Chapter 9

Introduction to Motor Imagery–Based Brain–Computer Interface:
Time, Frequency, and Phase Analysis–Based Feature Extraction for Two Class MI Classification

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ABSTRACT

In this chapter, motor imagery (MI) based brain-computer interface (BCI) is introduced incorporating the explanation of key components required to design a practical BCI device. Its application to the medical and nonmedical sector is discussed in detail. In the experimental study, a feature extraction method using time, frequency, and phase analysis of Motor imagery EEG is presented. For the classification of MI task, EEG signals are decomposed using a dual-tree complex wavelet transform (DTCWT) and then time, frequency, and phase features are extracted. The validation of the proposed method is conducted using BCI competition IV dataset 2b. A Support vector machine (SVM) classifier is used to perform the classification task. Performance of the proposed method is compared with the standard feature extraction methods. The proposed scheme achieved a larger average classification accuracy of 82.81% which is better than that obtained by other methods.

INTRODUCTION

The system aims to develop a communication pathway between the brain, and a computer is popularly referred as brain-computer interface (BCI) system (Chaudhary, Birbaumer, & Ramos-Murguialday, 2016). Such direct interaction of the brain activities with the computer facilitates a human subject to control surrounding electronic devices. In other words, BCI translates the neural responses directly to the computer which signals the external devices to respond in accordance with the subject's intentions. These capabilities of BCI makes it a promising system to be used in many medical applications such as rehabilitation of stroke patients, reinstating motor functions of paralyzed patients, building up communication with locked-in patients, and augmenting cognitive and sensory processing (Bi, Fan, & Liu, 2013). Other than building an interface, researchers find the scope of BCI systems in the diagnosis of brain tumor, sleeping disorders, and brain diseases (Sharanreddy, 2013).

Apart from medical applications, researchers have widened the scope of BCIs to assist healthy users for faster hand-free control of devices (Rao & Scherer, 2010). By using BCI, they can control devices such as a robotic arm, smart home appliances or a wheelchair using their thoughts and cognitive power. However, designing of the BCI for use in the real environment involves challenges like poor information transfer rate (ITR), and long training sessions of the users (Navarro et al., 2011).

From the above discussion, it is notable that BCI research can benefit both abled-body as well as disabled-body users. However, designing an effective real-time BCI device is still a complex exercise. In general, the first step in the BCI system design is to capture electroencephalogram (EEG) patterns that represent the neural responses of a human subject while performing a specific mental task. The second step includes pattern recognition algorithms and machine learning approaches that work to define human's intentions. In the third step, researchers generate controlling commands to operate various devices. The commonly used EEG patterns are steady-state visual evoked potential (SSVEP) (Norcia, Appelbaum, Ales, Cottereau, & Rossion, 2015), sensorimotor rhythms (SMR) (Yuan & He, 2014), motor imagery (MI) (Gert Pfurtscheller & Neuper, 2001), and event-related potentials (ERP) (Sur & Sinha, 2009). These patterns are originated from the different areas of the brain depending on the type of stimulus being provided to the subject. This chapter mainly focuses on MI-based BCI.

In the MI-based BCI, the EEG signals of a subject are recorded while performing a motor movement mental task (Kawasaki, 2017). In the mental task, the subject has to think about the movement of either right hand or left hand. The recorded data are then analyzed using pattern recognition techniques (Grosse-Wentrup, Liefhold, Gramann, & Buss, 2009). In MI BCI signal analysis, Feature extraction plays a vital role as it provides the main information contained in the raw EEG signal (Gert

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