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Control of LRF and Two DC Motors with Pattern Recognition Approach Based on Mental Tasks

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Abstract. Brain-Computer Interface (BCI) applications, which is a communication system that allows creating interfaces between the human brain and artificial devices, offers preferable options for people with various muscle, nerve and vision diseases, as well as contributing to the development of technological tools. In this study; with a pattern recognition approach based on mental tasks, a BCI application has been carried out with a laser distance measurement system that does not need to work all the time for individuals with muscle, nerve and visual diseases. This application has provided the control of 2 DC motors representing wheelchair and robotic arm. The results obtained with this application using the Emotiv Epoc+ device show that the control of peripheral units can be achieved with a few commands using the technologies adopted in this study. In addition, the advantages/disadvantages of the application are discussed.

INTRODUCTION

Brain-Computer Interface (BCI) is a system that enables direct communication between the human brain and computers. It receives the electrical signals produced by the brain, makes it meaningful, and communicates with computers or machines by sending commands to perform certain actions without the need for any muscle action. Brain-Computer Interface applications, which are in the first stage of the technological phenomenon, have gained an important place in the neuroscience, education, rehabilitation and video games industry [1].

Electrical signals in the brain can be obtained in many different ways [2]. Electroencephalography (EEG) method, in which the electrical signals of the brain can be detected by electrodes connected to the scalp, is the most common application preferred for use with BCI, which can be applied without harming health and without any surgical procedure [3] [4]. There are low-cost devices such as NeuroSky, Emotiv Epoc+, NeuroSpec, Neuroharmony that use the EEG method for BCI systems. Although these devices have a fixed number of sensors, lower sensitivity and resolution, they are preferred because of their ease of use. Using the EEG device; for patients who have difficulty in moving their muscles freely, a brain-operated wheelchair system can be designed [5], robot arm control can be provided with the help of ultrasonic distance meters and webcam [6], laser radar and computer vision technology can be developed to detect the environment for obstacle avoidance/target recognition [7].

In this study; with a pattern recognition approach based on mental tasks, a BCI application has been carried out with a laser distance measurement system that does not need to work all the time for individuals with muscle, nerve and visual diseases. This application has provided the control of 2 DC motors representing wheelchair and robotic arm. The results obtained show that any system control can be achieved with a few commands using the technologies adopted in this study. In this study, which can contribute to the development of any system using mixed reality to facilitate the lives of disabled people, the advantages/disadvantages of the application are discussed.

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METHODS

A basic BCI application based on mental tasks, enabling users to control 2 DC motors with a laser distance measurement system with a pattern recognition approach has been implemented. In this application, the Emotiv Epoc+ device was used to record EEG signals and convert them to command. In this system designed for individuals with muscle, nervous and visual diseases; “Forward" command is given to the Laser Range Finder (LRF) by the user's brain electrical signals, then the distances of the obstacles/objects in the environment are measured and converted into an audible warning message and the laser is turned off. As a result of the audible warning message, a DC motor defined as right or another DC motor defined as left is driven by the decision given by the user. These DC motors can be a simulated wheelchair, a robotic arm and/or a prosthetic leg. The flow chart of the study is given in Fig. 1. As seen in the diagram, the EEG signals obtained using the Emotiv Epoc+ device (01) are processed by transferring to the computer (02) and transmitted to the LRF (04) with the help of the software (03) that is transformed into the command. Thus, the laser distance measurement system is controlled with brain signals without the need work all time. A selected DC motor is moved using EEG signals, Arduino and motor driver (5).

