Gesture recognition system based on electromyography signals

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Abstract. The subject of the study is a gesture recognition system based on an electromyography signal for controlling anthropomorphic prostheses. As a result of the work, signals were received and written to files, software was developed for processing and filtering signals, as well as for recognizing gesture patterns. The resulting system will allow to determine various hand movements based on the electromyography signal and control anthropomorphic prostheses.

1. Introduction
The structure of the human hand, its anatomical features are the result of long evolutionary progress. Upper limbs are among the most important functional units in the control processes, and human life in general. These units are involved in both simple and complex behavioural processes. Unfortunately, the case of an emergency in which a person is deprived of one or both hands. In such a situation, there is only one solution - prosthetics. The Russian Federation has more than a thousand people a year in need of prosthetics. As a result, providing a person with a fully functional prosthesis is a very urgent and important task. When developing such devices, there are a number of limitations associated with signal instability, the influence of motion artefacts, various noises and interference. [1].

2. Theory
The main difficulties in the development of such areas as prosthetics of the upper extremities are caused by an acute shortage of methods, solutions and end products associated with the adequate reproduction of fine motor skills of the hands. The process of movement of the human hand occurs automatically, on a subconscious level. Most of these movements are performed simultaneously. And as a result, the human hand has more than 25 degrees of freedom, which imposes a great responsibility on the prosthesis management system. Upper limb prostheses can be divided according to various criteria: depending on the degree of limb loss, by its functional, by type of control. Figure 1 shows the classification of upper limb prostheses [2].
The process of functioning of modern prostheses is based on a non-invasive method of perceiving signals from the human body. Signals that carry useful information are electromyography signals (signals from human muscles) [3]. The main problem is the small number of attachment points for myoelectric contacts [4]. It is also necessary to filter various noise and interference in the signal under investigation. Obtaining the main characteristics and patterns of signals. If all the conditions are met, there is a potential opportunity to identify in the signals various patterns responsible for hand gestures. Which, in turn, is the main task of the prosthesis [5].

3. Research

3.1 Electromyography
Electromyography (EMG) is one of the most popular methods of collecting signals from human muscles. There are two main methods of electromyography: invasive and non-invasive. The invasive method is the placement of needle electrodes directly into a person’s muscle, which imposes some limitations for continuously controlling anthropomorphic devices. In this regard, it is allowed to use only the non-invasive method of perceiving biophysical signals: glued contact pads, dry electrodes.

To obtain electromyography signals suitable for processing and generating control actions, it is necessary to develop a technical recording device. This recording device must meet certain requirements: the presence of an amplifier with a high input impedance, operating in the EMG frequency range, with the ability to suppress common mode voltage. The frequencies of electromyography signals fluctuate in the range of 20 Hz - 2000 Hz [6]. The recording device is attached to the human body by means of glued electrodes. Previously, the surface of the skin should be treated with a conductive gel. This condition is necessary due to the fact that skin resistance can vary in the range from 0.5 kOhm to 500 kOhm depending on various factors: skin type, a person’s physical condition, his psych emotional state, temperature and pressure [7].

Based on the requirements, a system was developed for collecting and processing electromyography signals recorded from two muscles of the right arm, and their study was conducted. Since the recording system receives a potential difference, then for each muscle two electrodes are needed, as well as one common electrode connected to the electrically neutral tissue of the hand (mainly the elbow). The muscles to which the electrodes were connected are the radial wrist flexor
(musculus flexor carpi radialis) and the ulnar extensor of the wrist (musculus extensor carpi ulnaris). Sampling frequency selected during the collection process - 1000 Hz. These signals were recorded in csv files (Comma-Separated Values). This format is convenient for working with signals in any development environment and software products.

3.2 Software
To research the received signals, software was developed that allows their further processing, filtering, and obtaining the resulting patterns of hand movements. This software was written in the G language in the LabView software environment. Figure 2 shows the front panel of the program.

![Figure 2. The front panel of the program.](image)

The program consists of four main blocks: a settings block (1), a block for displaying information of the first signal (2), a block for displaying information of the second signal (3), an image block for the resulting gesture (4).

In the settings block (Figure 3), it is possible to select the files themselves with signals, with the possibility of their separate connection. The choice of type and order of filtration. Setting thresholds, which is a prerequisite for calibrating the entire system. Ability to display indicators of muscle contraction.
Figure 3. The settings block.

The blocks for displaying signal information (Figure 4) are identical and consist of: a signal output window without filtering (Figure 4, 1,4), a signal output window with filtering (Figure 4, 2,5) and the rms value of the signals (Figure 4, 3,6).

Figure 4. Signal information display block.
Filtering of signals was carried out on the basis of a discrete wavelet-transform. The choice of the basic wavelet and its order is carried out in the process of the program itself [8]. The most commonly used and popular type of basic wavelet is the Daubechies 4th (db04) 6th order wavelet. Wavelet transform and filtering are presented in more detail in another paper [9].

4. Results
A further implementation of the program is to obtain the resulting gestures. If the threshold value of the signal is exceeded, a logical one appears on the binary output. When a logical unit appears, the anthropomorphic prosthesis control system is triggered. If such logical units work simultaneously for two signals, then the gesture does not occur according to the logical function XOR. To obtain hand gesture values, the binary value of one of the signals is multiplied by 2, and as a result, four possible solutions appear. The logical values of the signals and the results of their mathematical operations are presented in table 1.

| EMG 1 signal | EMG 2 signal | XOR | EMG 2 signal *2 | Result | Gesture |
|--------------|--------------|-----|-----------------|--------|---------|
| 0            | 0            | 0   | 0               | 0      | Neutral |
| 0            | 1            | 1   | 2               | 2      | Closed  |
| 1            | 0            | 1   | 0               | 1      | Open    |
| 1            | 1            | 0   | 2               | 3      | Neutral |

In the fourth block of the program (Figure 5), the output of the resulting gesture is implemented and images of four possible solutions are presented. The first solution is that the arm is relaxed and in a free position. The second solution - the hand is open and raised up. The third solution is a hand clenched into a fist. The fourth solution - the hand is again relaxed and is in a free position. Figure 5 shows all the investigated gestures [10].
Figure 5. Gestures received on the basis of the program, a - in the free position, b - in the open position, c - in the closed position, d - in the free position.

5. Conclusion

The result of the work is a working gesture recognition system based on the electromyography signal. The developed software allows you to determine the muscle contraction in a particular muscle group, based on four points of perception. The opportunity was obtained to identify a specific position of the arm, and to develop an appropriate response to control an anthropomorphic prosthesis. There is an option to write received signals to files for storage and further processing.

6. References

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