computer interface is that biological signals are used to register signals directly from brain cortex as the informative parameter signal for executive electronics. Electrodes of the interface are implanted directly into the brain cortex sector to register signals. The obtained data are processed into the control code and then transmitted to prosthesis electronics. The electrode position allows applying this kind of interface in prosthesis for people with such disease as quadriplegia and also can be used in recovering techniques for paralyzed limbs and other parts of a human body. The main disadvantage of the method is invasiveness: getting signals requires a surgery on the brain and implanting a foreign object carrying risks for a patient.

Neural interface is based on using biosignals obtained from a nerve fiber transmitting afferent and efferent signals during the proposal of intended action. Electrodes for such interfaces can be implanted into nerve tissue or placed on or around it without invasion. The main risk of using such technology is probability to loss conductivity, sensitivity of nerve, fiber degradation, demyelinization of host nerve and stress to neural and surrounding tissues [3].

Myographic interface is based on biological signal that retrieved from muscle tissue. Common electrodes of such interfaces are placed over the muscle on the skin. But there is a practice of invasion electrodes into muscle tissue and individual fascicle. The last method can causes risks of muscle mechanical stress and infection of healthy body parts. Implementation of myographic interfaces is widespread in prosthetic devices. The usage of these interfaces is limited by the surface of other muscle parts which provide control of information for prostheses. Currently, the most advanced commercial electromechanical prostheses which replace complex parts of limbs, such as prostheses of arm parts below the elbow, usually require special control. This is a great disadvantage for a patient because of unnatural, cumbersome appearance [4].

Research conducted in Laboratory 63, Institute of Nondestructive Testing, Tomsk Polytechnic University allows achieving the results in enhancing biological interfaces based on electrophysiological signal recording approach of a human body [5]. The results obtained during the process of researching allow developing new class of nanosensors which do not have analogs in the world. Distinctive features of the developed sensors are high noise stability, long operation life, high sensitivity and biocompatibility [3]. The developed nanosesors allows designing new devices with high sensitivity, fast response time, and safe for a human body, such as medical measuring complex, which provide the possibility to look at a human body in a different way.

We plan to use the developed technology for implementation into myographic interface, which allows designing prosthetic devices with such features as high sensitivity, long durability, fast response time due to the absence of inertial blocks; usability and ease of control due to non-invasiveness.

The developed experimental prototype of biological interface consists of nanosensors, a biosignal amplifier block, and a signal processing block. Electrophysiological signals are recorded with nanosensors and amplified with the biosignal amplifier block. Then, the amplified signal transfers to the signal processing block into measuring data which is encoded into the command sequence by the command code formation block for executive components of prosthesis devices, Figure 1.

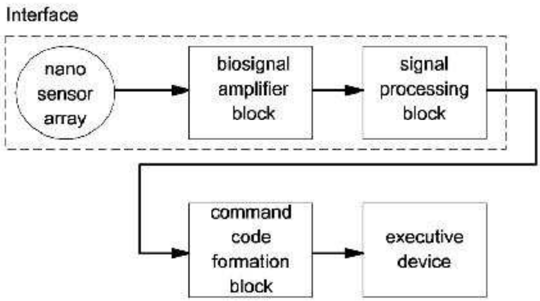

Figure 1. Conceptual structure scheme of the interface in a prosthetic device

Currently, research is aimed at solving such a problem as an optimal ergonomic form of a nanosensor which better fits a human anatomy. In this case the form improvement makes it possible to gain better contact with a body, to ease the use, and to lessen discomfort. By the end of the study, an experimental prototype of the ergonomic nanosensor is to be developed.

It is very important to find new ways to improve the prosthetic bioengineering technologies such as electrophysiological interfaces development, which allow designing efficient prosthetic devices to improve the life quality of disabled people. One of this ways is enhancing signal recording technologies and developing high sensitive and resistant sensors which will allow developing more stable devices and controlling systems for prosthetics.

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Electrocapacitive transducer to control in-process cable linear capacitance

The linear capacitance is a significant parameter of insulated electric cables, particularly, of radiofrequency cables, LAN-cables and communication cables. The value of the linear capacitance is normalized by the standard of an appropriate type of the cable. The technique of cable capacitance measurement is regulated by GOST 27893-88. This technique is used to control the capacitance of a finale cable segment. The disadvantage of this technique is that the cable cannot be controlled along its intire length and the conclusion about the wire quality is drawn after the cable has been produced only. Therefore, it is essential to perform the control of the cable in the process of its manufacturing. In this case the capacitance can be measured with a tubular electrode immersed in a bath of cooling water.

To perform the control the capacitance of a cylindrical capacitor is to be measured. This capacitor consists of a cable core as a cylinder-type plate of the capacitor, and the cooling water the cable is immersed into as the second cylinder-type plate of the capacitor.

Figure 1 shows a schematic diagram of the electrocapacitive transducer. The electrocapacitive transducer consists of a cylindrical metal housing 1, tubular