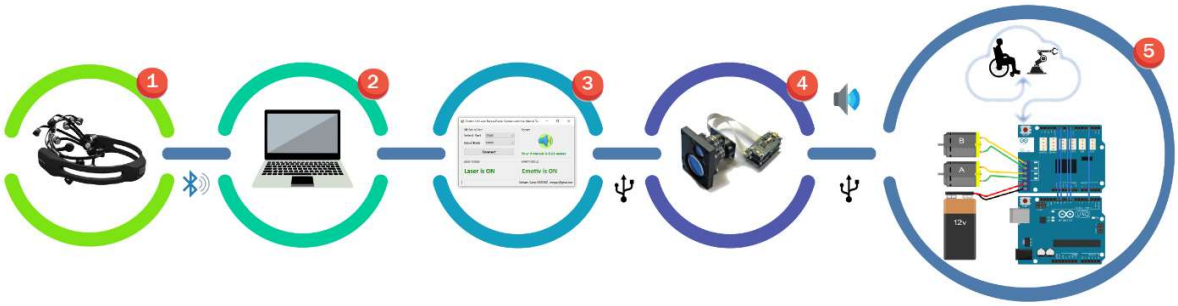
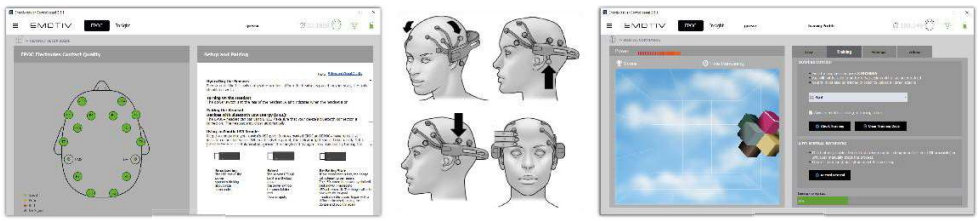


FIGURE 1. Flow Chart (01) Emotiv Epoc+ device from which EEG signals are obtained. (02) The computer where the signals are recorded and processed. (03) Software that enables communication between the computer and the LRF. (04) LRF. (05) The Arduino that provides communication between the computer and the DC motor, a motor driver and DC motors whose motion will be controlled.

Emotiv Epoc+ devise used to obtain EEG signals; it is portable, easy to use, rechargeable, provides wireless signal transmission and its sensors are renewable. It is an economical device with a sampling frequency of 128 Hz and a resolution of 0.5 µV. 14 Channel RAW EEG data can be obtained from this device. The position of the electrodes on the device is in the form of AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, AF4 according to the international 10/20 standard as shown in Fig. 2. (a) [8]. Electrodes need to be hydrated using saline solution for better detection and readability of electrical signals in the brain. If the electrodes are sufficiently wet, the correct positioning and quality signals is achieved (Fig. 2. (b)). The quality of the signals can be monitored instantly with the Emotiv Xavier ControlPanel software shown in Fig. 2. (a). The quality of the signals is expressed in 4 different colors. A green dot indicates a strong connection between the brain and the device, an orange/red dot indicates a weak connection, and a black dot indicates an unstable connection. In order for the study to be carried out in a healthy way, high signal quality is required. For spots that are not green in color; device control should provide answers to the questions such as; "Is there any obstruction between the electrodes and the scalp? Are the electrodes wet enough? Is the connection between electrodes and head kit healthy?"



(a) (b) (c)

FIGURE 2. (a) Monitoring of signal quality (international 10/20 standard), (b) Emotiv Epoc+ electrode placement, (c) Mental commands training interface.

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Emotiv offers three different machine learning algorithms, namely performance metrics, facial expressions and mental commands that write Xavier ControlPanel software [9]. The mental commands algorithm was used in this study. The training of the users for "Forward", "Right" and "Left" mental commands is carried out by asking them to imagine that they are moving the virtual object right, left and forward in the interface shown in Fig. 2. (c). This training is repeated until success is achieved.

DS00 Laser Range Finder (LRF), used for distance measurement, has a range of 100 m, resolution of 1 cm and exposure 100/s. Laser Range Finder was connected to the computer from the USB port in order to communicate with the laptop via the serial port. An application has been developed using C# language to communicate with LRF and control it with mental commands. Communication between the developed software and the LRF was provided over the serial port. Thus, for the correct mental command, the laser was turned on, the distance was measured, the measured distance was notified to the user with a sound notification and the laser was turned off. In the study, according to the result of the audio warning message informing the measured distance, the user is asked to decide and move a DC motor defined as right or another DC motor defined as left. The 2 DC motors here represent a wheelchair and/or a robot arm. Arduino 101 and Arduino Motor Driver were used to ensure the movement of the 2 DC motors used and to communicate with the Emotiv device. The codes that will enable the control of the motors with mental commands were written in C++ using the Arduino IDE. Arduino was connected to the computer through the USB port so that it can communicate with the laptop via the serial port.

In order to send the mental commands to the developed application, EmoKey software presented in the Emotiv Xavier ControlPanel was used. To establish a relationship between the signals from the Emotiv Epoc+ device, a rule has been written that sends keystrokes to the application developed through the EmoKey software. "Forward" command was selected for LRF to measure distance. The "Right" and "Left" commands were selected, respectively, to run the DC motors placed on the right and left sides according to the position of the subjects. According to this rule, if the transmitted signal strength is greater than 0.2, the "Forward", "Right" and "Left" commands are enabled to trigger the "P", "R" and "L" keystrokes, respectively.

