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EEG Control of a Radio-Controlled Car Using Wireless Network

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Abstract

Establishment and focus: This paper aims to develop a system that can control RC cars in five directions: forward, backward, left, right, and stop using EEG signals to apply BCI-based technology. The Neurosky's Mindwave device headset is used to measure brainwave signals and the Arduino Uno is used as a microcontroller for RC car control. The NeuroSky's eSense algorithm is used to represent mental state. The communication between the EEG headset and the PC was via Bluetooth and the communication between PC and Arduino for RC car control is done via Wi-Fi. The EEG signals are converted into attention and meditation values to present mental states.

System: The developed system can control RC car in 5 directions (forward, backward, right, left, and stop) by using EEG measured in real time. The wearable EEG mobile headset is used for user convenience. We have developed a web-based program to run on mobile devices. The program consists of RC car control module and EEG status information module. The RC car control module is for inducing user's RC car direction control. This module displays arrows for direction selection and number of eye blinking. When the arrow is in the desired direction, user blink his/her eyes to select the direction. The EEG status information module shows the attention and meditation values of the user and power value for each frequency band in real time. This module reflects the user's EEG status when the user wants to keep the RC car moving in the specified direction. The developed system has more than 80% accuracy when changing the direction of RC car. Also, the direction of RC car is changed within 1 second after the direction selection is made in WEB GUI program. The developed system can be used for wheelchair operation or other external device control technology for people with discomfort such as stroke or spinal cord paralysis patients.

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1. Introduction

Brain Computer Interface (BCI) is an interface technology that directly connects the human brain to a computer and controls the computer through brain waves. MIT Technology Review has selected BCI as the top 10 next generation technology. In 2009, the Korea Institute of Science and Technology Evaluation and Planning (KISTEP) selected it as one of the 10 promising technologies that will greatly change our lives for the next 10 years [1-3]. BCI technology was mainly used for medical purposes, such as the control of ADHD children or severely disabled

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persons. Globally, BCI is used in a variety of medical purposes, including early detection of dementia, treatment of depression, psychoanalysis, and even marketing and game [4-6]. If BCI research and technology is further developed, it will be used as next-generation interface technology beyond touch screen and augmented reality [7,8].

Recently, lightweight and easy-to-wear devices in the form of headsets have been released at low prices and are being used for various purposes. Wearable and portable EEG devices can measure the level of intention or attention of the user in real time. Also, it can deliver measured data to a computing device such as a mobile phone using Bluetooth [9,10]. Using such devices, it is possible to express in web page where the user's attention level is high. Web developers provide this information in the form of web content to induce user feedback. Users can easily check their EEG status through the websites [11].

BCI is a new technology that extracts features from EEG and converts them into device control signals. EEG is obtained using electrodes attached to the scalp. The signal obtained is so weak that it is amplified and then converted into a digital signal. The transformed EEG signal is characterized in the signal processing step, and the noise is removed in this step. The BCI system extracts the features of EEG and converts them into control signals. EEG μ waves, ERP P300, etc. are used to characterize and classify brain waves. The BCI technology is used to control various devices such as a wheelchair, a robotic arm, a mouse, and a cursor [12-14]. Figure 1 shows the BCI system.

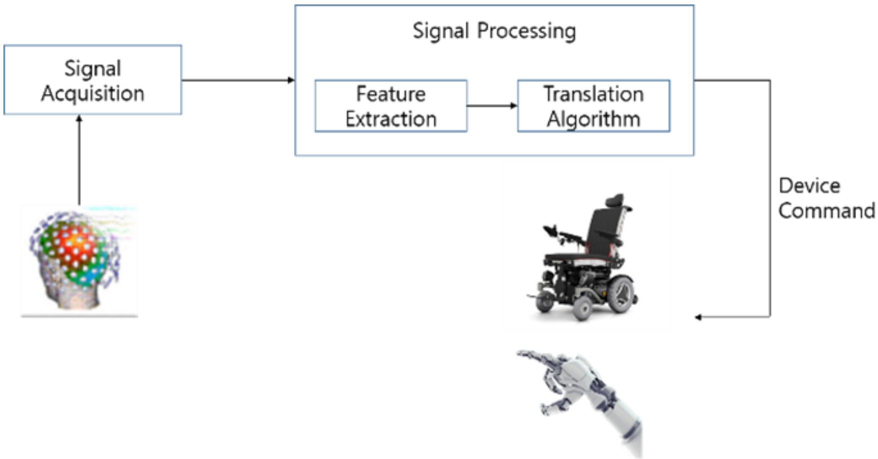

Figure 1. Brain Computer Interface.

