# The Manipulation of Bionic Prosthesis Using Neural Network Processing Information Principles

Oleg N. Bodin, Galina A. Solodimova, Andrew N. Spirkin

*Abstract*—**The features of the use of bionic principles for the control of robotic mechanisms are considered. It is revealed that the control system of bionic prosthesis should correspond to the biological properties of human body and perform quite complex and complete actions of the motor cycle without direct human intervention, as well as be adaptive with purposeful behavior changes under the influence of external conditions. The article describes the approach to the construction of a control system for a full-functional bionic prosthesis of the lower limb of a person. A neural network algorithm for prosthesis control is proposed, which allows to reduce the power consumption of computing means and increase the speed of the control system. The presence of sensors in the control system allows you to respond to external stimuli and provides a high degree of stability and safety of operation of the prosthesis. The modification of the control system of bioelectrical prosthesis, which is the synthesis of devices for processing of primary information and a control actuator, and the ways of its implementation, allow increasing the functionality of a hip prosthesis, to reduce the cost and size of its elements, to realize his movement in accordance with the natural movement of a person.**

*Index Terms*—**Bionics, robotic mechanism, verticalization, pattern, anthropomorphism, adaptability, neural network.**

## I. Introduction

Despite manifest successes the application of robotic mechanisms in the industry, there are quite a few restrictions on their use. Generally, a strong program manages them. It is not always realized in areas related to control of difficult predictable objects. The problems arise in ensuring the stability, interference protection, adaptability and quality devices, in which standard methods do not necessarily provide right decisions. This problem particularly acute in rehabilitation, where a human was being managed. The object of the study is robotic mechanisms for rehabilitation medicine, where using bioelectric signals for control.

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## II. Statement of the Problem

As we know, one of the most important properties of a living organism is the movement in space. The motor function is one of the only ensuring active interactions human with the environment and his adaptive reaction, among the numerous organism's functions.

Now rehabilitation specialists are focused on restoration not only of standard indicators of motor activity, but, on the formation and rehabilitation of physical pattern of walking. One of the first tasks of stepwise rehabilitation is verticalization patients with amputation of the lower limbs. Currently, bionic prosthesis require the rehabilitation doctors' demands, which are the closest in design to the amputated of the lower limbs. Electromyography signals are used to manage them. The purpose of article is to develop a system the manipulation of bionic prosthesis of the lower limbs, which helps to identify signals of muscle activity and to adapt to the patient.

## III. Analysis Systems Control Bionic Prostheses

Almost until the end of the twentieth century, all inventions in the field of prosthetics were inherently mechanical. The main problem of traditional designs is the lack of flexibility and any connection with the human body, as well as the fragility and unnatural, unsightly appearance. Prostheses, which in the old days replaced the arm / leg, could not work as their full - fledged prototype-the corresponding parts of the body, and were not able to approach their capabilities to the natural counterpart, it's just a surrogate, replacing the active parts of the body, but unable to approach the natural counterpart. All that remains to do their owner is to use them as an element of the wardrobe, which eventually wears out and becomes unfit for further use.

Three types of prosthesis can be allocated by the possibilities of rehabilitative function, amputation of the lower limbs and replacement of cosmetic defect:

1) working prostheses, the simplest in terms of technology products, which are anatomical model of the amputated lower limb, they are usually used for temporary prosthetics, so that a person can adapt and learn the basic skills of using prostheses;

2) functional prosthesis carries out a support function and assists in walking without help. They are passive (do not contain electronic control units). This kind of prosthesis is not

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intended for masking a cosmetic defect. After attachment to a stump such prosthesis can be covered with clothes simply.

3) bionic prosthesis designed for full-functional replacement of a lost limb because of amputation. It is one of the last and the newest generations in prosthetics of the lower limbs.

As a rule, the Russian prosthetic and orthopedic enterprises release functional prosthesis, while the foreign enterprises, such as OSSUR (Iceland/the USA) [1], Freedom Innovation (USA) [2], Endolite (England) [3], Otto-Bock (Germany) [4], Cyberdyne (Japan) [5] offer a big variety of bionic prosthesis for their clients. Bionic prosthesis can fully reimbursed the ability to move after leg amputation. Modern smart systems contain sensors, artificial intelligence and technology drives that can respond to external stimuli like a human: counteract applied load, reduce vibrations, change shape, increase flow and natural movement. However, foreign enterprises use the closed proprietary in their development. This approach guarantees the efficiency of the prosthesis but their use arise dependence on foreign firms for supplies and technical support. Besides, their cost is too high for national consumer.

