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Mental Task Design Based on EEG Signal for Brain Computer Interface System

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Abstract:
Brain computer interface (BCI) system empowers command over external device by retrieving brain waves and interpreting them into machine instructions. The system utilizes electroencephalogram (EEG) for receiving, processing and classifying signals to control by means of brain generated signals. The paper focused on mental task designs for BCI by acquiring the signals generated by mental activity using EEG comb electrodes, placed over three-dimensional (3D) printed headset. The experiment involved the blinking of left and right eyes for the forward and backward movements of the prototype wheelchair. The experimental measurement was performed using a Cyton board where the information was transmitted through Bluetooth which were later processed and translated to the wheelchair to perform activities. The system has successfully achieved the real time control of an assistive device by using signals from the brain.

Keywords: BCI; Cyton; Mental activity; Mental task; Wheelchair; Assistive device

1. Introduction

Computer commands are analyzed and translated to computer commands with the help of Brain Computer Interface (BCI). Brain helps to build the direct linkage to the computer by utilizing muscles and Central Nervous System (CNS). There are abundant possibilities of implementing this technology which can help for significant and valuable applications. With efficient signal acquisition technique and robust methods of signal processing and machine learning, BCI can be used to ease life of an individual having physical disabilities. Driving a wheelchair or walking in exoskeleton by utilizing the power of thoughts can return functional life from a paralyzed or partially paralyzed disabilities.

The recent development of research has opened up the field of brain computing interfaces (BCIs) paired together with electroencephalogram (EEG) signal where the signals are applied as an input channel in order to control the assistive device for handicapped or disabled person [1, 2]. A neuromuscular pathway can be built up by using EEG which aids creating the neuromuscular bypass by an external device by the help of retrieved information coming directly from the EEG electrodes placed on the scalp. The signals are acquired in the form of brain potentials where information is later changed into commands to perform various functions [3]. Recently studies have shown EEG as a human-machine interactive technology which is used to monitor states of human which then later modeled [4–7]. A BCI communication system is the system that allows the person to involve his thoughts which is retrieved in the form of bioelectric potentials carried out from brain's neural pathway to the communication system [8–10].

Beside EEG, there are other methods to study the brain activity, such as functional magnetic resonance imaging (fMRI), positron emission tomography (PET) and magnetoencephalography (MEG) having enhanced spatial sensitivity [11]. However, EEG is still preferred because of its low cost and availability. Unlike to other methods which require bulky and immobile equipment, EEG requires a quiet room and small-sized equipment. However, it requires precise placement of the electrodes around the user's head and requires the use of gels to be pasted on the scalp to maintain a good conductivity. Furthermore, it has poor signal-to-noise ratio, hence require sophisticated data analysis and signal processing.

Consequently, the objective of the study is to plan mental task strategy for BCI utilizing EEG comb electrodes placed on a 3D printed headset. It requires precise placement of the electrodes around the user's head, and signal processing to improve the signal-to-noise ratio of the signal acquired. The expected outcome is to produce control signal accurately based on task such as eye blinking to generate signal in order to control an external device such as wheelchair.

2. Methodology

The study was initiated with the development of 3D printed headset for the placement of EEG electrodes around the user's head. The brain signals were acquired from EEG electrodes which connected to the OpenBCI Cyton board. Since the signals were contaminated with noise and artefacts, which is generally due to the blinking or movement of an eye, heartbeat, muscular movement or powerline noise, the pre-processing of signals was taken place.

The overall system of BCI-based wheelchair is shown in Figure 1. The system divided into various phases, initially the control system was designed where the data and signal acquisition were carried out following with the circuit development. The study was then proceeded towards the development of prototype wheelchair control. From Figure 1, EEG signal was measured on the scalp and then sent to BCI system for signal processing. Then, signal classification using machine learning was performed and were translated into signal. These signals acted as a command, which was then sent to Arduino through Bluetooth to control the wheelchair.