The purpose of this paper is to control the RC car in the desired direction using BCI technology. In addition, the BCI system that works well in a web browser for use in mobile devices for user convenience. To do this, a web page is used to induce the direction selection of user. A web page is needed to give the user feedback on the current EEG status for accurate EEG induction. Also, it is necessary to reduce not only the accuracy of the system but also the delay time in command delivery to increase system efficiency.

2. Methods

2.1. Methodology

The developed BCI system consists of several devices. This system consists of a NeuroSky Mindwave headset, a PC with Windows operating system and RC car with an Arduino Uno microcontroller. The interconnection between the devices is illustrated in the Figure 2.

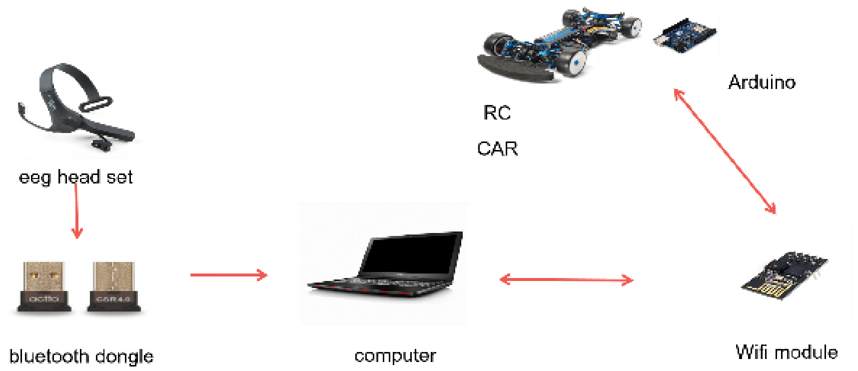

Figure 2. Block Diagram of BCI System.

After collecting EEG from EEG headset, send EEG data to PC through Bluetooth communication. The PC processes the received data and displays it graphically on the screen, and transmits the control command generated according to the EEG change to the RC car through Wi-Fi communication. Table 1 shows the function of each module.

Table 1. Function of Hardware Module.

Module	Function
EEG headset	Collects EEG signals from the user and passes them to the PC
Arduino	Receives control signal from PC and moves RC car in specified direction
Wi-Fi	Communication module mounted in RC car. Used to receive control signal from PC
PC	Responsible for processing EEG signals received from EEG headset and control signals to RC car

2.2. Hardware

• EEG Device.

In BCI, user has to monitor his own brain waves in real time to control the given application. For extraction of EEG signal from the brain, ThinkGear device is used. The ThinkGear reports EEG raw data and information about the brainwave frequency bands and user's mental state in the form of attention and meditation. Also, the Mindwave outputs the EEG power spectrums (delta, theta, alpha, beta, gamma waves). The device consists of a headset, ear-clip and a sensor arm. The reference and ground electrodes of the headset are on the ear clip. The EEG electrode is on the sensor arm. The position is FP1 on the forehead above the eye [15].

• Microcontroller.

Arduino Uno microcontroller board is used. This microcontroller has ATmega328P microcontroller IC, 14 digital I/O pins and 6 analog inputs. Within these 14 digital I/O pins, 6 of them can be directly configured as PWM output. There is also a 16 MHz quartz crystal on this microcontroller board. The board consists of a voltage regulator IC that can support an input voltage of 6 to 20 V. The dimension of this microcontroller board is 68.6 mm x 53.4 mm. This microcontroller is relatively small size. Therefore, it is convenient to mount on RC car. This microcontroller is used to connect with the Wi-Fi module. This allows the microcontroller board on the RC car to receive control signals wirelessly from the PC [16].

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2.3. Software

• eSense Algorithm.

eSense is a NeuroSky's algorithm for characterizing mental states. In the developed system, eSense algorithm plays an important role in EEG signal acquisition and classification. To calculate, NeuroSky amplifies the EEG raw signal and remove the noise and muscle movement. The eSense algorithm is then applied to the remaining signal, resulting in the interpreted eSense meter values. For each different type of eSense such as attention and meditation, the meter value is reported on a relative eSense scale of 1 to 100. On this scale, a value between 40 and 60 at any given moment in time is considered "neutral" and is similar in notion to "baselines" that are established in conventional brainwave measurement techniques. The eSense attention meter indicates the intensity of a user's level of mental attention and the eSense meditation meter indicates the level of a user's mental relaxation [17].