The development of national prosthesis with adaptive information and measuring control systems is a pressing challenge. This solution will allow the quality of prosthesis functioning and significantly reduce their cost.

A bionic prosthesis is a complex of electromechanical object with a number of features. First, the prosthesis is characterized by a complex of kinematic structure containing many independent or interrelated links. Secondly, change in the orientation of the latter has an impact on a physical forces acting on mechanism. Thirdly, there is a need of synchronous control of a large number of links. Due to these features, the prosthesis requires to a specially developed control systems for full functioning.

Complex of robotic mechanisms, such as the prosthesis, increases the requirements for objectivity of the results of medical and biological research. Variability and individual variation of parameters of objects, their interrelated, non-linearity of these connections, presence of significant in fur make the objective assessment of amputee as a human being very difficult [6].

In order to understand the flow of information from a human being, there should be clarity of his characteristic. The process of manage in such devices implies a feedback and its implementation requires feedback sensors, which measure variable parameters – coordinates, speeds, accelerations, forces, moments, etc. The more importance is in the knowledge of the characteristics of the organization of biological systems during the developing the robotic mechanisms, that communicates biological and technical links in a single control loop. The effectiveness of such systems is fully defined how accurate will be harmonized characteristics of these links, to ensure uniform information environment in which interaction heterogeneous links happens, and the principle of adequacy in selecting of means of exposure is observed.

In this case, the bionic approach is characterized by the adoption of a functional model of the robotic mechanism of the model of the nerve system of higher vertebrates and, above all, of the central nervous system of humans.

The lower limb prostheses should provide two basic functions: the function of supporting (the patient on the prosthesis) and the function of attachment (the prosthesis to the patient's body). The first function is the responsibility of the entire prosthesis design, including the prosthetic socket, and the second function is the attachment system, which is the part of the prosthetic socket [7]. Besides these functions prosthesis of the lower limbs should be ensured stability during standing and during movement (static and dynamic stability respectively), adequate dynamism (mobility of its components relatively each other), the constructive (mechanical) durability, reliability and durability, and a cosmetic (completion of esthetic losses after amputation). In appearance, the prosthesis should be similar to a healthy limb, and walking on it should near to walking of healthy person (if possible) in a kinematic drawing and should not be unnecessarily tedious [8], [9].

## IV. THE CONTROL SYSTEM OF BIONIC LOWER LIMB PROSTHESIS

A generalized structural diagram of the manipulation bionic prosthesis of the lower limb can be provided in the form of two systems (Fig. 1):

1) supporting system ensuring motor function with the help of drives and working body – pivot arm;

2) sensor system supply the mechanism by information about external environment.

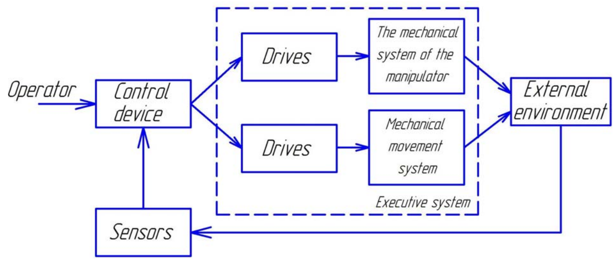


Fig. 1. Structural diagram of robotic mechanism for rehabilitation.

The bioelectric effect transmits from the central nervous system to the muscles reflecting by the increase in amplitude in the so-called motor points – places of the largest accumulation of motor units [7]. The motor point region is the most excitable muscle's section. If the biocapacityis recording in the locations of the motor points through electromyography (EMG), we can get the initial signals for prosthesis control. It is safer to use surface EMG to record biocapacity. The process of mechanical movement control device the manipulation of bionic prosthesis carries out basic functions in real time with processing of sensory information. Organization for control of functional mechanism's movements involves coordination for manage of mechanical movement and co-occurring external processes. As a rule, digital inputs/outputs of the device are used to implement management function of external processes. The interaction is available through the computer-based interface with the human-operator in the autonomous programming mode (offline mode) and directly during the movement's system (online mode). Further, the exchange of information with peripheral devices, sensors and other devices of the system is the function of the control system (Fig. 2) [9].

