Development of Real-time Controlling of Zumo Robot Movement using Brainwave Sensor

UDIT BHAKTA PRADHAN[†1] CHEN FENG[†1] TIPPORN LAOHAKANGVALVIT[†1]
PEERAYA SRIPIAN[†1] MIDORI SUGAYA[†1]

Abstract: Brain Computer Interface (BCI) is a system that allows users to send information from their brain to an external computer. These brain signals can be used to control wheelchairs, prosthetics, switches, robots and more. As the preliminary stage of our study on BCI, we aim to build a simple BCI system employing an Arduino-controlled Zumo robot and a commercially available brainwave sensor (i.e., Neurosky Mindwave Mobile 2). In this study, we used Attention level calculated by an original algorithm of the brainwave sensor as it can consciously controlled by an individual and is also a simple parameter to work with for preliminary stage in developing BCI system. Firstly, we obtained the Attention level from the brainwave sensor, and sent it to the Zumo robot through Bluetooth module in order to control the robot movement in real time. If the Attention level is higher than a predefined threshold, the robot will move forward. Otherwise, the robot will stop moving. As a result, we succeeded to build the EEG-based controllable movement on a simple robot. Also, we were able to grasp the basic understanding of how a BCI system works and to create a foundation for future BCI studies.

Keywords: BCI, Brainwave, Attention, Zumo robot

1. Introduction

Brain Computer Interface (BCI) is a system that allows you to send information from your brain to an external computer without relying on conventional brain output pathways [1]. These brain signals can be used to control wheelchairs, prosthetics, switches, etc. Unique electromagnetic signals are produced in the brain when we want to do specific things, for example, move our hands [2]. Several methods have been used to process brain signals. Since brain signals are complicated, machine learning algorithms are developed to learn the correlations between different brain signals. We can transform these signals produced into control signals, which can be used in BCI applications.

Neural oscillations or brainwaves are the rhythmic or repetitive patterns of electrical/neural activity in human's brain. Neural oscillations are the data that to be collected from the brain in order to further use it for BCI applications. In order to obtain this data, we need to monitor the electrical activity of the brain which can be done by these two main approaches [3]:

1. Invasive approach: Sensors are surgically implanted in the brain to acquire brain signals. Electrocorticography or ECoG is an example of this approach.
2. Non-Invasive approach: Electrodes placed on the scalp are used to measure electrical signals. Some examples of this approach are Electroencephalography (EEG), Magnetoencephalography (MEG), and Functional Magnetic Resonance Imaging (fMRI).

In this study, we employed EEG not only because it is non-invasive, but also inexpensive and portable. The EEG was used for controlling a Zumo robot which has simple operations as it is the first prototype in our BCI study. This paper presents our prototype, so called BCI-ZUMO, including its design and evaluation.

2. Components and Software

The components used in this study includes:

- EEG sensor (NeuroSky Mindwave Mobile 2)
- Zumo robot with Arduino as controller
- Bluetooth module (HC-05)

The EEG sensor is the most important component of the study. It is a device that can be used to measure the cortical activity in the brain and send the data wirelessly to an external computer via Bluetooth. The sensor is equipped with one channel to measure the brain activity, and it is placed above the left eye. This records the brain activity from the frontal cortex of the brain which is often used for an integrated measurement of concentration and drowsiness. In addition, some studies reported that emotion estimation accuracy of 90% or more could be achieved only with a couple of electrodes placed in the frontal lobe [4]. Due to the limitation of one channel, it might not be as accurate as other EEG sensors fitted with multiple channels. The different parameters and data that the sensor can record include, Attention values, Meditation value, blink strength, EEG band values, and raw EEG data. This study only used the Attention level for the sake of simplicity. The Attention values indicate the intensity of a user's level of mental "focus" or "attention", such as that which occurs during intense concentration and directed (but stable) mental activity. Its value ranges from 0 to 100. Distractions, wandering thoughts, lack of focus, or anxiety may lower the Attention meter levels [5].

Zumo robot is Arduino-controllable tracked robot platforms. This study used the Zumo robot as the robot platform that is to be controlled using Attention values. The data collected from the EEG sensor is sent to the Zumo robot using the Bluetooth module connected to the Arduino. The Bluetooth module allows all serial-enabled devices to communicate and transmit/receive information using Bluetooth. By using this Bluetooth module,

†1 Shibaura Institute of Technology

the robot controlling can be done in real time.

