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Brain Controlled Wheelchair: A Smart Prototype

Brain Controlled Wheelchair: A Smart Prototype

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Abstract. EEG has been largely used in both clinical and research applications. Brain computer interface (BCI) system is one of the major EEG research applications which can provide a new way of communications for special users who cannot communicate via normal pathways. This paper focuses on the development of the brain controlled wheelchair which incorporates two additional control interfaces including joystick and a remote control through an android phone. All three controls are integrated in such a way that it allows the user to change the mode of control by simply changing the state of the slide switch. This work utilizes the Neurosky Mindwave Mobile headset to capture the EEG signals through a single channel placed at the FP1 position. Eye blinks and attention levels are the key features of the captured EEG that are extracted and identified through an android application. The design also assimilates ultrasonic sensors based safety system which is capable of detecting the obstacles in all four directions to ensure the safety of the user.

1. Introduction

In year 2011, statistics shows that approximately 15% of the populations are disabled people [1]. Among the disabled people, most of them suffer difficulty in mobility. They face discrimination on regular basis which takes many forms. These people are considered more as a liability than an asset to the society. Since they encounter discrimination, they tend to alienate themselves from the society as they feel unwanted and rejected.

The amount of disabled persons who lost their mobility are significant. There needs any engineering assistance which can help them to move around on their own without anyone's help. The traditional way of providing them mobility was to use the simple wheelchair; but later on, power wheelchairs were introduced which were operated by the analog joysticks [2, 3], head [4], tongue [5] and voice actuated switches [6, 7]. Most of the products lack the intelligent obstacle avoidance system; the shortcoming leads to unwanted outcomes.

Apart from their disabled body, they have sound and operational brains. The brains can be utilized to provide them opportunities to move freely by controlling the wheelchairs using their thoughts.

Brain Computer Interface provides a platform that helps us in creating a communication link between the users and the computer systems [8]. It allows us to communicate by using only our brains. BCI system does not require the actual muscles that are usually involved in the process of communication. The research communities around the world are developing different medical applications based on BCI, thus helping patients who have lost their ability to communicate and providing them mobility [9].

There are several methods available in order to record electrical signals corresponding to some type of mental or physical response of any human. These methods are electroencephalography (EEG), magnetoencephalography (MEG), electrocorticography (ECoG), functional magnetic resonance imaging (fMRI) and functional near-infrared spectroscopy (fNIR), etc. [10].

Electroencephalography (EEG) is a method used for the recordings of brain's electrical neural activities [11]. Most of the BCIs utilizes EEG technology. This is because the EEG is portable, non-invasive and less expensive. EEG or Brain signal is the recording of the electrical activity along the scalp [12]. Each thought or action generates a unique brain signal which may differ from person to person.

EEG signals acquired from scalp has different amplitudes and frequencies according to which they are divided into different EEG bands [13] mentioned in Figure 1 and Table 1 below.

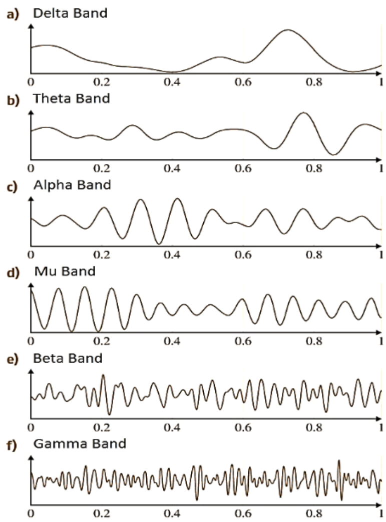

Figure 1. Brain Waveforms.

Table 1. EEG frequency bands.

EEG Band	Description
Delta (1–4 Hz)	Delta waves are generally generated by the brain during deep sleep.
Theta (4–8 Hz)	Theta waves are generally generated by the brain under emotional tension, stress, etc.
Alpha (8–13 Hz)	Alpha waves are released when the brain is in inactive state or relaxed.
Mu (8–12 Hz)	Mu waves are generated when the person performs or imagines any motor action.
Beta (13–30 Hz)	Beta waved are released by the brain during active thinking, focus or solving a problem.
Gamma (30–50 Hz)	These waves are released by the brain during conscious perception.