2.4. Data Processing

Figure 3 shows the overall system data processing. The Mindwave device will pick up the raw data of EEG. The obtained signal is transmitted using Bluetooth. The data which is transmitted is to be processed in PC. The Brainwave Control program receives EEG data from COM11 port and then send it through curl to bp_middle program. The bp_middle.js program transmits in real time to the WEB GUI via socket communication through the socket.io module. The bp_middle program is implemented using jsp. The WEB GUI program represents graphically the EEG data transmitted in real time. The WEB GUI program for RC car control receives user's blink information and converts it into control command for direction control. It is implemented using HTML5 and javascript. The microcontroller mounted on the RC car receives the control command via the Wi-Fi module. In response to the received control command, the microcontroller drives the wheel motor to move the RC car in the specified direction.

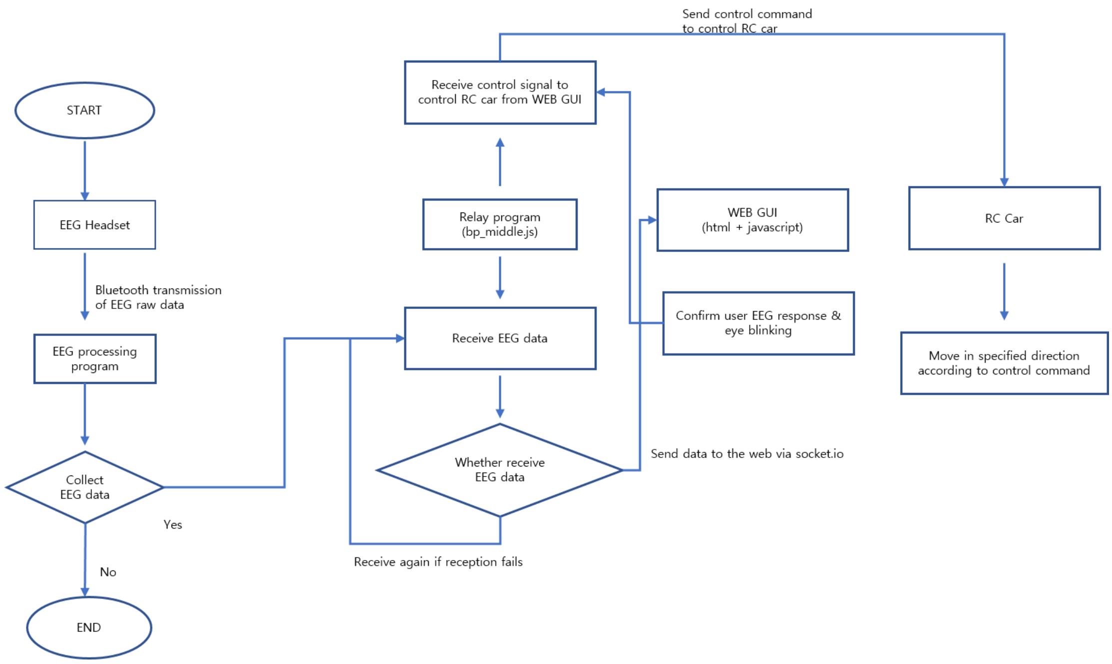

Figure 3. Flowchart of System Data Processing.

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3. Results

3.1. Design of GUI for RC car control

The developed system provides two GUI modules. The direction control module represents five directions (right, left, up, down, stop) to control the RC car. The EEG status information module is a module that shows EEG status information during RC car control. Figure 4 shows the GUI screen for RC car control. The direction control module represents five directions (right, left, up, down and stop) to control the RC car. The arrow on the control screen indicates the direction you want to go. Arrows are highlighted sequentially. When the arrow in the desired direction is highlighted, blinking the eye selects the direction. Once the direction is selected, the specified direction arrow remains bright. The control signal for the selected direction is sent to the RC car. Movement of the RC car in the specified direction depends on the degree of attention meter level. If user close his/her eyes for about 1 second, it induces an increase in alpha waves. It is interpreted as a stop signal. If user open his/her eyes, arrows are highlighted sequentially again. The right side of the screen shows the attention, mediation meter level and available number of blinks.