The software we used includes Python and Arduino. Python code was used to get the incoming data packets and transfer them to the Bluetooth module. Arduino code was used to parse and accept the data packets into the Zumo robot. Figure 1 shows the BCI-ZUMO system and the EEG sensor (Mindwave Mobile 2). The general flow of data transmission is illustrated in Figure 2.

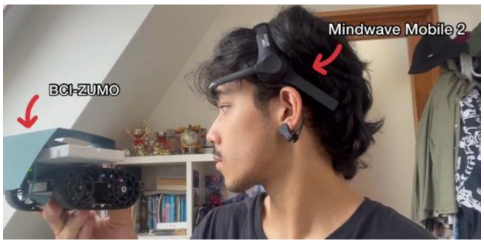


Fig.1. BCI-ZUMO system and the Mindwave Mobile 2

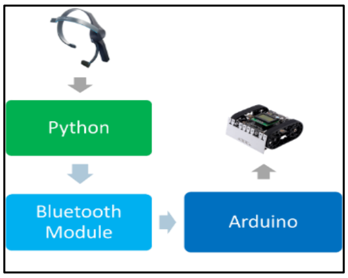


Fig.2. General flow of data transmission

3. Design and Development

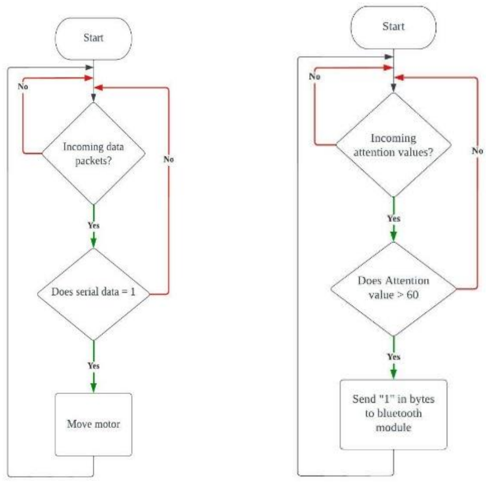
The steps taken in order to develop the robot is as follows:

1. Establishing connection of Bluetooth module and MindWave Mobile 2 to the computer.
2. Parsing data: It is to transform data from one format to another format. The method of receiving data packets and learning their structure is important to write and understand the Python and Arduino code. The MindSet Communications Protocol available in the NeuroSky Official Website was referred to learn this concept.
3. Using Python code to obtain data (Attention values) from MindWave Mobile 2 and sending it to Arduino as serial stream of data (Figure 3a). The Attention values range from 0-100. The Attention values from 60-80 are considered slightly elevated, and 80+ is considered elevated. When the sensor detects Attention values over 60, it signals the Bluetooth module by sending the serial data “1”.
4. Using Arduino code to receive serial data from the python code and sending it to the Zumo robot through Bluetooth module. Figure 3b shows how the Arduino code works. Once the Arduino board receives the signal (serial data = 1), the Zumo robot moves forward by increasing the motor speed. When the Attention values are 60 or less, it does not move.

4. Experiment and Discussion

The Zumo robot can be moved by calming down and focusing, which in turn should increase the Attention value. We were successful in moving the Zumo robot when we tried focusing on a particular activity, such as reading a book. However, we experienced some input lag which led to problems in communications in real time. Since this is our initial step to develop the BCI system, there is still a lot of rooms for improvement as follows:

- Add other robot movements in addition to moving forward
- Employ other EEG data for BCI-Zumo system
- Add EEG data visualization to observe current EEG values.
- Minimize the input lag



(a) (b)

Fig.3. (a) Flowchart for obtaining data from EEG sensor (b) Flowchart for sending data to Zumo robot

5. Conclusion

This study aims to create a simple functioning BCI system to test the waters of the field. We designed and developed a simple robot movement controlled by EEG sensor. As a result, we succeed to create a basic prototype of BCI abiding by constraints and limits of a simple EEG sensor. For future work, we will continue to improve to the functionality of the BCI-ZUMO system to make it more practical for daily usage.

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