To record electrical activity generated by the brain, EEG researchers use sensors known as electrodes. These electrodes can be invasive or non-invasive. Generally, electrodes being used in research are non-invasive which can be further distinguished as wet or dry electrodes [14].

The electrode sensors are part of some EEG devices that are extensively used to record brain signals. There are several wired and wireless portable EEG devices that can be found in the commercialized market [12]. Some of famous devices are OpenBCI, Enobio, OpenEEG, Mattel Mindflex, Neurosky Mindwave, Muse and Emotiv EPOC.

The paper describes the development of a smart wheelchair which is controlled by the human brain that can assist the disabled ones in their daily life to move around independently; this will be cost effective, comfortable and safe for the society to take these technologies at their homes by introducing a proper hurdle avoidance system. Furthermore, the proposed system provides the user the ability to switch the wheelchair control from brain to joystick or remote control using an android device.

2. Methodology

The aim behind the proposed system is to develop a smart wheelchair which can be controlled through three different modes. Brain control is defined as the primary control while joystick and remote control are considered to be the secondary controls for the wheelchair. All the three modes are independent among one another, which allows the user to switch the control of the wheelchair at any time. An ultrasonic sensor-based safety system is interfaced with each control mode to make the wheelchair safe and secure for the user. Figure 2 describes the idea of the proposed system.

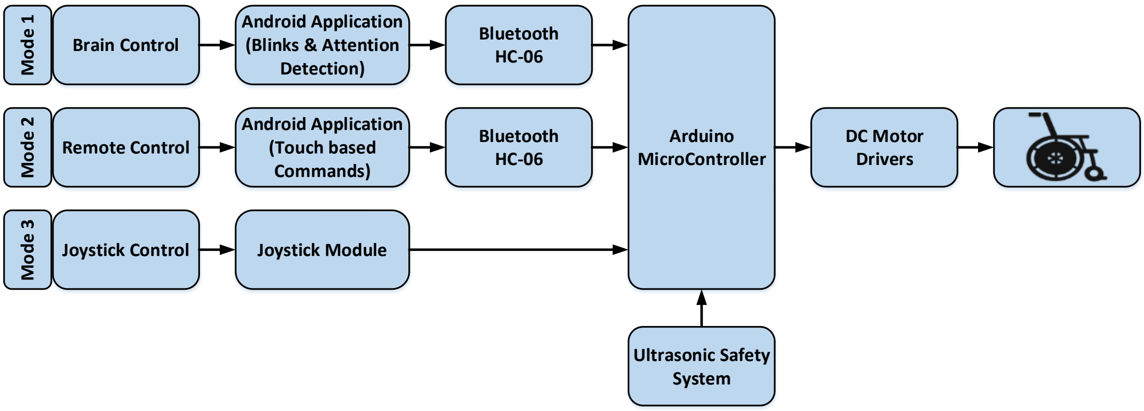

Figure 2 Proposed system.

2.1. Primary Control system

Brain control is considered as the primary control of the wheelchair. It involves the EEG data acquisition using Mindwave mobile headset. An android based smartphone is the platform which is used to receive the EEG data transmitted from the wireless headset.

The android application is developed using an android development tool kit provided by Neurosky. The application is built in such a way that it can identify eye blinks strength and intensity of attention. The application follows Bluetooth communication protocol to receive the EEG signals from the wireless headset and transmit the required output using the same protocol.

