REAL TIME EMG DETECTION IN THERAPEUTIC GAME

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Abstract: This article focuses on real-time detection of activity in electromyographical signal. The study is based on controlling the therapeutic game through the muscle activity, called myofeedback. Many different algorithms can be used to detect EMG signal. Nowadays there is rapid development of artificial intelligence not only in biomedical engineering. In this paper there is implemented convolutional neural network for signal segmentation with accuracy 97,13%.

Keywords: EMG, UNET, game, signal, biofeedback

1 INTRODUCTION

This work deals with sensing the electromyographic signal (EMG) and detecting muscle activity in real time. Electromyography is used in the diagnosis and therapy of the musculoskeletal or nervous system. To increase the motivation of the proband, a therapeutic game based on myofeedback was designed and implemented. The game is used to measure and possibly improve the user's reaction time.

There are a large number of methods that can be used to detect activity in an EMG signal. These can be based, for example, on thresholding, wavelet transform, empirical signal decomposition or artificial intelligence. [1] In order to calculate the reaction time, it is desirable that the chosen method of activity detection in the EMG record be as accurate as possible and at the same time the data processing time is minimal.

In recent years, there has been a rapid development of artificial intelligence, which also increases the popularity of these methods in solving segmentation problems. In most cases, however, these are two-dimensional signals (images), not one-dimensional signals. Equipping already learned networks is very fast. In this work, a convolutional neural network with U-Net structure was designed and programmed for signal classification. The network classifies individual samples of the EMG signal into two categories - resting sections and sections representing muscle activity, which then allows the calculation of the proband's reaction time.

2 BIOFEEDBACK

Biofeedback, or biological feedback, is used for therapeutic purposes in various medical disciplines. This technique is based on real-time recording of a biological signal. Feedback is most often communicated to the patient in audio or visual form. The patient's task is to achieve a predefined goal. For greater motivation, a game is very often implemented, which is controlled based on signal evaluation. [2]

This work focuses on myofeedback, which is feedback using an electromyographic signal. Myofeedback finds application in both diagnostics and therapy. Using myofeedback, it is possible to determine the proband's reactions to stimuli from the environment. It is a very widespread clinical technique in rehabilitation, intended for patients with disorders of the central nervous system (CNS) and patients with diseases or spinal cord injuries. The probe may not be able to function the limbs, but still has the ability to activate the muscles and it is possible to sense the EMG signal, which extends the field of application to robotic limbs controlled by the signal. [2]

3 THERAPEUTIC GAME

In the work, a therapeutic racing game controlled by muscle activity was implemented. The task of the proband is to control the game of contractions and expansion of the muscle and to react as quickly as possible to the surrounding stimuli. The aim of the game is to avoid obstacles, react quickly enough to the relevant stimuli and thus achieve the highest possible score. The development of the game is outlined in Figure 1. During the game, the color of the traffic light changes at random time, to which the player must respond within three seconds by moving the limb (pedal simulation), otherwise the game ends. At the same time, they must avoid oncoming vehicles. If the oncoming vehicle is an ambulance, it will sound and the same reaction is required as when the traffic light changes color and the car disappears. During the game there is a gradual acceleration, which increases the difficulty. At the end of the game, the reaction times of the probands are displayed - the average and the best reaction time.

Figure 1: Therapeutic game

4 EMG SIGNAL RECORDING AND PROCESSING

The BITalino platform is used to record the EMG signal. It is hardware designed to record biological signals. An important parameter is the sampling frequency, which was selected as the maximum possible - 1000 Hz. The signal is stored in the BITalina tank and then loaded into the computer in the window. The window must be long enough to be informative, but it cannot be too long due to the long response time. The signal from BITalina is transmitted to the computer via Bluetooth 2.0, which causes a transmission delay in the range of 90-130 ms. The total delay is therefore given by the sum of the delay caused by the transmission (90-130 ms), the size of the loaded window (100 ms), the signal processing time (max. 5 ms) and the displaying of the corresponding response in the game (max. 3 ms).

