

Brain Computer Interface for Controlling RC-Car Using Emotiv Epoc+

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Abstract—The research presents a control of a mobile robot/RC (Remote Control) car using EEG brain signals. Hardware composed of Emotiv Epoc+ EEG headset, computer, Wi-Fi router, and ESP8266 Wemos D1 microcontroller. The project is used for remote commands to navigate mobile robots into the specified position. In this research, the Steady State Visual Evoked Potential (SSVEP) with stimuli frequencies of 12, 15, and 20 Hz is used to control the direction of the RC-car (i.e. forward, right, and left). Two volunteers have participated in the experiment. They sit in a chair looking at the monitor screen with 3 flashing picture boxes with frequency of 12 Hz (go-forward), 15 Hz (turn right), and 20 Hz (turn left). This project uses SVM pattern recognition methods to differentiate brain pattern. Recognition rate accuracy achieved 88% for turn-left command, 91% for turn-right command, and 90% for go-forward command.

Index Terms—BCI; CSP; Emotiv EPOC; Mobile Robot; SSVEP; SVM.

I. INTRODUCTION

The brain is the main processor in giving orders to the human body to perform physical activities. With technological advances, today's brain signals can be used as commands to control electronic devices. For example, disabled people can use their brain signals to give commands to move a wheelchair or operate a mobile device such as a smartphone, tablet, etc. [1, 2]. Emotiv is a company that develops Electroencephalogram (EEG) signal processing technology and produces Emotiv EPOC+ headset that serves to capture brain signals [3]. The EEG signal activity is captured by the sensor of Emotiv Epoc+ headset. The brain's signal activity stores important information as the primary source when the brain gives commands to do something. The EEG pattern recognition using Support Vector Machine (SVM) has been utilized to recognize the EEG signal and classify it into classes, such as command to forward, backward, turn left, and turn right as explained on [1]. Bagus Kumbara, Arjon Turnip, Waslaluddin used EEG signal and SVM method to detect a lie. They obtained 3 SVM models that can classify the state of lie with 70.83%, 70.83%, and 75% of accuracy and 0.014594, 0.009003, and 0.009208 seconds of computation time respectively [4].

Brain signal detection applications have been developed in various fields. The Steady State Visual Evoked Potential (SSVEP) is one of the major brain biosignals that has broad applications in examining brain activity and cognitive function [5, 6]. This signal is a natural response to visual

stimulation over a certain frequency range. When the retina is attracted by visual stimuli ranging from 3.5 Hz to 75 Hz, the brain usually produces electrical activity at the same frequency (or multiple of the designed visual stimulus frequency). This method is used by the brain to distinguish which stimulus the subject sees in the event of different frequency stimuli [6, 7].

In this project, we used SSVEP and SVM methods for an RC-car control system using brain signals command. We used an EEG sensor from Emotiv. The movement of the RC-car can be controlled into 3 types of command: moving forward, turn left, and turn right with a constant speed. We use a microcontroller of ESP8266 Wemos D1 series with a built-in Wi-Fi interface to control the movement of the RC Car wirelessly.

II. MATERIALS AND METHODS

A. System Setup

The BCI project is used for remote commands to mobile robots (remote control/RC-car). The user navigates the robot to move towards into the specified position. Two volunteers have participated in the experiment. They sit in a chair looking at the monitor screen with 3 picture boxes flashing with each frequency of 12 Hz (forward), 15 Hz (turn right), and 20 Hz (turn left). The generated frequency is already programmed by the application.

The EEG signal is obtained with the 14-channel sensor from Emotiv Epoc+ Research Edition. The EEG signal is processed and transmitted wirelessly to the computer. The EEG signal is filtered using a pass-band between 12 and 20 Hz (depending on blinking setting on the screen). EEG Emotiv Epoc+ operated at a sampling frequency of 256 Hz with 16-bit resolution for each channel.

A simple robot/RC-Car (dimension: 22×17×12 cm) is controlled by a small Wemos D1 ESP8266 microcontroller that has a built-in Wi-Fi connection. The movement command is sent from the computer using UDP connection via Wi-Fi to the robot.

