# Prospects for the Use of Wireless Reading of Prosthetic Control Signals and Methods for Generating Commands

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***Abstract*—In order to develop effective low-cost prosthetic limbs for people with disabilities, it is proposed to implement wireless communication of sensors used to pick up control commands and prostheses. In this case, the sensors can easily be placed anywhere in the patient's body, which expands the choice of effects on the prostheses. This concept is based on the decision to abandon the built-in biosensors in order to reduce the cost of prostheses, reduce the pain of their use and expand the range of prosthetic coverage, including segments of the population with incomes below average. The paper substantiates the use of low-power mobile phone network and the use of neural networks to create individual prosthetic control algorithms. The results of the first experiments in this area are given.**

***Keywords*—bio prostheses, robotics, androids, artificial limbs, intelligent sensors, wireless communication**

## I. Introduction

The task of creating effective prostheses based on low-power electric motors and sensors is fundamentally solved, but this solution remains quite expensive and therefore it is not available for most people with disabilities in countries with not the highest standard of living. Effective limb prostheses cost more than $100,000 [1], while the simplest models that provide the minimum necessary functionality and form an acceptable appearance can cost up to $350. Indeed, the recent appearance on the market of a large number of cheap MEMS units, that is, technical means based on electrical and mechanical micro assemblies, makes it easy to assemble quite complex robotic products. The main difficulty in creating these is the best choice of components and in combining their functionality with using software tools, the development of which is the most time consuming [2–13]. Separate missing parts of the robot can be made individually on a 3D printer.

In this case, the problem of reading of the commands from the body of the disabled person and transferring them for the performance of the electromechanical part of the prosthesis is relevant. It is proposed to expand the area of the skin from which such signals are taken using electrical potential sensors (or other sensors that the patient can influence). In this case, it would be inconvenient to stretch the wires from a large number of skin areas to the prosthesis, therefore, a wireless connection of a group of sensors to the prosthesis is proposed, or, if necessary, a wireless connection of each sensor separately. The rationale for this decision is the fact that the remaining part of the limb may not provide the patient with sufficient opportunities to form a sufficient set of commands, however, the patient can adapt to use other areas of the skin to send similar commands.

## II. Statement of the Problem

Based on the said problems, the actual direction is the wireless communication between sensors that send commands and the prostheses. In this regard, the question may again be raised whether this approach will not lead to a substantial appreciation. The answer is that, if the cost of prostheses is critical, of course, the user can refuse the wireless solution and use a primitive technical solution with ordinary wires. But as many people with disabilities exist in the world, so much, it seems, there are also peculiarities, both financial and specific in the sphere of needs and capabilities of a disabled person. Wireless communication is becoming more affordable and cheaper, especially since this is not about long-distance communication, but about the closest one, the distance corresponds to the distances from a regular phone to its wireless headset, or from a wireless mouse (or keyboard) to its master computer. The relevance of this approach is due to the need to use such prostheses by people with disabilities, as well as the availability of the necessary software and hardware to implement such devices.

The tasks requiring wireless control solutions are the following:

• creation of a data acquisition and transmission system based on a microcontroller board;

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• creating a program with a server and visualization of the collected data;

• modeling a data processing system based on the neutron network.

## III. Implementation of the Data Transmission System

As an example, an ordinary joystick was selected for the input device, giving two signals to the output (X-axis, Y-axis). A modified WeMos D-1 Mini board with an STM-32 microcontroller and an integrated Bluetooth module was chosen as the control device. Data transmission was carried out using low-energy Bluetooth technology specification - BLE [2].

As a server, a mobile application developed in the C # language in the Unity3D development environment. A 3D model of the hand was made and animated with four main gestures. For the model experiment, a remote control of the hand model was carried out with a joystick.

Such a data transmission system is the most optimal solution in terms of speed, track and power consumption. BLE technology has proven itself in many Internet of Things projects. The characteristics of the selected board (dimensions - 31×39 mm2, weight - 3 g) make it possible to mount it to any sensor system without a significant change in weight and size. Table 1 provides a comparison of the characteristics of the technology BLE and Bluetooth. It can be concluded that the main parameters of the technology with low power consumption are not inferior to the classical ones, the data transfer rate in any case remains sufficient, the range is not relevant, a small radiation level can be regarded as an additional positive feature from the perspective of safety for the user.