In 20 probands, lower limb movement was recorded when the pedal was depressed. During the recording, the patient can sit or even stand. The electrodes for sensing the signal are placed on the lower limb according to the SENIAM recommendation, where to measure the activity of the gastrocnemius lateralis muscle, the active electrode should be placed in one third between the head of the fibula and the heel. [3]

4.1 U-NET NEURAL NETWORK

It is very important for myofeedback that the signal processing is realized in a very short time, ideally real-time. However, for the purpose of calculating reaction times, the accuracy of detection cannot be reduced. For these reasons, the convolutional neural network U-Net was selected and implemented, the calculation of which can be performed on a computer graphics card.

U-Net is a fully connected convolutional network, its structure is shown in Figure 2 on the left. It consists of two sections - an encoder and a decoder. The dimensions of a feature map are shown at the bottom left corner of the element. The value above the rectangle indicates the number of channels. The arrows represent the individual operations according to the legend in the picture. [4]

The input of the designed neural network is the raw signal, so no signal preprocessing is required. In the descending part (encoder) the signal size decreases. Convolution operations create feature maps, these data are normalized and are an input to the activation function ReLU, the course of which is outlined in Figure 2 at the top right. The "max pool" operation performs data subsampling. From a window the size of two samples, only the sample with the higher value is always left, which halves the signal. This operation is described in Figure 2 at the bottom right. In the ascending part (decoder) the signal is resampled.

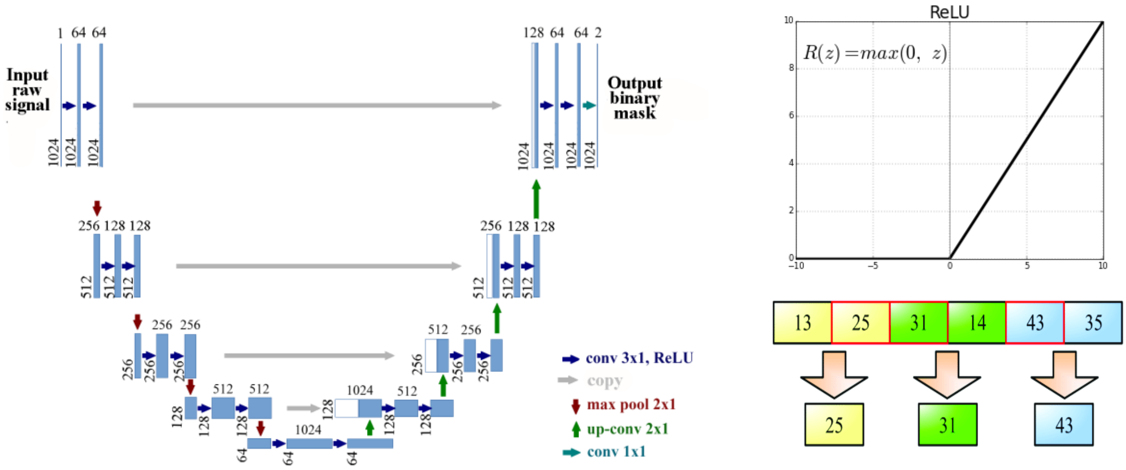

Figure 2: Hierarchy of convolutional neural network U-Net [4]

For network training, a database of manually annotated signals was created, which were marked at the site of apparent muscle activity. The annotation takes the form of assigning a binary value to each signal sample: 0 for calm EMG, 1 for activity. An example of annotated signals is shown in Figure 3. The database is divided into a training and test set, with the training set containing 544 signals and a test set of 42 signals.