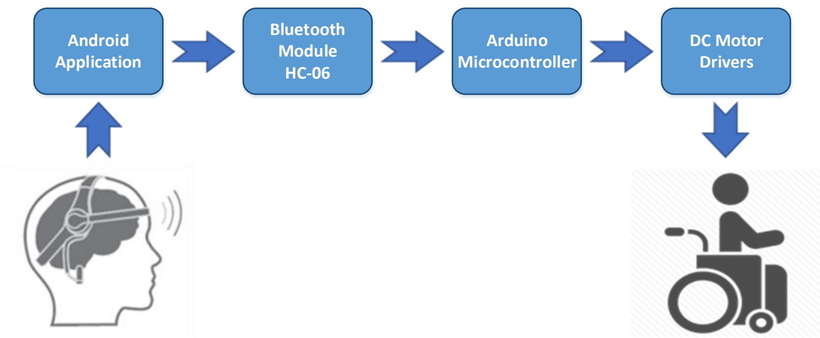

Figure 3. BCW using mindwave headset.

The aim of proposed system is to acquire and identify the EEG signals that is related with the user intentions to operate the wheelchair. Figure 3 shows the general block diagram of proposed system.

2.2. EEG Acquisition System

The proposed work utilizes wireless headset (Mind Wave Headset) which reduces the overall cost of the system to operate the wheelchair in four directions such as forward, backward right side and left side. The technical specification of EEG headset is given in Table 2.

Table 2. Neurosky headset technical specification.

Manufacturer	Channels	Electrode type	Sampling rate	Bandwidth	Communication	Battery life	Weight
Neurosky	1	Dry	512 Hz	3-100 Hz	Bluetooth	8 Hours	90g

Figure 4(a) shows the Mindwave headset which is used for EEG acquisition. The Neurosky Mindwave Headset has a single dry electrode, located on the FP1 frontal lobe which is used to capture the EEG and identifies basic states like attention and eye blinks. The FP1 position for electrode is shown in Figure 4(b) below.

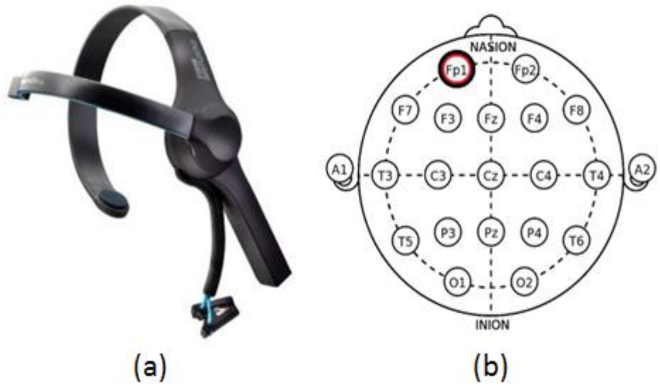

Figure 4. Neurosky mindwave Headset (a) and electrode placement at FP1 (b).

Brain signals captured using the Bluetooth enabled EEG headset from FP1 position are analysed and processed using a custom algorithm available in the android based smart phone.

2.3. Secondary Control system

Apart from the primary control, i.e., EEG based wheelchair control, the wheelchair also incorporates secondary control system in the form of a joystick control and an android based remote control.

The Dual Axis XY Joystick Module is interfaced with DC motors using Arduino microcontroller to control the wheelchair movement. An android based smart phone application is also developed, which helps the user to remotely control the wheelchair using the touch screen android phone. The remote control android application is capable of sending 5 type of commands i.e., left, right, forward, backward and stop. It utilises the Bluetooth communication to transmit the direction commands from the android phone to the microcontroller.

2.4. Safety System

Safety is considered to be the key aspect of an electrical wheelchair [15-17]. The objective is to minimize the risk of collision and to make sure the safety of the user. The wheelchair is equipped with 4 ultrasonic sensors (1 on each side) to detect any type of obstacle. The whole process is based on the ultrasonic beams. The sensor sends an ultrasonic beam to a target point and it reflects back to the sensor. The duration from sending and receiving the beam is measured and converted into a distance. The calculated distance plays a key role in order to avoid the hurdle in the safety system.

