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VARIOUS CONTROL STRATEGIES FOR THE ARTIFICIAL HAND USING SURFACE EMG SENSORS: FIRST EXPERIMENTS AND RESULTS

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Abstract: *In this article short overview of existing methods of electromyography sensors placement and control strategies of the artificial prosthetic hand was made. Also the explanation of necessity for different strategies was given. The new methods and algorithms to process electromyographic signal were proposed. The experimental results for one of the described methods were shortly estimated and analyzed.*
Key words: electromyography, signal processing, prosthetics, control system (12pt)

1. INTRODUCTION

According to the current level of technology it seems strange that the bionic prosthesis doesn't appear as common thing. The main problems are their high cost, not intuitive control system, lack of feedback, limited functionality, limited battery life, poor dexterity - all of these criteria restrict and hinder wide spread of these products. Most of bionic prostheses use electromyography (EMG) as a way to receive signals from the muscle groups in the hand of the patient to fulfil control tasks, but their interpretation is still causing difficulties and far from perfect. Various research groups conduct studies in the field of signals processing, but the investigation shows that only small part of the results is used in real devices, which would be used by patients with amputation of the hand.

The aim of the work is to create a set of different control strategies for the bionic prosthesis and their further implementation by using EMG sensors and their direct connection to the MatLab environment to process signals and to control the wrist prosthesis. After this stage the effectiveness of the key parameters and implementation of strategies for the different occasions will be assessed.

It is necessary to highlight some of the most critical parameters, which will effect on the strategies and their subsequent evaluation. The following parameters were chosen:

- the number of electrodes;
- the zone of electrodes placement;
- the height of amputation;
- the processing speed;
- the intuitiveness of control system;
- the number of functional grasps.

Research groups around the world use a different number of electrodes for obtaining data from the surface of the hand. In particular, there were variants with 2 electrodes [4], 4 electrodes [2,3], 10 electrodes [1], 14 electrodes [6], thereby increasing the amount of processed data that affect the data processing speed and consequently for the convenience user, as there is a delay can be critical in some situations, the use of the prosthesis. Furthermore, there were different variants of electrodes placement on the arm of an object, depending on the number of electrodes and height of amputation.

2. STRATEGIES

The following control strategies were identified on the basis of the number of electrodes: strategy with one electrode, with two electrodes, with three electrodes and n number of electrodes. For all the signals obtained via electromyography certain requirement was emposed: the signal had to overcome the input threshold value of 1 mV to prevent involuntary muscle tremors.

2.1 Strategies with one electrode

The several control strategies for a single electrode have been proposed. The first strategy is receiving a signal, i.e. the electrode located on the muscle group receives a signal. The signal processing is took place in MatLab and hand prosthesis performs simple actions - power grip. Moreover, the force of the grip can be adjusted depending on the duration of the muscle contraction. For the opening of the prosthesis the muscle contraction should be repeated. In this case electrodes were placed on flexor digitorum profundus. A result after primary filtration and processing in MatLab is shown in Fig. 1.

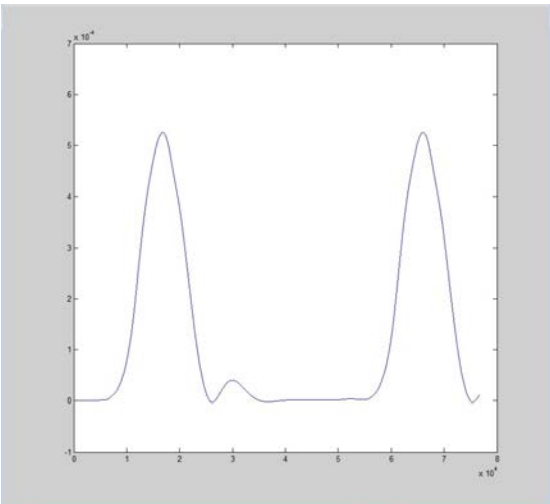

Fig. 1. Receiving of a single signal on flexion and extension after the initial treatment

The second strategy using a single electrode was to obtain a specific set of commands that are described in [5]. In this case, it is necessary to receive a certain command signals, and the patient was at high speed to reduce / relax the muscle group. single muscle contraction, prolonged muscle contraction single, double muscle contraction intervals between innervation than 2 seconds - the next signal system has been proposed. Display signals in Matlab is given in Fig. 2. In this case, the patient had had a choice of at least three pre-stored grasps.

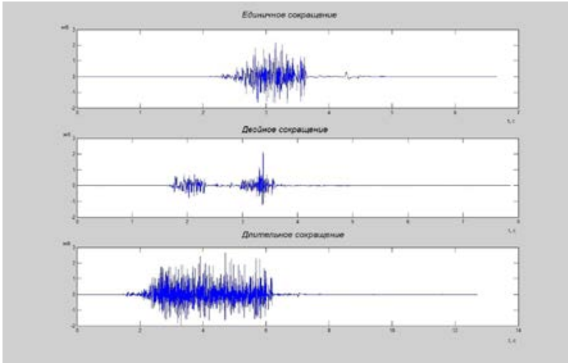

Fig. 2. The examples of three types of signals for the second strategy with one electrode

The muscle contraction should be repeated to exit from the working mode and return to the initial position of the prosthetic hand. The transition between the different types of grasps was assumed via the using of the pre-programmed muscle contractions. In this case, sensors also were placed on the flexor digitorum profundus.