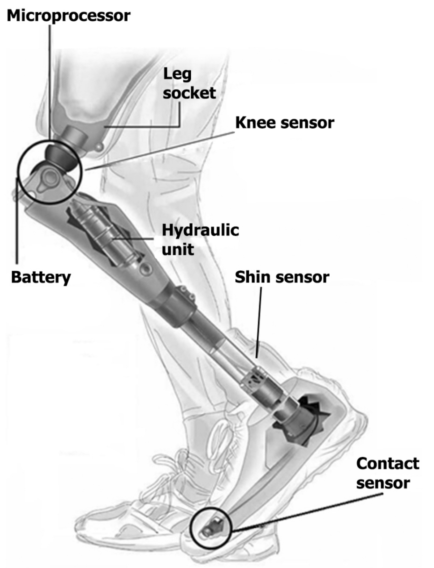


Fig. 2. Structure of the prosthesis.

The reconciliation of identifying functions of the type and values the movement of prosthesis and generation of the manage signal of executive mechanism makes it possible to simplify the structural design of the control system by bionic prosthesis at the level of a single processor. As well as, it makes to increase, the speed of the generation signal control and to exclude appearance of locally conducted signals.

Figure 3 shows the structural diagram of a neural network including recognition and control systems. The diagram shows: RS– recognition system, CS – control system $u_1(t)$, $u_2(t)$, $u_3(t)...u_n(t)$– set of electrical signals human's nervous system, $u'_1(t), u'_2(t), u'_3(t)$– signals characterizing the specified movement's user, $u_{oc1}$ (t), $u_{oc2}$ (t), $u_{oc3}$ (t)– signals from feedback sensor's prosthesis, $u_{упр}(t)$ – the manipulation's signal of neural network.

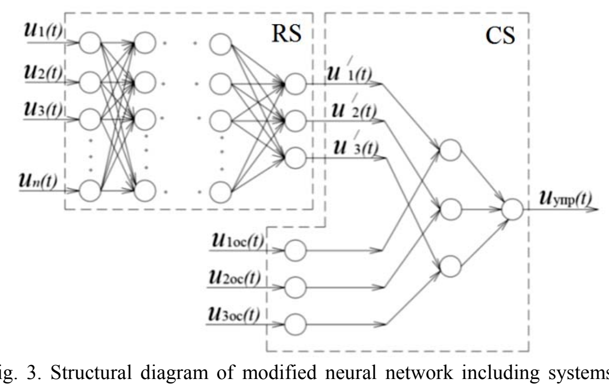


Fig. 3. Structural diagram of modified neural network including systems of recognition and control of a bionic hip prosthesis.

According to the block diagram, the signal generated by the central nervous system of human, will go to the input of the neural network in the form of a set of neural impulse. Neural network provides signal characterizing kinematic and dynamic variables of human motion (angle, speed, increasing inversion of joints). Signals from feedback sensors are proportional to actual values of kinematic and dynamic deviation variables of prosthesis links also are transmitting to neural network input. It should be noted that this method of prosthesis control helps to adapt the movement of the device to the movement of the user, thereby providing a high degree of stability and safety of the prosthesis operation. Thus, the proposed modification of the control system of bioelectric prosthesis, which consists in the synthesis of devices for processing primary information and control of the actuator, as well as ways of its implementation, can improve the functionality of the hip prosthesis, reduce the cost and size of its elements, to realize its movement in accordance with the natural movement of man.

In the process of designing prostheses with bionic control, the main stage is the creation of algorithms for controlling their movement, which are used in the implementation of the prosthesis movement with microcontroller and neuroprocessor formation of control signals of Executive mechanisms. In accordance with the structural diagram of the control system of the bionic prosthesis, the algorithm should contain the following main stages: initialization of the primary signal values, recognition of the type and values of the human motion variables with the device, formalization controlling signal of the executive mechanism, correction of the actual motion variables in accordance with the preset parameter. Then the block diagram of the algorithm has the form shown in figure 4.