A buzzer is also available in the safety system. It can be operated automatically whenever the ultrasonic sensors detect some obstacles, and also manually as a horn using a push button.

3. Design Flow

This section of the paper describes the step by step operation of the brain controlled wheelchair. The general design flow of the wheelchair operation is shown in Figure 5. The wheelchair operation is controlled by the user's eye blinks and his/her attention. Four directions are cycled at 2 second interval in the app as well as on the LED direction panel. The User is required to select the direction by performing two consecutive blinks. Afterwards, he/she has to be attentive in order to increase the focus level. If the level reaches a certain threshold i.e., 60 in our case, the wheelchair will start moving in that particular direction.

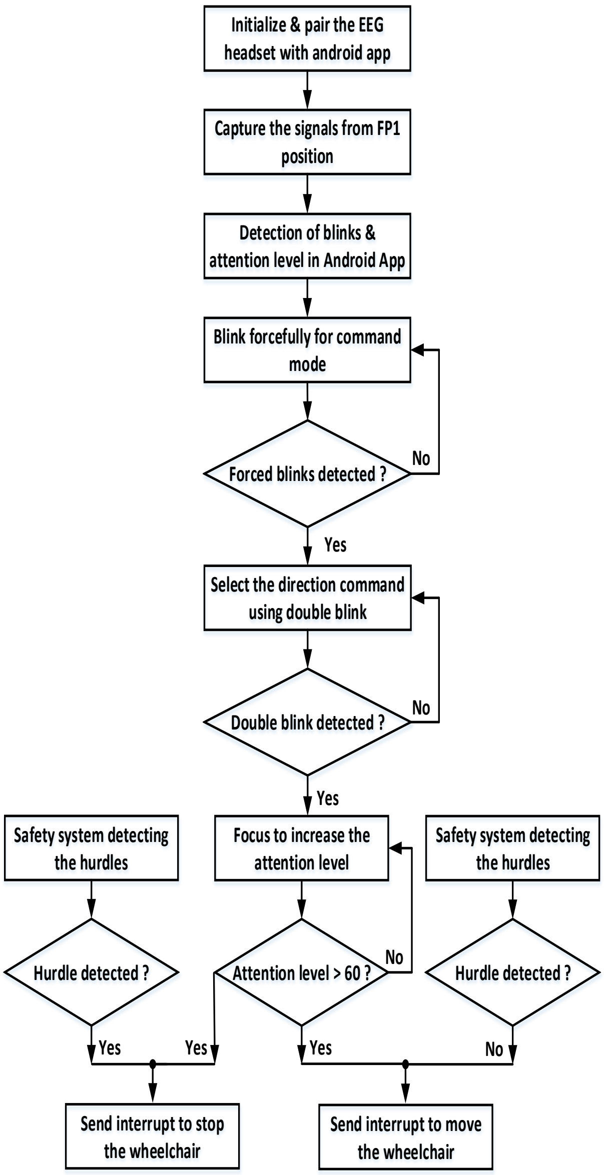

Figure 5. Design flow of brain controlled wheelchair.