2.2 Strategies with two electrodes

In the case of usage of two electrodes is also several control strategies have been proposed. The general concept was the fact that the electrodes are placed on the antagonist muscles, in this case it were the extensor & flexor digitorium. The first strategy proposed to implement a strategy similar to the first, with one electrode, when a person sends a signal to the prosthetic control system and mechanism came into one of the pre-programmed grasps. The difference lies in the fact that the patient have to make contraction of extensor muscle to return into initial position. This approach is similar to the approach implemented by nature.

The second strategy with two electrodes was an extension of the first strategy with two electrodes, but with the difference that it allowed you to use a larger variety of the grasps. This was achieved by using two electrodes to switch between the grasps. The man had to make a simultaneous contraction of antagonist muscles to switch between grasps, and then repeat the algorithm described in the first strategy for the two electrodes. In this case were used the same muscle groups - extensor & flexor digitorium.

2.3 Strategies with three electrodes

The control strategy with three electrodes brings us to the issue, which had not previously been reviewed in the proposed strategies - the separate control of each of the finger. In this strategy, we have made some assumptions. We divided the work of fingers into three groups: I - thumb, II - index and middle finger, III - the ring finger and little finger. We defined following muscle groups as places for receiving signals via palpation and observation of hand movement. The electrodes were placed on forearm as shown in Fig. 3. For the work of first group was responsible brachioradialis muscle (musculus brachioradialis); for the second square pronator (musculus pronator quadratus) and for the third group the deep digital flexor (musculus flexor digitorum profundus).

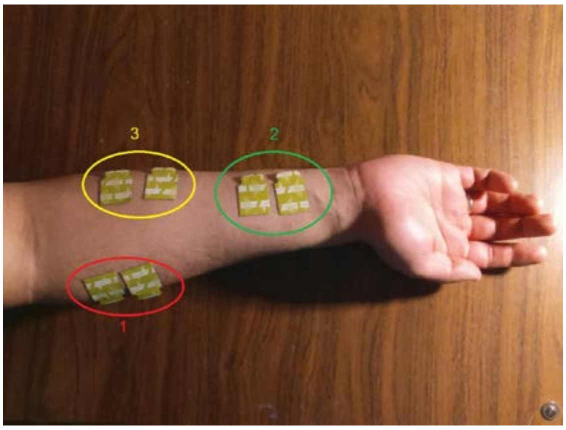

Fig. 3. The electrodes placement of the forearm (first, second and third group)

As a result, several types of grasps of healthy human have been analysed and it is determined that the data signals can be used to control the prosthesis in its simplest form, ie man exercising muscle contractions and a group of fingers are bent in accordance with the wishes of the patient. This strategy is quite simple to implement, since it is necessary to recognize the muscle contractions, which directly control designated fingers. The algorithm is based on analysis of the three channels of the electromyograph, if the threshold is exceeded the system understands that it is necessary to produce flexing of fingers associated with the channel.

3. FIRST TRIALS

The first experiments were carried out on the above mentioned strategies and received data was analyzed. However, the equipment used for the experiments does not allow the processing of data received from the electromyography sensors in real time. Therefore another type of sensors ("Grove - EMG Detector") were used. These sensors can be connected to the Arduino board with an opportunity to process the data in Matlab.

The electrodes were placed as shown in Fig. 4. The signals from the sensors after muscle contraction were sent to the Arduino Uno. To prevent unexpected movements into the body of control code threshold was added.

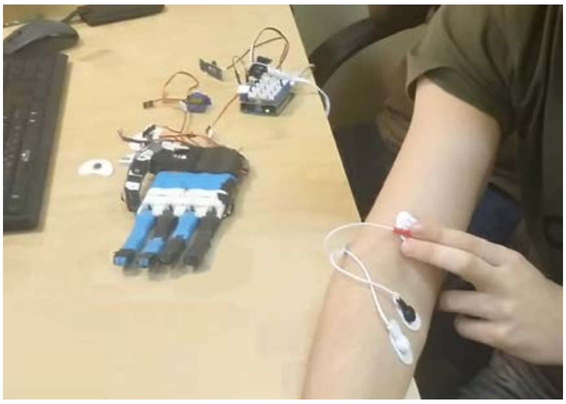

Fig. 4. Testing control system based on EMG signals

After obtaining of the desirable value a control system sent a signal to the motors to move into pre- programmed position (desirable grasp). In this version a hand could move into one position, but in the nearest future it will be available to use at least three different type of the grasps via using just one electrode (second strategy with one electrode).

4. CONCLUSIONS AND FURTHER PLANS

As a result of theoretical, practical and analytical work It has been proposed and partially implemented control strategy with one, two, three electrodes and formed a work plan with the direction with the n-number of electrodes.

Based on the criteria given in the beginning, we can say that the most attractive in the processing speed is a strategy with one or two electrodes, since they require minimal signal processing time can be used irrespective of the the height of the amputation of the patient, as well as take up a minimum amount of space. In terms of the number of grasps are the most effective strategy with three and two electrodes operating in switching mode.

The most successful in terms of intuitiveness (one of the most important parameter, since it directly affects the patient's addiction to the prosthesis) was an approach with three electrodes and two electrodes operating in a mode and mode switching with a simple grip.

These algorithms will be tested in the near future in healthy subjects as well as subjects with amputations. In addition, it is necessary to work out approaches with the use of neural networks as in [7], and other algorithms to create patterns according to the received signals, which will increase the amount of seized and increase agility wrist prosthesis.

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