Classification of motor imagery parameters from EEG using SVM

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Abstract: Brain Computer Interface (BCI) is a technology to control devices such as prosthetics, cars, and other control-related applications using brain signal directly. Currently, EEG-based BCIs are mostly used for classification between different limb effectors, and only few commands can be generated directly. To improve the command number and control efficiency, both clench force parameters and clench speed parameters are studied independently. In this paper, we try to decode speed and force hand movement imagination at the same time. Alpha band power of EEG signal is extracted as feature and then classified by Support Vector Machine (SVM). The primary result shows that speed and force motor imagery of the same hand is distinguishable, which means direct BCI control commands in the future.

Keywords: Brain-Computer Interface (BCI); motor imagery parameters; Support Vector Machine (SVM)
different combinations of RTD and target-torque (TT) from single-trial MRCPs during right foot imaginary tasks. Their results indicate that both TT and RTD can be classified using single-trial EEG traces [19]. On the other hand, Yuan proved that alpha, beta and gamma bands all correlated with speed decoding of imagined hand movement [15].

In this paper, we first attempt to investigate different EEG characteristics between clench speed motor imagery and clench force motor imagery, and classify EEG of the two types using support vector machine (SVM). Our results show that speed and force motor imagery is separable, which may provide more direct control commands for BCI systems.

2 EXPERIMENT DESIGN

2.1 Subjects

Six subjects aged 24-33 years (mean 26.8 years) took part in the study, including 3 male and 3 female. According to training level, they are divided into two types. One type are trained more than 3 times, while the other type are not trained and only be told how to complete the experiment. All of them are healthy subjects without sensory-motor deficits or any history of psychological disorders. The experimental procedure is approved by the Ethical Committee of the Shenyang Institute of Automation (SIA), Chinese Academy of Sciences (CAS). Written informed consent to participate in the experiment was signed by all of them.

2.2 Experiment paradigm

A single trial of the experiment is divided into four periods. A short beep is excited to remind the subjects the start of the trial. After 10 seconds baseline time, a cue is presented to inform the subjects which type of hand movement is to imagine when the cue disappears 2 seconds later. The motor imagery task sustained 10 s, followed by a random rest time between 10-12 s. The baseline time, task time and rest time is much longer than usual EEG paradigms because we acquired functional near-infrared spectroscopy (fNIRS) signals at the same time. The results of the fNIRS signal analysis can be found in our other papers [31, 32]. We will research the combined EEG-fNIRS signals in the near future.

Every subject participates in 3 sessions of the experiment, and every session includes 30 trials of right hand clench speed imagination task and 30 trials of right hand clench force imagination task.

2.3 Data acquisition

EEG signals are acquired by Neuroscan synamps2 with a sample frequency of 1000 Hz. 21 Ag/AgCl electrodes are used according to 10-20 system [33], as shown in figure 1. A1 is used for reference, and Fpz is used for ground.

3 DATA PROCESS METHODS

3.1 Preprocess

The EEG data acquired is re-referenced to common average reference first and down sampled to 250Hz to decrease the feature dimension. Then, each channel is processed with a Laplacian filter described in Equation 1 to increase spatial resolution, where $S_j$ is the set of 4 channels around the channel $j$. A 4th order IIR Butterworth band pass filter with a cutoff frequency of 0.5 Hz is used to remove low frequency drift, and two notch filters with stop band center frequency of 50 Hz and 100 Hz are used to remove power line noise and its higher harmonic waves.

$$V_j^{lap} = V_j - \frac{1}{4} \sum_{k \in S_j} V_k$$

3.2 Feature selection

In our research, the power of alpha band (8-12Hz) extracted from 21 channels are as feature spaces, as is shown in Figure 2 and 3, the channel spectra maps of clench force motor imagery are different from that of clench speed motor imagery, so the alpha power feature is reasonable.

3.3 Support vector machine

Support vector machine (SVM) is a classifier that can separate examples of two categories with a maximum margin using a small data set [24], and it is widely used for object recognition, speaker identification, face detection in images, and other pattern recognition related areas. SVM is especially appropriate for BCI application because EEG trials used in training is usually very small. In SVM, only exam
For the nonlinear classification problem, the sample vector is converted into a transformed feature space by a nonlinear kernel function [25].

In our paper, the Gaussian radial basis function $K(x_i, x_j) = \exp(-\gamma \|x_i - x_j\|^2)$ is used to classify EEG feature space of clench speed motor imagery from the feature space of clench force motor imagery. The classification is implemented by libSVM [26], and the 5-fold cross-validation is used to make the results more reliable.

4 RESULTS

The classification results between speed and force motor imagery of right hand is shown in Fig 3. The mean identification accuracy is 67.65% and 59.68% for the trained subjects (subject number: 1, 2, and 6) and the no-trained subjects (subject number: 3-5), respectively, both above chance level.

Although the result is not as well as the classification accuracy between imagination of different limbs, such as left hand and right hand, it does show that decoding of different motor imagination parameters is possible.

5 DISCUSSIONS AND CONCLUSIONS

BCI is an efficient method to facilitate the rehabilitation process for stroke patients who lose voluntary limb movement. Although many EEG-based non-invasive BCI systems use motor imagery paradigm to control rehabilitation devices, their command number is very few because only different limb movement imagination is used. To increase the command number and control efficiency, both clench force parameters and clench speed parameters have been studied independently.

In this paper, we try to decode speed and force hand movement imagination at the same time, and the primary result shows it is distinguishable. Classification motor parameters of both hands will be researched.
in our future work, as well as more advanced feature optimization methods and classification methods.

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