B. System Diagram

The RC-car is equipped with a Wemos D1 esp8266 processor board which is connected to the motor driver. RC car circuit can be seen in Figure 1. The BCI system utilizes OpenVibe platform [8]. The OpenVibe platform is used for EEG recording, pre-processing (low-pass and high-pass filtering, windowing), EEG feature extraction, SVM

training/modeling, as well as EEG recognition to command RC-car movement. The block diagram of BCI system can be seen in Figure 2.

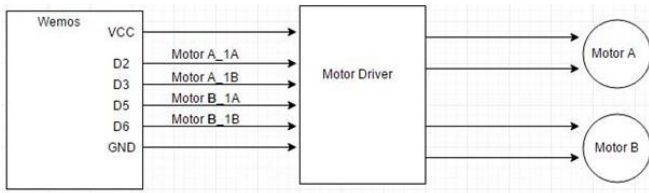


Figure 1: RC-Car Circuit

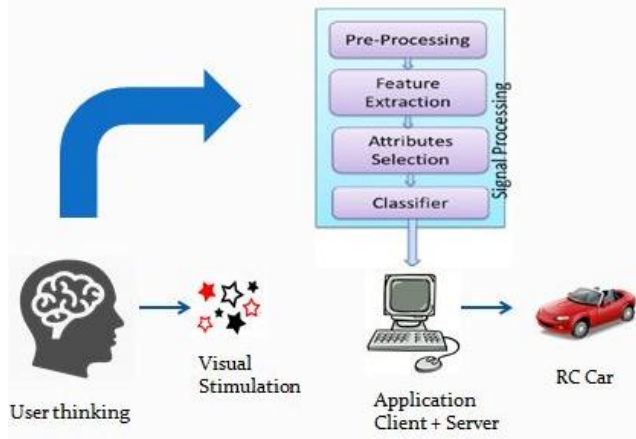


Figure 2: BCI System Block Diagram

C. Virtual Reality Peripheral Network (VRPN)

Computer communication to the RC-car uses VRPN button server on the OpenVibe. By using the VRPN button, the result of EEG command is sent to a client application that developed using Microsoft Visual Studio 2013 and C++ programming language. Then the client application command is sent to the UDP server of Wemos ESP8266 (RC-car) to drive the motor. The UDP server application is coded using Arduino IDE and C++ programming language.

D. Data Acquisition

EEG data recording utilizes acquisition server on the OpenVibe. On SVM training process, the user will be assisted by viewing a flickering box stimulation using a method of Steady State Visual Evoked Potential (SSVEP) [6]. By using SSVEP, the frequency of the flickering is adjusted according to the flickering frequency of pre-set boxes. When the user wants to pass a command to the robot, he looks at the flickered and specified stimulator box, then BCI will detect the user's intent. The pattern recognition method is using SVM. BCI can generate three commands to the robot, i.e. "forward", "turn right", and "turn left", each in accordance with the user's view of the corresponding box (Figure 3).

E. Feature Extraction and Training

After the data has passed the preprocessing, then the process will be executed on each channel of data with the method of Common Spatial Pattern (CSP) [2, 6]. The process is using the CSP box on the OpenVibe platform which will generate the .cfg file containing the results of the feature set of the EEG data.

Once the EEG feature is obtained for each channel, the feature will be trained using the Support Vector Machine classification method. This method is executed by using classifier training on OpenVibe. Whenever the training process is accomplished, it will generate .cfg file containing

SVM predict model of EEG class for further EEG recognition process.