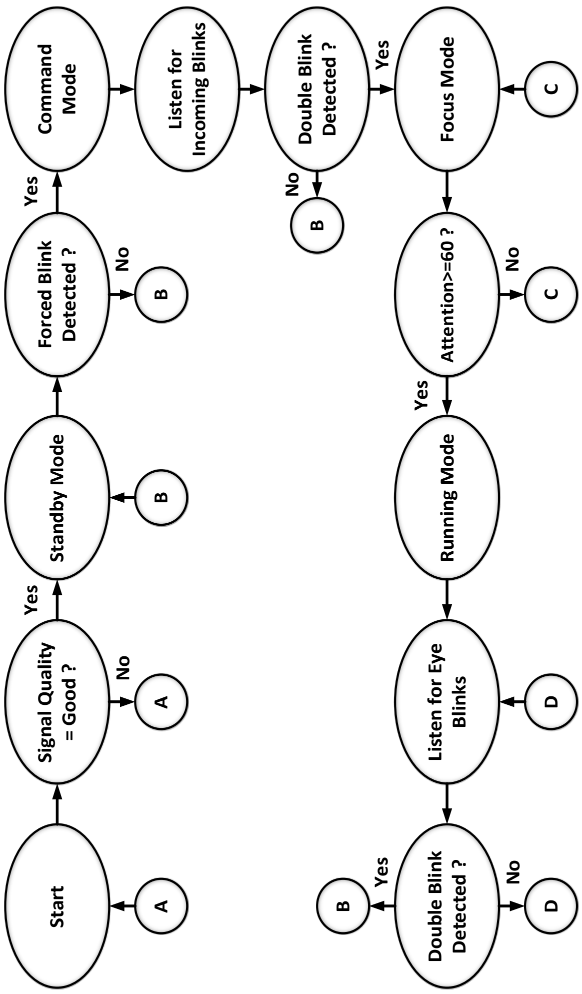

Figure 6. State diagram for EEG based android application.

Figure 6 describes the state diagram of EEG based android application. It comprises 4 basic states namely standby, command, focus and running. Initially the application stays in the standby mode until it detects the blink strength above 95. As the stated threshold is achieved, the application switches from the standby mode to the command mode, where four directions are cycled. Each direction appears for 2 seconds and if any of the direction is not selected it goes back to the standby mode.

In order to select the direction, the user is required to blink twice. As the double blink is detected, it goes to the next mode, i.e., focus mode where, the user starts focusing to increase his/her attention level. When attention level goes above 60 in the focus mode, finally the state mode goes to the "Running" mode and the wheelchair starts moving in the direction selected earlier.

4. Experimental Results

Different features of the smart wheelchair are evaluated in different phases. Operational results for each feature are described below.

4.1. Primary control of wheelchair through Mindwave headset

A total of five trials were conducted to evaluate the performance of the wheelchair. Five healthy subjects participated in the experiment to validate the feasibility of the brain controlled wheelchair. The below tables shows the successful as well as unsuccessful trials performed by all the 5 subjects.

Table 3. Results of brain control task (Experiment 1).

Brain Controlled Wheelchair							
Trial	**Direction**	**S 1**	**S 2**	**S 3**	**S 4**	**S 5**	**Performance**
1		✓	✓	✓	✓	✓	
2		✓	✓	✓	✓	✓	
3	Left	✓	✓	✓	✗	✓	84 %
4		✗	✓	✓	✓	✗	
5		✓	✗	✓	✓	✓	
6		✗	✓	✓	✓	✗	
7		✓	✓	✓	✗	✓	
8	Right	✓	✓	✓	✓	✓	76 %
9		✓	✓	✗	✓	✓	
10		✓	✗	✓	✓	✗	
11		✓	✓	✓	✓	✗	
12		✓	✓	✓	✓	✓	
13	Forward	✓	✓	✓	✓	✓	92%
14		✓	✓	✗	✓	✓	
15		✓	✓	✓	✓	✓	
16		✓	✓	✓	✓	✗	
17		✗	✗	✓	✓	✓	
18	Backward	✓	✗	✓	✓	✓	80%
19		✓	✓	✓	✓	✓	
20		✓	✓	✗	✓	✓	

The results show that maximum accuracy (i.e., 92%) is obtained by the subjects lies under the forward category. On the other hand, left, backward and right directions have accuracy of 84%, 80% and 76%, respectively.

4.2. Secondary Wheelchair control through Joystick and Android application

The performance of secondary wheelchair control through Joystick (conventional) and android application (remote control) are evaluated by five trials each. The joystick control of wheelchair is validated by 5 healthy subjects. The results of each trial performed by the subjects are given below in Table 4. The results show that the joystick mode of the wheelchair has got 100% accuracy.

Table 4. Results of joystick control task (Experiment 2).