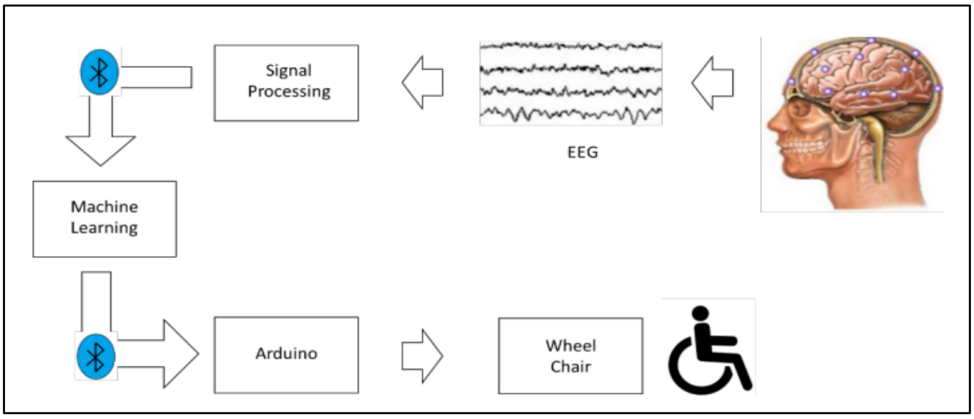


Figure 1. System block diagram

After the command is translated, it was sent to the Arduino through Bluetooth system to control wheelchair as shown in Figure 2. The Arduino received the signal in order to control the movement of wheelchair through HC-05 Bluetooth module. The communication was done using serial communication which made an easy way to interface with controller of wheelchair.

The basic idea of the BCI-based control system for next generation of electric wheelchairs is shown in Figure 2. Signals from the brain were acquired through electrodes on the scalp focusing the occipital region and processed to extract specific signal features (e.g., amplitudes of evoked potentials or sensorimotor cortex rhythms, firing rates of cortical neurons) that reflected the user's intent. These features were then translated into commands to operate the wheelchair. Accomplishment was dependent on the interaction of two adaptive controllers, user and system. The user was advised to develop and maintain good correlation between his intent and the signal features employed by the BCI. The BCI could possibly select and extract the features so that the user could effectively control and translate those features into device commands correctly.

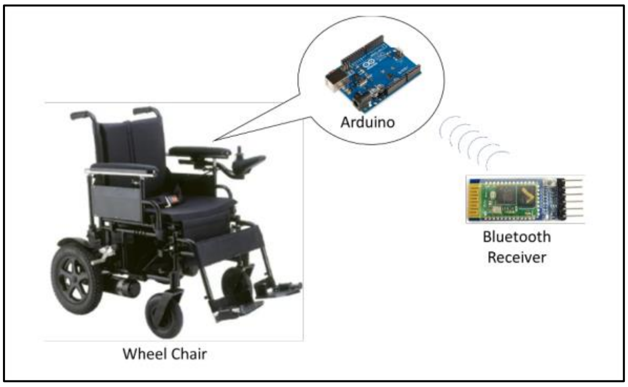


Figure 2. Arduino controller for wheelchair

2.1 Circuit design

The conventional DC motor was used in the study for a low-cost solution. The study utilized DC brushless motor due to its higher dynamic feature characteristic and better performance. For propulsion and steering control, both the motors were installed on either side of the chair. The user intent was sent to central control unit (CCU) which contained all kinds of algorithms and electronics.

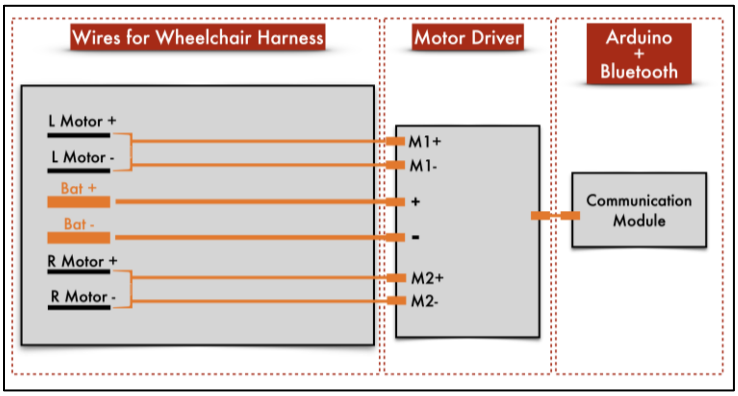


Figure 3. Circuit design

The wiring stretched from each of left and right-side motor (MY1016Z, 24V, 250W) of the electric wheelchair to DC motor driver (DRI10018) powered by a battery shown in Figure 3. The Arduino UNO and a Bluetooth module (HC-05) were used to provide communication between wheelchair and computer. Motor driver received the command signal from Arduino to control the motor where the motor of the wheelchair was connected to motor driver. Bluetooth module was used to receive the command signal wirelessly where Arduino Uno functioned as a microcontroller which allowed to receive the signal via Bluetooth and signals were sent to motor driver. The circuit was powered by the 12000mA battery shown in Figure 4.