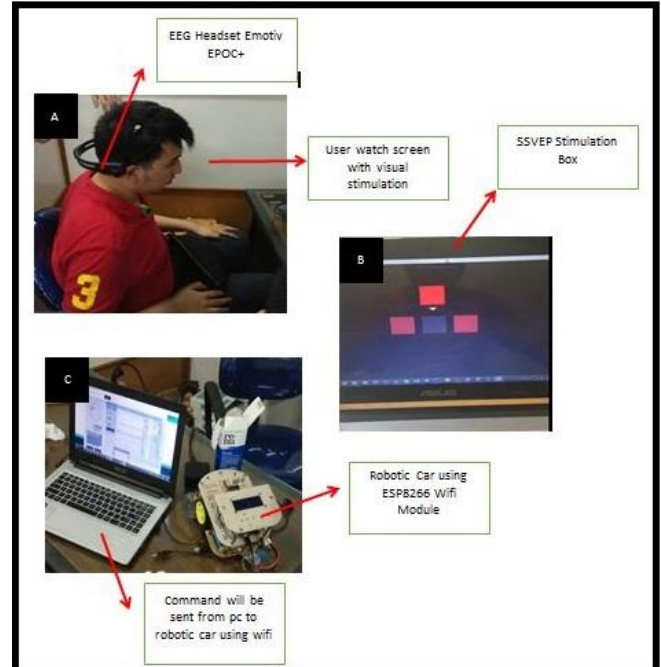


Figure 3: BCI System Setup

F. EEG Recognition

EEG recognition on OpenVibe is executed using an offline EEG data (recorded EEG) and an online EEG data directly from Emotiv EPOC+. The result of the EEG recognition process is the recognized class (the command direction to the RC-car movement). The classes are forward, left, and right commands. Then, the recognized class will be sent to the client application using Virtual Reality Peripheral Network (VRPN) button on OpenVibe.

III. RESULT AND DISCUSSION

In this project, two volunteers have participated in the experiment. The experiment was established under various condition: 1) varying sensors contact quality; 2) using different SVM kernels; 3) various error tolerance of Epsilon. This variation of parameters will affect the accuracy of the EEG recognition rate. We used computer specification as follow:

- OS: Windows 10 Pro 64-bit (10.0 build 15063)
- Processor: Intel (R) Core (TM) i3-3217U CPU @ 1.8Ghz (4 CPUs)
- RAM: 4 GB DDR 3

A. Sensor Contact Quality

We tested the effect of sensor contact quality to the EEG recognition accuracy. Our 14-channel EEG sensor has not all perfect contact to the scalp, resulting in the lost signal. The sensor channel that has good contact is indicated by the green indicator of the software. Often the thickness of the hair makes the sensor contact not actually attached to the scalp, so that it loses contact. The results of the test can be seen in Table 1. This test groups sensor contact into 3 types as follow:

- Type 1: 90% contact quality
- Type 2: 70% contact quality
- Type 3: 50% contact quality

Table 1
Recognition Rate With Different Sensor Contact Quality

Sensor contact	Left (%)	Right (%)	Forward (%)
90 %	88.5	91.2	90.7
70 %	77.4	74.8	81.2
50 %	52.3	70.2	65.2

B. SVM Kernels

We also tested the influence of using various type of SVM Kernel and Epsilon to the accuracy of SVM recognition. The kernel used in this experiment are:

- Linear kernel
- Radian Base Function (RBF) kernel
- Kernel polynomials
- Sigmoid kernel

The results obtained from the test can be seen in Table 2 below.

Table 2
Recognition Rate with Different Kernel

Kernel	Left (%)	Right (%)	Forward (%)
Linear Kernel	88.51	91.23	90.73
RBF Kernel	88.44	91.19	91.24
Polynomial Kernel	85.79	90.90	91.05
Sigmoid Kernel	88.49	91.28	90.81

C. Error Tolerance (Epsilon)

We tested the influence of epsilon value on the accuracy of the SVM recognition. This test was performed using data type 1 (90% sensor contact quality) and linear kernel. The result is depicted in Table 3.

Table 3
Recognition Rate with Different Epsilon

Epsilon	Left (%)	Right (%)	Forward (%)
0.05	88.51	91.24	90.72
0.1	88.51	91.23	90.73
0.15	88.49	91.28	90.81
0.2	88.58	91.28	90.71

D. Movement Test Using Offline Data

We also inspected the RC movement by comparing the motion of RC car with the packet received from VRPN client.

This test was performed offline with the following data set:

- Quality Contact Sensor = 90%
- Kernel = linear
- Epsilon = 0.1
- Class = left, right, forward, neutral
- Number of data per class = 8

The complete results of EEG recognition can be seen in Table 4.