Figure 1 shows a diagram of a data acquisition and transmission model. Figure 2 shows the main gestures that were worked out according to this scheme.

In the case of using the chosen sensors, the main problem is the interpretation of the combination of signals from the electrodes as a specific hand gesture. In the case of a large number of sensors, this combination can be very difficult and the construction of a specific mathematical model using standard methods is extremely difficult. In addition, the complexity of the bijective mapping of sensor signals to the position of the hand is obvious (the dimension of the input and output tensors do not coincide, and if such a coincidence is artificially achieved, the physical meaning of the tensors will still be different). For example, Figure 3 shows such a display by the example of three sensors controlling a prosthesis with 15 servo drives.

Based on this, a method of two-factor identification of the hand posture based on neural networks is proposed. The same data from the EMG sensor system is first launched into the neural classification network, which determines which particular gesture they are closer to (for example, capture), and then into the neural regression network, which determines the linear degree of action (how much to squeeze the arm during).

Figure 4 shows the neural network classification model (3 logical outputs - 8 different gestures), and Figure 5 shows the model of a neural network of regression with the calculation of the optimal number of neurons in the layers and an indication of the position of the Dropout.

TABLE I. COMPARISON OF BLE AND BLUETOOTH TECHNOLOGIES [2]

| **Data sheet** | **Classical Bluetooth** | **Energy efficient Bluetooth** |
|---|---|---|
| Radio frequency | 2.4 GHz | 2.4 GHz |
| Distance | 100 m | >100 m |
| Airspeed | 1 – 3 Mb / s | 1 Mb / s |
| Bandwidth | 0.7-2.1 Mb/s | 0.27 Mb/s |
| Minimum total data transfer time (depends on battery status) | 100 ms | 3 ms |
| Power consumption | 1 W as initial | From 0.01 W to 0.5 W (depending on use cases) |
| Maximum current consumption | < 30 mA | < 15 mA |

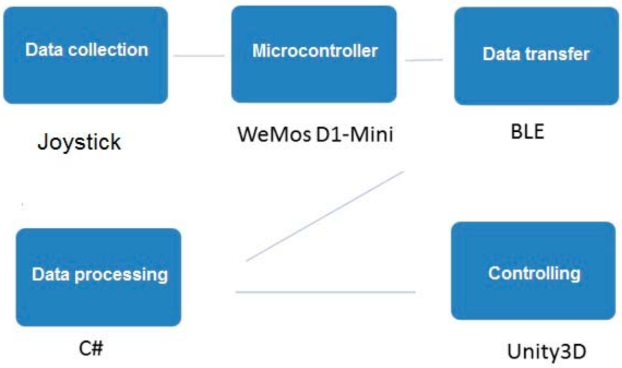


Fig. 1. Diagram of the data collection and transmission model

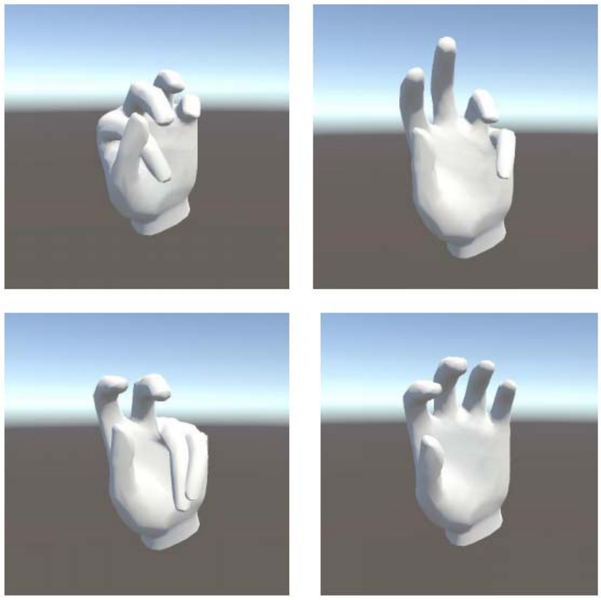

Fig. 2. Basic gestures in the mobile application interface

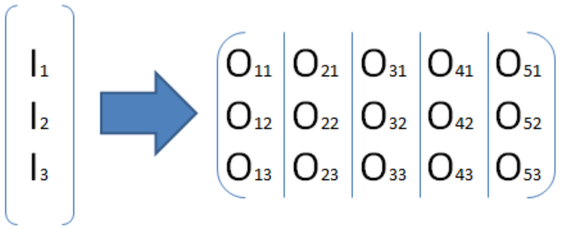


Fig. 3. Display on the example of three sensors that control the prosthesis with 15 servo drives