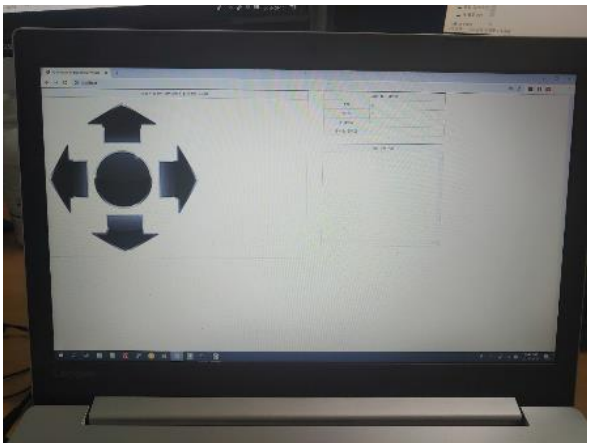

Figure 4. GUI for EEG Controlled RC car

3.2. Design of GUI for EEG status information

Figure 5 shows EEG status information while controlling and RC car in real time using EEG. After the user selects a direction to move the RC car, the user must concentrate to move in that direction. The speed of RC car may vary depending on the degree of attention meter level. For this purpose, EEG status information module displays the attention and meditation values that change in real time in the form of a bar graph. Also, the power of each frequency band (Delta, Theta, Alpha, Beta, Gamma waves) is displayed to indicate a change in mental state. Attention meter value is closely related to beta power, and meditation meter value is closely related to alpha power. In general, the higher the attention meter value, the higher the beta power, and the higher the meditation meter value, the higher the alpha power.

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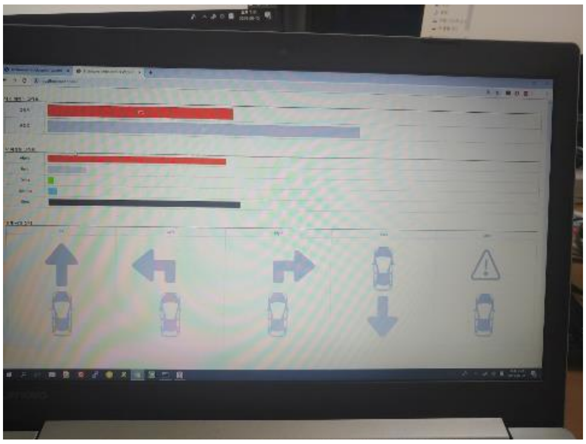

Figure 5. GUI for EEG Status Information

3.3. Test Result

The developed system was tested as shown in Table 2. RC car operation confirmed that each motor is operated using firmware. To check whether the Wi-Fi communication between the RC car and the computer is possible, we check whether the control command is transmitted through the URL. Bluetooth communication between the EEG headset and the computer was confirmed by connecting the computer and the EEG headset and receiving EEG information. The developed signal processing program was operated to check the connection status, signal collection and processing. Also, after sending the control signal to the RC car through the program, the response time of signal was checked. We confirmed whether EEG data is normally delivered through WEB GUI program. Also, as a method for evaluating the performance, the accuracy of the change of direction was confirmed. We also checked the time taken to change the RC car direction after selecting the direction in the WEB GUI. Then tests were performed each in five directions (forward, backward, right, left, and stop). The accuracy in each direction was 78%(forward), 80%(background), 82%(right), 75%(left), and 90%(stop).

Table 2. Test Result for System Accuracy

Test Item	Result
Communication between computer and RC car	Normal operation
Delay time of communication between computer and RC car	Within about 1 second
Eye blink recognition of EEG processing program	More than 90% accuracy
Attention recognition of EEG processing program	More than 90% accuracy
Communication between EEG processing program and GUI program	Normal operation
Total delay time until EEG is transmitted to GUI program	About 0.8 seconds
Directional accuracy of RC car	More than 80% accuracy

4. Conclusion

In this paper, we developed a BCI system that can control RC car using EEG. The developed system is implemented in web browser for user convenience. It utilizes wearable device and can operate on mobile device. The system has more than 80% directional accuracy of RC car in terms of system performance. The current system focus on device control based on attention and meditation level. However, adding processing for various frequency bands can be extended to BCI systems that reflect more diverse mental states. The developed system uses a power spectrum analysis through FFT transformation on collected EEG raw data.

Attention and meditation meter values are based on power values. For more detailed device control, brain waves that reflect the user's intention should be classified and controlled. By applying the deep learning technique to the collected EEG raw data, EEG signals can be classified more accurately according to the user's intention. In the future, we will conduct research to improve system efficiency by applying deep learning techniques to the developed system.

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