Journal of Fiber Bioengineering and Informatics 7:2 (2014) 261–271
doi:10.3993/jfbi06201412

Feature Extraction of Time-Amplitude-Frequency Analysis for Classifying Single EEG

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Abstract

Feature extraction and feature classification are two important stages in most EEG based Brain-computer Interfaces (BCI). The features extracted by Discrete Wavelet Transform (DWT) have a great relationship with sampling frequency. On the other hand, the features extracted by Amplitude-frequency Analysis (AFA) always ignore time information. In this paper, we proposed a feature extraction scheme based on Time-Amplitude-Frequency analysis (TAF) for classifying left/right hand imagery movement tasks. The time and frequency information are included in the proposed features. The Graz datasets used in BCI Competition 2003 and the datasets collected in the lab of Electromagnetic Theory and Artificial Intelligence of Chongqing University are used to show the effectiveness of the proposed features. The simulation showed that the proposed features improved the classifying accuracy and the Mutual Information (MI) for both datasets. The mutual information of TAF for Graz2003 dataset is 0.58 which is better than that of AFA and DWT.

Keywords: Brain-computer Interfaces (BCI); Electroencephalogram (EEG); Motor Imagery (MI); Discrete Wavelet Transform (DWT); Amplitude-frequency Analysis (AFA)

1 Introduction

Brain-computer Interface (BCI) provides us a new way to control a device or computer. This communication method does not depend on the peripheral nerves and muscles but only on the signals detected on the scalp that represents different brain activities. The BCI system can provide for disabled people a new method to communicate. It also gives the healthy subjects a new path to control computer games. Moreover, BCI research can explain how to reflect different mental states and how to characterize respective electroencephalogram (EEG) patterns [1-3]. In this paper, we focus on non-invasive EEG-based BCI systems.

An effective EEG-based BCI system focuses on two aspects: (1) The EEG features can be extracted to distinguish different brain states; (2) The classification methods are efficient. However, the EEG is very complex; it is very difficult for the BCI system to extract accurate transcendent

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June 2014

information. Currently, most feature extracting methods are based on Power Spectral Density (PSD) [4], autoregressive (AR) models [5], wavelet transform [6-8], Fast Fourier Transform (FFT) [9], and so on.

As EEG signals are non-stationary, traditional feature extraction method such as amplitude-frequency analysis based on FFT only uses amplitude and frequency information and not time domain information. However, much research has shown that the information of time domain is very important for improving the classification performance of EEG signals. Wavelet decomposition is a good time-frequency analysis method since wavelets allow decomposition into frequency components while keeping as much time information as possible. Event-related Desynchronization (ERD) and Event-related Synchronization (ERS) are the underlying neurophysiological phenomena accompanying motor imagery. It provides the theoretical basis of the the motor imagery-based BCI research [10-12].

The rhythm μ (8-13 Hz) and β (14-25 Hz) originating in the sensorimotor cortex have been postulated to be good signal features for EEG-based BCI [11, 12]. In this study, the μ and β band are used to extract the features for classification. Although the Wavelet decomposition can provide both time and frequency information, it cannot get an accurate frequency band information such as μ and β band.

In order to combine the time and the accuracy frequency information of motor-imagery based on EEG signal, we proposed a new feature extraction scheme to classify left and right motor imagery tasks. In the new scheme, both wavelet features and accuracy frequency features were adopted as the input of the Fisher classifier. In order to evaluate the effectiveness of this feature set, the LDA classifier are adopted to classify the Graz2003 BCI dataset which was used in the BCI-competition 2003 [13] and the CQU dataset which was collected in the lab of Electromagnetic Theory and Artificial Intelligence, Chongqing University, China. The offline analysis has shown that the new features extracted with the proposed scheme discriminated the motor imagery tasks well.

2 Data Acquisition and Description

The first dataset is the dataset III of BCI Competition 2003. It comes from Department of Medical Informatics, Institute for Biomedical Engineering, University of Technology Graz. In this paper, it was termed Graz2003 dataset. All the trials in this dataset were recorded from a 25 years old female during session with a feedback. C3, Cz and C4 channels were measured. The female was asked to control a feedback bar by imagining left or right hand movements according to the cue shown on the screen. In the available 280 trials, there are 140 trials for training and another 140 trials for testing. Each trial lasted 9s. The electrode locations and scheme is shown in Fig. 1. The EEG was sampled with 128 Hz. More details can be found in reference [13].

The CQU dataset was collected in the lab of Electromagnetic Theory and Artificial Intelligence, Chongqing University, China. This dataset is recorded from 4 subjects (S1-S4, one females and three males, ages from 22 to 25 years old.) in timed experimental recording procedures. Neuroscan was used to record the EEG signals over C3, Cz and C4. The subjects were asked to sit in a comfortable chair in a relaxing posture. They were asked to imagine the left or right hand movement according to the cue showing on the screen before them. The order of the left or right cues were random. A trial began at $t = 0$ s, a red button appeared on the black screen.