Chapter 25
Single-Channel Region-Based Speller for Controlling Home Appliances

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ABSTRACT

The brain-computer interface (BCI) system uses electroencephalography (EEG) signals for correspondence between the human and the outside world. This BCI communication system does not require any muscle action; hence, it can be controlled with the help of brain activities only. Therefore, this kind of system is helpful for patients, who are completely paralyzed or suffering from diseases like ALS (Amyotrophic Lateral Sclerosis), and spinal cord injury, etc., but having a normal functioning brain. A region-based P300 speller system for controlling home electronic appliances is proposed in this article. With the help of the proposed system, users can control and use appliances like an electronic door, fan, light, system, etc., without carrying out any physical movement. The experiments are conducted for five, ten, and fifteen trails for each subject. Among all classifiers, the ANN classifier provides the best off-line experiment accuracy of the order of 80% for fifteen flashes. Moreover, for the control translation, the Arduino module is also designed which is low cost and low power-based and physically controlled a device.

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INTRODUCTION

People suffering from neuromuscular diseases like brain stroke and Amyotrophic Lateral Sclerosis (ALS) have very limited muscle-based control capabilities; hence they are heavily dependent on secondary caregivers. For such patients, Brain-computer interface (BCI) is a useful approach for interaction with the outside world. This technology provides communication between the human brain and the external environment. BCI systems acknowledge the subject's intentions and convert these brain patterns and signals into control command (Mak & Wolpaw, 2009). Once the signals are converted into control commands they are used in a wide range of applications such as controlling a wheelchair, 2-D cursor, keyboard, mobile robot, home appliances (Hoffmann, Vesin, Ebrahimi, & Diserens, 2008), etc. BCI-based home appliances control system is an important application that will give an easy life to a patient who has a neuromuscular disease. Moreover, BCI also reduces the cost of care and dependency on others. The use of Brain waves for controlling the support system has been an active research and development area for about the last 10 years. Some of the major contributions in BCI are now described.

Brain patterns are analyzed by acquiring electroencephalography (EEG) signals. Both invasive and non-invasive techniques are used to acquire EEG signals (Ramadan & Vasilakos, 2017). Non-invasive methods are more popular for BCI as do not require surgical implantation of the devices. The ease of access along with the painless acquisition of EEG signals inspired the author to use the noninvasive method. There are six types of signals generated from the scalp which is dependent on the frequency band. A P300 potential is one of the most important components of EEG which works on the principle of odd-ball paradigms (Farwell & Donchin, 1988). It is used to transfer subject intention into input command. For EEG-based BCI, several other signal patterns are used. These include steady-state visually evoked potentials (SSVEPs) (Zhang, Yu, Jiang, Wang, & Qin, 2019), motion-onset visually evoked potentials (MEPs) (T. Ma et al., 2017), motor imagery (MI)(Jais, Mansor, Lee, & Fauzi, 2017), hybrid signal (Masud, Baig, Akram, & Kim, 2017), etc. BCI-analysis is a useful approach for clinical applications like understanding the need & requirement of totally disabled patients in hospitals. Many paradigms like single character (SC)(Pan, Li, Gu, & Yu, 2013), row/column (RC)-based (Farwell & Donchin, 1988), region-based (RB)(Fazel-Rezai & Abhari, 2009), checkboard (CB) (Townsend et al., 2010), rapid serial visual presentation (RSVP)-based (Acqualagna & Blankertz, 2013) have been investigated using BCI analysis.

Controlling home appliances using EEG-signal based approach in a real environment is a complex task due to various difficulties like the cost of software and hardware, stability in system performance, convenience for users, and technical challenges that occurred in real life. Some of the real-life examples for BCI-based home appliances control systems are wireless BCI-based system especially P300 and SSVEP based signal translation, Bluetooth-based wireless transmission of EEG signal, infra-red (IR) technology, TCP/IP communication and UPnP (Universal plug and play). But limitation these systems are that they depend upon the availability of the internet and many times they are not capable to interact with many devices at a time. Several research publications discuss about single appliance control, for example, fan device (Wang, Lv, Wen, He, & Wang, 2016), TV (Hsieh, Sun, Yeh, & Pan, 2017a), cooling system (Hsieh, Sun, Yeh, & Pan, 2017b), door (Alrajhi, Alaloola, & Albarqawi, 2017), buzzer and music system (Chowdhury, Kashem, Hossan, & Hasan, 2017; Tseng, Wang, Lin, & Hsieh, 2012). Some researchers proposed multiple appliance control (TV, Fan, AC, Door, light, etc..), virtual reality-based (Holzner, Guger, Edlinger, Gronegress, & Slater, 2009), microcontroller-based (Alshbatat, Vial, Premaratne, & Tran, 2014), FPGA-based (Belwafi, Ghaffari, Djemal, & Romain, 2017), infrared-based