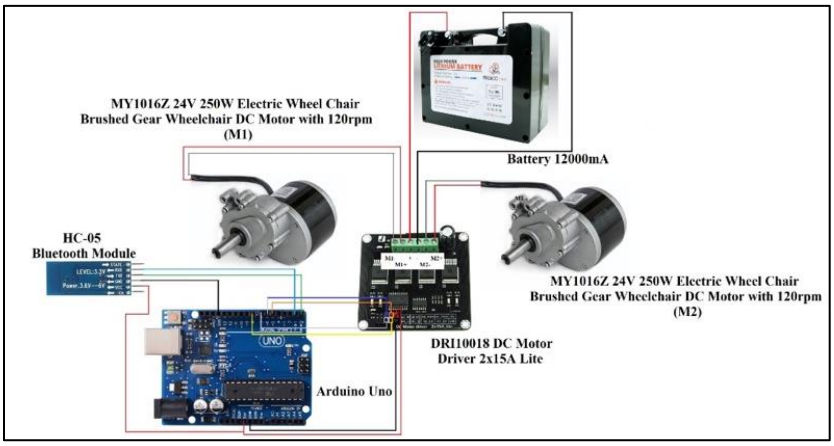


Figure 4. Circuit connection

Bluetooth Remote Control was designed to be used with a MODIFIED RC car. This application allowed the user to reprogram and control the circuit with a micro controller. It allowed user to control a micro controller and Bluetooth fitted RC car with user's smart phone. The flow of information transfer is illustrated in Figure 5.

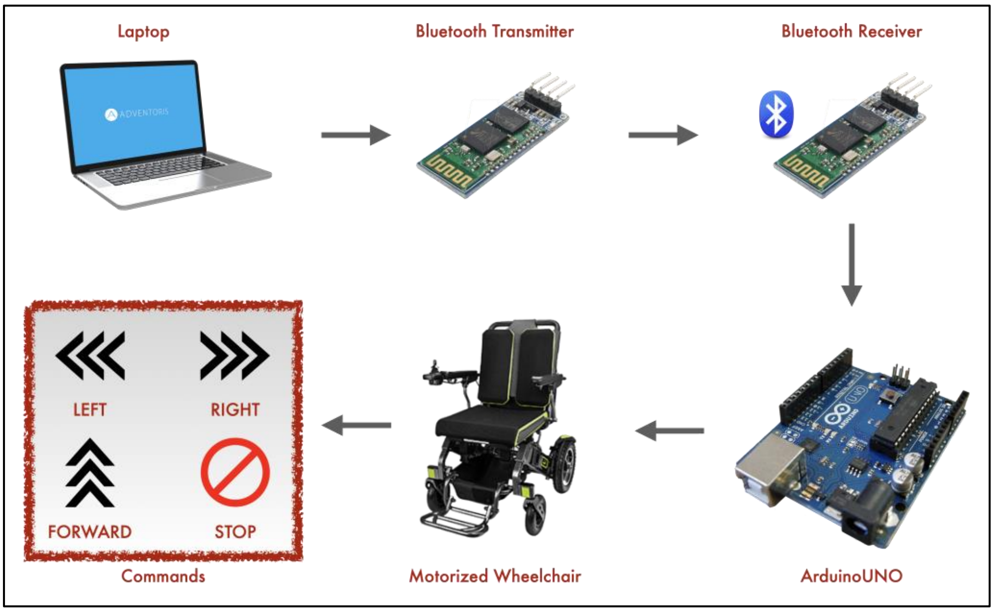
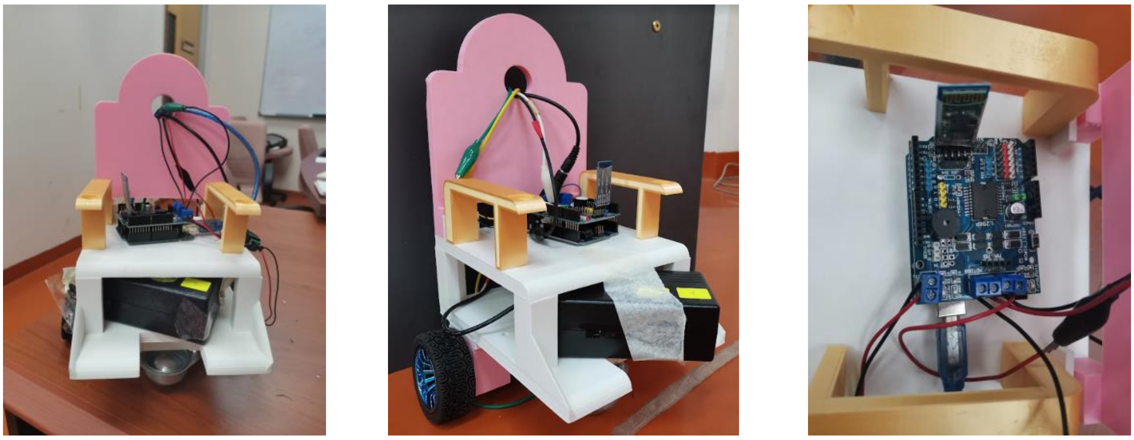