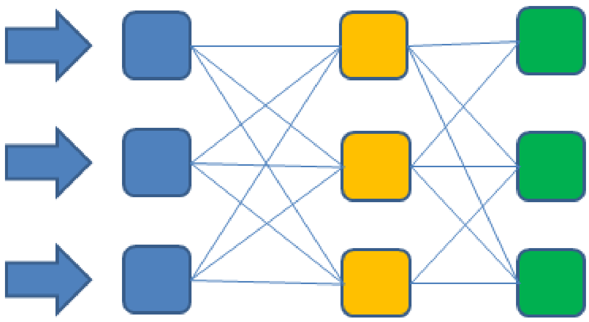

Fig. 4. Model of neural network classification (3 logical outputs - 8 different gestures)

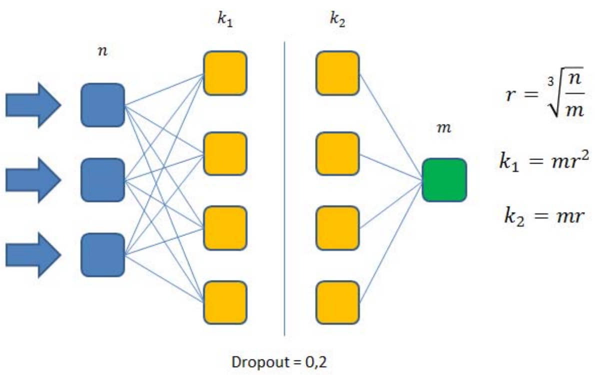


Fig. 5. Model of the neural network of regression with the calculation of the optimal number of neurons in the layers and indicating the position of the Dropout

Network models were implemented in Python using the Keras machine learning library. Due to the alleged work with a large amount of data, Dropout was placed on some layers, randomly removing some of the connections to prevent retraining (for example, over-fitting a particular person). In the future, it is planned to generate material for teaching models by simultaneously wearing a man of our system of myoelectric sensors and wearing finger position sensors. After that, the data will be synchronized in time and transferred to the model.

## Conclusion

Based on the analysis of the main problems of creating low-cost prosthetic limbs for people with disabilities, it was proposed to exclude the use of implantable electrodes for mass products, replacing them with a sufficiently large number of sensors applied to the patient's skin. It was proposed to expand the places of application of electrodes, adding to them, perhaps, skin areas not only from the residual part of the limb, but along the entire body of the disabled person, based on his personal preferences and capabilities to a greater extent than on the technical capabilities of a specific prosthesis model. In this case, it is proposed to use the wireless connection between a group of sensors and a prosthesis or in perspective between each sensor and a prosthesis to eliminate the problem of long wires throughout the body. The dependence between the removed control signal and the action performed by the prosthesis can be easily reprogrammed, the most effective set of functional solutions are proposed to be found using neural networks. In this case, if the patient's preferences regarding the placement of sensors on the body and their functions in the formation of commands change or if these preferences are different when performing different operations, the established dependency can be rearranged or one of the preset control options can be selected. For example, when performing household functions, the patient can only comfortably control the brush as a whole, that is, the command set can be small, for more reliable control various sensors can perform the functions of ensuring the reliability of command perception. If the patient wants to train to perform more complex operations (flipping a book, working on a computer, a hobby), he can assign a special option to manage the prosthesis, including using such unexpected features as, for example, toes. The advantages of the proposed individual adjustment of the connections between the sent signals and the commands performed become most effective with sufficient freedom in placing the sensors and varying their number, which is achieved by wireless communication and neural networks to decipher the commands and form stable connections between the commands sent and the actions performed. The use of actuators to form a reverse effect on the skin of a person in the form of a small pressure allows the disabled person to "feel" the effects of artificial limbs on objects, creating the effect of sensation. The use of wireless technologies based on low-power Bluetooth technologies or their analogues has been proposed and experimentally justified. Conducted preliminary research.

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