Table 4
RC Car Movement

Sequence	Recognized Command	Ground Truth (Expected Result)
1	Neutral	Neutral
2	Left	Left
3	Right	Right
4	Forward	Forward
5	Left	Left
6	Forward	Forward
7	Forward	Neutral
8	Right	Right
9	Forward	Forward

Sequence	Recognized Command	Ground Truth (Expected Result)
10	Left	Left
11	Right	Right
12	Neutral	Neutral
13	Left	Left
14	Neutral	Neutral
15	Right	Right
16	Forward	Forward
17	Neutral	Neutral
18	Right	Right
19	Forward	Forward
20	Right	Left
21	Right	Right
22	Neutral	Neutral
23	Forward	Forward
24	Left	Left
25	Forward	Forward
26	Right	Right
27	Left	Left
28	Neutral	Neutral
29	Right	Right
30	Forward	Left
31	Neutral	Neutral
32	Forward	Forward

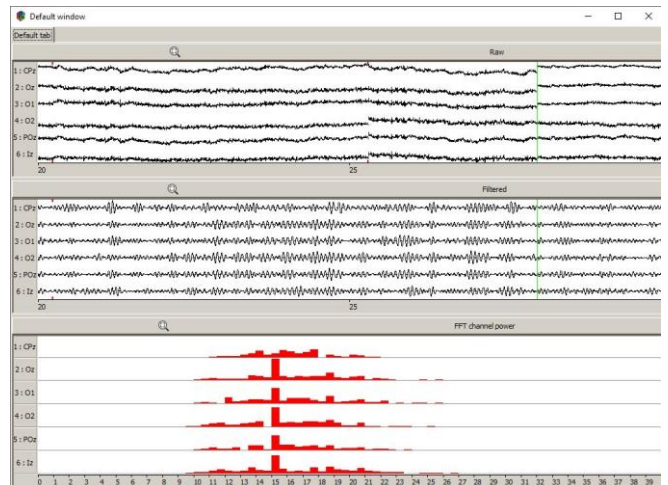


Figure 4: The Frequency Response of Left Command

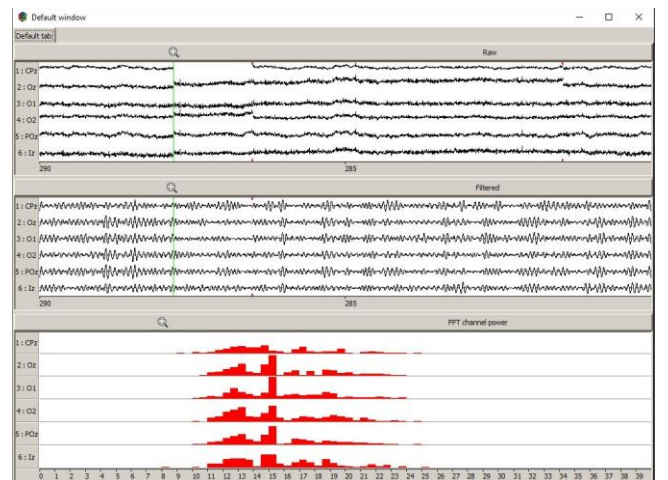


Figure 5: The frequency response of Right Command

E. EEG Frequency Response

In this section, we tested the frequency response of EEG signal with the specific mind command that has been issued by the user. The response is depicted in Figure 4 and 5 for the frequency of each SSVEP class (left and right command).

This test was performed with Epoch duration of 0.5 and delay interval 0.1.

- Left Class – SSVEP Box (15HZ)
- Right Class – SSVEP Box (17Hz)

IV. CONCLUSION

From the results of the experiment, it can be concluded that by using Emotiv EPOC+ and SVM method for EEG signal classification, BCI system of RC-car control can be functioned appropriately. The system accuracy is 88% for the left command, 91% for the right command, and 90% for the forward command. The best kernel of SVM is using the linear kernel, whereas for the best error tolerance is using $\epsilon = 0.5$.

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