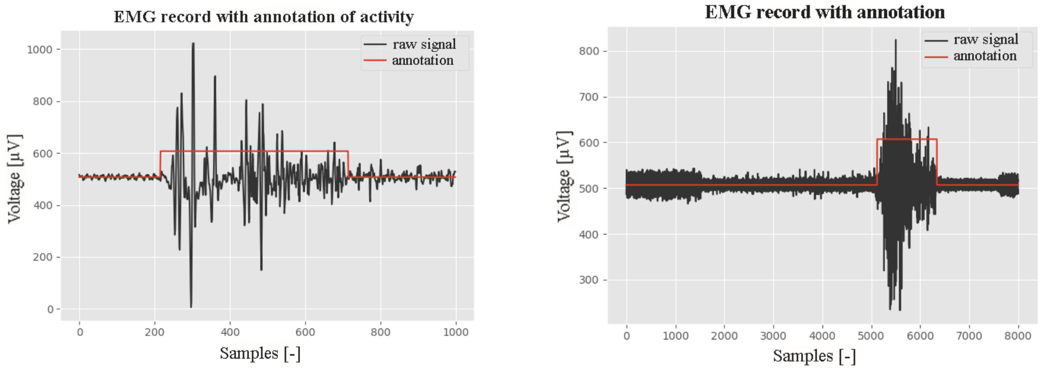

Figure 3: Manually annotated signals

When learning the network, the Adam optimization algorithm is used, which is very efficient. Adam uses adaptive learning speeds for various parameters. The difference between the network output and the reference data is described by the "Cross-Entropy" error function. When training a network, a "dropout" is included in the output layer, which helps reduce the interdependencies between neurons, thereby reducing the likelihood of re-learning and making the neural network more robust. The output of the network is a signal in which all samples are classified into two categories (calm / activity), as shown in Figure 4 on the right. Figure 4 on the left shows the output of the designed U-Net.

4.2 REAL-TIME DETECTION AND RESULTS

The signal from BITalina is read in windows with a size of 100 samples. A signal length of 1024 samples is required at the input of the neural network. Since immediate processing of the current section of the signal is required, this section is connected to the previous, already recorded, signal so as to produce a signal of the desired length - 1024 samples.

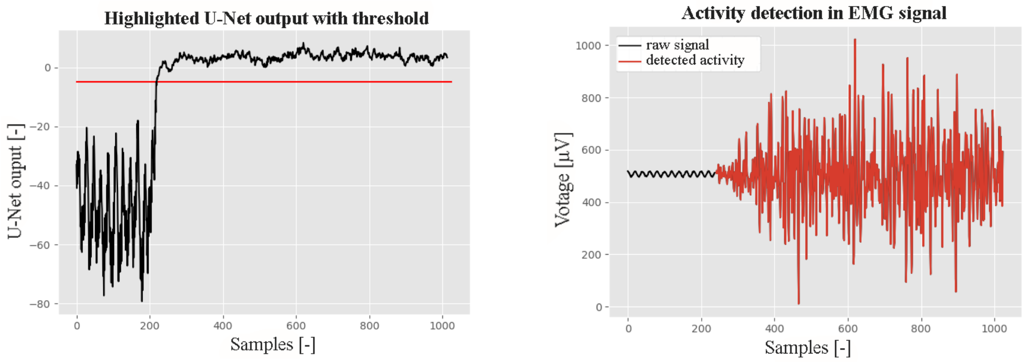

Figure 4: Neural network output, detection of EMG activity

The signal was processed by three different algorithms - the U-Net neural network, the Support Vector Machine (SVM) and the thresholding of the signal modified by the TKEO operator. The calculation was performed on a computer with an Intel i5 processor and an NVIDIA GeForce 940MX graphics card. The results of the methods are compared in Table 1.

Method	Accuracy [%]	Sensitivty [%]	Specificity [%]	Time [ms]
U-Net	**97,13**	**96,50**	**97,30**	4,61
SVM	95,36	94,82	95,47	2,03
TKEO	94,71	90,54	96,19	**1,45**

Table 1: Comparison of detection results by different methods

5 CONCLUSION

An approach for EMG signal processing was designed and implemented in the work, the output of which are signal samples classified into two categories: muscle activity or calm. Compared to other implemented methods, U-Net achieves the highest accuracy (97.13 %). The accuracy of the detection is important especially for the subsequent calculation of the reaction time. The processing of one section of the signal by the U-Net method takes an average of 4.61 ms, but a maximum of 5 ms, which is sufficient for the proposed game. The implemented therapeutic game is used to measure the reaction time, and possible to improve it.

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