Chapter 8
Review of Applications for Wireless Brain–Computer Interface Systems

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ABSTRACT

In this chapter, to the authors review the research trends for wireless Brain-Computer Interface (BCI) systems as well as their current and anticipated applications. Wireless BCI systems have clear advantages when compared to wired BCI systems, in that they have simpler shapes and can be convenient and portable devices. Recent wireless BCI applications attempt to help people live more conveniently in many areas of life: medical engineering, rehabilitation, and everyday life.

INTRODUCTION

Over the past couple of decades, the study of Brain-Computer interfaces (BCI) has grown into a rich and diverse field, the critical goal of which is to allow the operation of various devices. The BCI system sends command signals to the receiver of a specific application. The target application then converts these signals into commands that cause movements of a target device. The more often a BCI is utilized over a wide variety of such applications, the more its importance has grown. Current applications have mostly been aimed at helping disabled people utilize machines such as robots, wheelchairs, smart TVs, computers, and home appliances.

Traditional BCI systems are wired. Arto Nurmikko, a professor of the engineering school at Brown University, emphasizes that, “current wired BCI systems constrain the action of research subjects.” (David O. 2013) This is because wired BCI systems have bulky preprocessing units. Wiring in connections is complicated due to the considerable number of wires required between

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electrodes and the data acquisition part. This limits the subject's movement and the applications of BCI are restricted to those deployable within the realm of a research laboratory. Wireless BCI systems aim to remove the cables between the signal acquisition and the translation parts through the use of a modern wireless communication unit, to enhance the portability of BCI systems. As a result, wireless BCI systems can go out of the laboratory and be useful for cultivating new applications from which more people can benefit.

This chapter focuses primarily on the applications of wireless BCI systems, and introduces existing wireless BCI systems used in entertainment, biomedical engineering, and everyday life applications. In the past, researchers have proposed wired BCI system applications to diagnose diseases (Boyd et al., 1988). However, the current focus is on making wireless BCI applications that help people live more convenient lives. These applications are able to offer improvements in entertainment, games, medical engineering, rehabilitation, and everyday life, because such systems have obvious advantages over pre-existing ones. They are simpler, more convenient, more mobile, and more flexible than wired BCI systems. Finally, we will discuss future applications and anticipate the limitations of such wireless BCI systems.

This chapter will be divided into the following eight subchapters: Introduction, Background, Recent Research into Wireless BCI Systems, Applications of Wireless BCI Systems in Everyday Life, Medical Engineering, and Entertainment, Future Research Directions, and Conclusion.

Background

In 1924, Hans Berger found that electrical signals can be measured from the scalp of the human brain and published a paper that has ever since established that Electroencephalography (EEG) is a basic tool for clinical diagnosis and brain research (Berger, 1929).

BCI systems provide a communication and control channel between the user's brain and an external device, such as a computer or prosthetic hand. EEG signals are recordings of the brain waves generated by electrical activity along the scalp. BCI does not rely on the brain's normal route through nerves and muscle. These signals can be mapped to create different commands using a series of refined signal processing procedures. Hundreds of research laboratories and companies around the world currently focus on BCI research and performance. Some examples of EEG-based applications include the control of cursors (Wolpaw et al., 1991; 2003; Kostov et al., 2000), wheelchairs (Vanacker et al., 2007; Luth et al., 2007; Rebsamen et al., 2007; Iturrate et al., 2009), robots (Tonin 2009; 2010), typing skills for communication (Cass and Polich, 1997; Covington and Polich, 1996; Sugg and Polich, 1995; Vesco and Bone, 1993), virtual reality games (Leeb et al., 2013), and the diagnosis of disease (Gotlib et al., 1998; Pfurtscheller et al., 2003; Hebert et al., 2004; Dauwels et al., 2010; Elgendi et al., 2011; D'Arcy et al., 2011).

BCI systems can be categorized as invasive, partially invasive, or non-invasive. In invasive BCI systems, electrodes are surgically implanted directly into the grey matter. Invasive devices are capable of measuring high quality EEG signals such as spike waves. In partially invasive BCI systems, electrodes are implanted into the subdural space, which is located in the intermediate space between the skull and the brain. They can provide higher quality EEG signals with a greatly reduced noise level compared to what can be provided by non-invasive BCI systems. Both invasive and partially invasive systems, however, are accompanied by the obvious risk that brain surgery always carries. In non-invasive BCI systems, EEG signals are recorded at the scalp of the human brain. Non-invasive systems are susceptible to noise and distortion of the recorded signals compared to the invasive and partially invasive systems,

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