According to the presented scheme, the prosthesis motion control program works as follows:

Block 1. Initialization of input variables characterizing electric signals generated by human's central nervous system.

Block 2. Recognition of a type of the movement of the person on input findings: rise and the movement on an in-line surface, each of which contains own values of corners of a deviation of joints lower limbs. The values of speed and increased rotation hinges of prosthesis are carried out in this stage.

Block 3. The movement of the prosthesis checked on conformity of predefined.

Block 4. If the condition of block 3 is implemented, then control signals are generated for rectilinear movement and during the rise. If neither condition is not fulfilled, then program transition to block two.

Block 5. Spin cycle of prosthesis joints is performing with preset values by angle, speed and moment until angle to turn engine rotor came to value a1кон. At the same time, kinematic and dynamic rotation variables correspond check to human variables motion. If condition is not fulfill, then electric engine rotation variables are correcting.

Block 6. If $a(t) = a_1кон$, then a cycle of reversible rotation of prosthesis joints is performed with specified values in angle, speed and moment. If $a(t) = a_2кон$, then the motion cycle is complete.

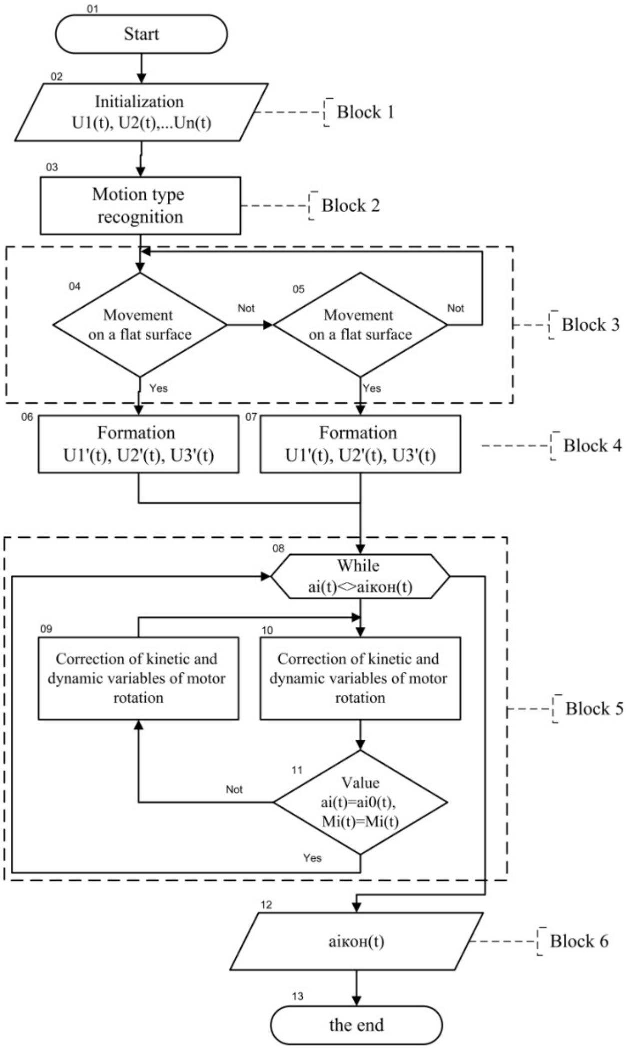


Fig. 4. Algorithm's control bionic prosthesis motion.

It should be noted that the hardware implementation of the presented algorithm for controlling the movement of bioelectric prosthesis is possible on the basis of microcontrollers and neural network processors.

## V. Conclusion

The proposed system and control algorithm gives the user the opportunity not to think much about how to perform movement but at the same time gives the possibility to directly influence the parameters of functionalization of its bionic intellectual limb.

That there were sensors in the control system will allow responding to external stimuli as human: to counteract the applied load, to reduce vibrations, to change the shape and to increase the smoothness and naturalness of the movement.

Thus, the development of a prosthesis taking into account bionic control methods makes the prosthesis intelligent, that is can collect information about the environment, making decisions and controlling its behavior in a real environment. The use of neuroprocessor allows not only to increase the speed of the system, but also to reduce the resource-intensity of software algorithms.

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