Figure 5. Bluetooth communication

The most commonly used method to control the power across the loads is Pulse width modulation (PWM) which is highly efficient.

2.2 Experimental setup – Prototype wheelchair

The prototype wheelchair was 3D printed and two motors were installed on either side demonstrated in Figure 6 (a) and (b). The wheelchair was controlled using a Bluetooth module and Arduino microcontroller to send and receive commands to function accordingly demonstrated in Figure 6 (c).



(a) Prototype wheelchair front view (b) Prototype wheelchair side view (c) Bluetooth and Arduino controller

Figure 6. Prototype wheelchair

The eye blinking test was performed to operate the prototype wheelchair. The test involved the blinking of right and left eye. The motion involved was forward and backward. For the forward and backward movement, both the motors were allowed to function simultaneously in the same direction either forward or backward.

3. Results and Discussion

The 3D headset is printed for the placement of EEG electrodes around the user's head as shown in Figure 7. The headset was placed on a subject's head and electrodes were gently screwed so that the direct contact could be attained regardless of interference of hair. The development of the prototype of wheelchair shown in Figure 6. was done in order to test the subject and movement of prototype wheelchair.

Figure 7. 3D printed headset

With the movement blinking of left and right eye, the 3D printed wheelchair could successfully move forward and backward. The signals were transmitted through Bluetooth module to the controller where motion was made by the command given by subject through eye blinking activity as shown in Figure 8. Ten trials were made for two types of motion as summarized in Table 1.

Figure 8. Prototype wheelchair movement control

Table 1. Experiment result for eye blinking test with different subjects

Subject	**Activity**	**Trial**										**Accuracy (%)**
		1	2	3	4	5	6	7	8	9	10	
Subject 1	Left eye (forward)	T	T	T	T	T	T	T	T	T	T	100
	Right eye (backward	T	T	T	F	T	T	T	T	T	T	90
Subject 2	Left eye (forward)	T	T	T	T	T	T	T	T	T	T	100
	Right eye (backward	T	T	T	F	T	T	T	T	T	F	80
Subject 3	Left eye (forward)	T	T	F	F	T	T	T	F	T	T	80
	Right eye (backward	T	T	F	F	T	T	T	F	T	T	80

The outcomes from the test demonstrated the accuracy of the system controlled with the movement of an eyeball where the success results were at least 80% for all the subjects tested. This would justify the practicality of utilizing EEG signal from human to control external device such as wheelchair which could benefit disabled person. The system can further be improvised with more control signal for different moving direction, safety feature such as emergency stop button and sensors to detect any nearby foreign objects, and additional tests that can further be implemented to control the real wheelchair by a person sitting on it.

4. Conclusion

The investigation concludes the accuracy of the system that resulted to be helpful to control the external software without the need to use our hand or feet. The investigation utilized eye movement which could easily control the movement of wheelchair to move forward or backward with accuracy of minimum 80% which is precise across three different subjects. With minimum training required, subjects were able to control the 3D printed wheelchair which proven the practicality of the system especially for those disabled person. The results demonstrated the appropriate connection and signal acquisition from the brain which can further be used to develop and control the actual BCI smart wheelchair.

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