Chapter 11
Identification of Motor Functions Based on an EEG Analysis

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ABSTRACT
A combination of several techniques is necessary for a reliable identification of activities based on EEG signals. A separation of the overlapping patterns in the EEG signals is often performed first. These separated patterns are then analysed by some artificial intelligence methods in order to identify the activity. As pattern separation and activity identification are often linked, the two processes must be tuned to a specific problem, thus losing some generality of the procedure. The complexity of the patterns in EEG signals is often too great for completely automated pattern recognition. In this case, phase demodulation was introduced as a procedure for the extraction of the phase properties of the EEG signals. These phase shifts are known to correlate with the brain activity; therefore, phase-demodulated EEG signals were used to predict the motor activity. Three studies with off-line identification of the motor activities have been performed so far. In the first study, a continuous gripping force was predicted. In the second study, index- and middle-finger activation was predicted, and in the final study, wrist movements were analysed. The presented procedure can be used for designing a continuous brain-computer interface.

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INTRODUCTION

While several fictional films show the extensive use of brain-computer interfaces (BCIs), reality lags a long way behind. The reason is the complexity of the brain functions and their adaptive character, which keeps changing the patterns of brain activity. Several methods for measuring brain activity are nowadays used in medicine, such as functional magnetic resonance imaging (fMRI), magnetoencephalography (MEG), electroencephalography (EEG) with surface and, in special cases, with implanted electrodes. fMRI measures changes in the blood flow, while MEG and EEG measure the electric activity of the brain. All of these methods produce data that characterise certain aspects of brain activity and can be used as the basis for BCI development. However, fMRI and MEG are extremely expensive, while implanted electrodes present certain health risks. Therefore, a BCI with surface-mounted EEG electrodes seems to be the most feasible technology of the moment. Several BCI systems have been developed on the basis of EEG so far (Birbaumer et al., 1999; Wolpaw & McFarland, 2004; Taylor et al., 2002; Wessberg et al., 2000); however, their common feature is a discrete-event type of functioning. As soon as the BCI detects a certain pattern in the EEG signals, it triggers a series of pre-programmed events. The discrete-event functioning of BCIs somewhat limits their use and reduces the computer functionality. The alternative is to develop a BCI with the possibility for the continuous control of machines. Our group introduced a phase-demodulation (PD) approach that was successfully applied for the off-line identification of several motor activities in humans (Logar et al., 2008a; Logar et al., 2008b; Logar & Belič, 2011). The main problem for continuous BCI systems is represented by a reliable identification of the patterns associated with the force- and position-control functions in the brain.

In this chapter, we would like to show several aspects of EEG signals analyses, especially the necessity of combining several methods, as well as expert knowledge, in order to identify the specific patterns of the EEG signals that are associated with the position and force control of the hands.

BACKGROUND

The history of the discovery of the EEG started with Richard Caton, a Liverpool physician and medical school professor, who discovered electrical brain signals by probing the surface of the exposed brains of animals. He published his first results in 1875. Two years later, Caton reported that when he interrupted light falling on an animal’s eye, he detected negative variations in the electrical activity of the brain. He also discovered that electrical activity in the brain occurred on the opposite side from the eye. Adolph Beck of Poland repeated and published his work about 15 years after Caton, in 1890. However, he went beyond Caton when he found that though a sensory stimulus, such as a sound clap, induced a response at a single point, there was also a brain-wide interruption of the slow, even pattern of the brain waves. It was not until 1949 that the reticular activating system of the brain was discovered, which had an important role in controlling the states of the brain. Hans Berger, an Austrian psychiatrist was the first to record electroencephalographs from humans. In 1897, Berger became aware of Richard Caton’s work. His experiments with animals were inconclusive by 1910, but after the First World War he decided to look for the EEG in the human brain. In the early years of the 1920s Berger obtained his first results in subjects who had skulls with gaps under the skin where a piece of bone was missing. He made recordings on moving photographic paper with a wavy spot of light. This was how Berger found the regular waves at about 10 cycles per second that he named the Alpha waves. Later