Joystick Controlled Wheelchair							
Trial	**Direction**	**S 1**	**S 2**	**S 3**	**S 4**	**S 5**	**Performance**
1		✓	✓	✓	✓	✓	
2		✓	✓	✓	✓	✓	
3	Left	✓	✓	✓	✓	✓	100%
4		✓	✓	✓	✓	✓	
5		✓	✓	✓	✓	✓	
6		✓	✓	✓	✓	✓	
7		✓	✓	✓	✓	✓	
8	Right	✓	✓	✓	✓	✓	100%
9		✓	✓	✓	✓	✓	
10		✓	✓	✓	✓	✓	
11		✓	✓	✓	✓	✓	
12		✓	✓	✓	✓	✓	
13	Forward	✓	✓	✓	✓	✓	100%
14		✓	✓	✓	✓	✓	
15		✓	✓	✓	✓	✓	
16		✓	✓	✓	✓	✓	
17		✓	✓	✓	✓	✓	
18	Backward	✓	✓	✓	✓	✓	100%
19		✓	✓	✓	✓	✓	
20		✓	✓	✓	✓	✓	

Table 5. Results of remote control task (Experiment 3).

Remote controlled wheelchair							
Trial	**Direction**	**S 1**	**S 2**	**S 3**	**S 4**	**S 5**	**Performance**
1		✓	✓	✓	✓	✓	
2		✓	✓	✓	✓	✓	
3	Left	✓	✓	✓	✓	✓	100%
4		✓	✓	✓	✓	✓	
5		✓	✓	✓	✓	✓	
6		✓	✓	✓	✓	✓	
7		✓	✓	✓	✓	✓	
8	Right	✓	✓	✓	✓	✓	100%
9		✓	✓	✓	✓	✓	
10		✓	✓	✓	✓	✓	
11		✓	✓	✓	✓	✓	
12		✓	✓	✓	✓	✓	
13	Forward	✓	✓	✓	✓	✓	100%
14		✓	✓	✓	✓	✓	
15		✓	✓	✓	✓	✓	
16		✓	✓	✓	✓	✓	
17		✓	✓	✓	✓	✓	
18	Backward	✓	✓	✓	✓	✓	100%
19		✓	✓	✓	✓	✓	
20		✓	✓	✓	✓	✓	

An android based application which is used to control the wheelchair remotely through Bluetooth communication is tested and validated for all four directions. Table 5 demonstrates that the remote control mode is tested by 5 healthy subjects using 20 trials i.e., 5 trials for each direction. It can be concluded that this control mode has achieved 100% perfection for all classes.

5. Conclusion

An economical and reliable BCI based wheelchair is developed using NeuroSky's MindWave Mobile headset that acquire EEG signal from the FP1 position. An android application is designed using NeuroSky's Android Development Toolkit to acquire and extract Attention and Blink Strength from the headset. Wheelchair control is designed using these two features. Four directions are cycled at 2 seconds interval in the app. The user is required to perform double blink in order to select a direction. As the direction is locked, the user needs to focus. In the meantime, attention level is examined. If it goes over 60, the application will send a command via Bluetooth to a microcontroller in order to move the wheelchair in that particular direction. Brain controlled wheelchair has an average accuracy of 83% due to limitation of stable EEG signal detection through the Mindwave headset.

The wheelchair is also equipped with the safety system to ensure that the user is protected from any dangerous situation. The safety system has 4 ultrasonic sensors, one on each side of the wheelchair. Whenever any obstacle occurs within the range of the sonar sensor, the buzzer starts buzzing to indicate the hurdle and the microcontroller sends the signal to stop the wheelchair immediately.

Apart from the primary control, i.e., to operate the wheelchair using the brain signals, the wheelchair also supports two secondary control modes. Joystick is also deployed to operate the wheelchair while it can also be controlled remotely using the smart phone through an android application via Bluetooth communication. Each primary and secondary mode is interfaced with the safety system making it reliable and safe for the user. Both the secondary controls have achieved 100% accuracy.

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