RESULTS AND DISCUSSION

In this study, which shows that any system control can be achieved with a few commands, findings that can be described as positive and negative that can contribute to the planning of future studies have emerged. Using the methods detailed in the method section, this BCI application was performed with volunteers, two female participants, 54 years old and 28 years old, and two male participants, 54 and 29 years old. Before the study, the participants were informed about the devices and mental tasks. In the first step of the study, the electrodes were hydrated with contact lens solution and placed on the participants' head. In the second step of the study, the participants were asked to imagine that they were moving the virtual object (Fig. 2. (c)) "Forward", "Right" and "Left" for 8 seconds. The training was repeated for the "Forward", "Right" and "Left" commands until it was successful. Participants (Male-56 and Female-56) who did not have experience using the Emotiv Epoc+ device did more repetition.

Participants who completed their training were taken to the experimental environment prepared for them to measure the distance by sending a command to the LRF, who had an obstacle, and then start a DC motor they decided on. In the study carried out, it was observed that a strong "Forward" signal (greater than 0.2) came from the Emotiv Epoc+ device placed in the heads of the participants, sending the "P" value to the target application as a keystroke and the target application took measurements by communicating with the LRF. The measurement taken was audible to the user and the LRF was turned off. The user then decided to operate the DC motor representing the wheelchair or the DC motor representing the robot arm. As a result of the decision made by the user, it was observed that the Emotiv Epoc+ device started the DC motor (A) representing the wheelchair or the DC motor (B) representing the robot arm with a strong "Right" signal or a strong "Left" signal. The skill levels of the participants for each action are shown in Table 1. The skill rating is calculated during the study process and provides a measure of how consistently the user can mentally perform the intended action [10].

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TABLE 1. The skill grade of the subjects (a) to operate the LRF (b) according to the mental commands to run each DC motor.

Subject Gender-Age	Skill Grade Command Forward - Repeat
Male -29	88% - 4
Male -56	67% - 11
Female-56	62% - 10
Female-28	71% - 6

(a)

Subject Gender-Age	Skill Grade Left Command - Repetation	Left Command - Repetation
Male -29	93% - 4	77% - 6
Male -56	72% - 8	63% - 17
Female -56	91% - 6	39% - 15
Female -28	71% - 4	77% - 4

(b)

It was observed that besides the difficulties faced by the participants in obtaining the appropriate skill level, environmental factors were also effective in obtaining healthy measurement results. Charging the Emotiv Epoc+ device used within the scope of the study takes 4 hours and takes about 10 minutes to prepare. If the device is not used for a long time, it needs to be charged for 24 hours. The device is easily affected by environmental noise (mobile phone signals, Wi-Fi and Bluetooth signals, etc.). For this reason, measurements were carried out in an environment free from environmental noise as much as possible. Due to the rapid drying of the liquid solution used to increase the conductivity of the electrodes, their working time is limited to 30 minutes. Since the head kit has a flexible structure, it has been observed that small changes may occur in the position of the electrodes, the electrodes can oxidize over time and damage the head kit during assembly/disassembly. For this reason, head kit checks were made in each application.

With this study, it is seen that Brain-Computer Interface systems can be developed quite easily with the Emotiv Epoc+ device and the software it provides. In this designed system; the distances of obstacles/objects in the environment are measured by commanding the LRF with the users' brain electrical signals. According to the suitability of the environment, DC motors are moved with the brain electrical signals. These DC motors can be a wheelchair, a robotic arm and/or a prosthetic leg when this system is customized for individuals with muscle, nerve and vision disorders. By providing user training, various systems can be developed for different abilities by using more commands.

CONCLUSIONS

With the Emotiv Epoc+ device, a BCI application that provides the control of the laser distance measurement system and DC motors that do not need to work all the time for individuals with muscle, nerve and visual diseases with a pattern recognition approach based on mental tasks has been implemented. It is possible to control many devices by spending sufficient time for brain training of BCI applications. In addition, BCI applications are easy to access and low cost, and these applications facilitate the lives of individuals with muscle, nerve and vision diseases or those with limb deficiency. BCI applications can be made with other machine learning algorithms offered by Emotiv and these algorithms can be compared with each other. In addition, mixed reality applications can be developed by providing manipulation of objects with the Brain-Computer Interface.

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