Mindwave Device Wheelchair Control

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Abstract: *A brain-computer interface (BCI) is a direct neural interface between a human or animal brain and an external world. In this paper the system is presented in which wheelchair is controlled using EEG signals obtained from the human brain. The Neurosky product i.e. mindwave device headset is used to measure the human brainwave signals. The signals are then mapped and compared with the reference value of attention and meditation level along with blinking eye signal. The wheelchair moves in different directions and can be controlled effectively using thoughts of the individual precisely. So the human ability is used effectively to control the given wheelchair using accuracy of about 95%.*

Keywords: Brain Computer Interface, EEG, Thinkgear, eSense, Mindwave

1. Introduction

In the first international meeting which is devoted to BCI research held in June 1999 at the Rensselaerville Institute near Albany, New York, brain computer interface was defined as "A brain computer interface is a communication system that does not depend on the brains normal output pathways of peripheral nerves and muscles"[13]. It is also called as Brain Machine Interface (BMI), or often called a Mind-Machine Interface (MMI), or sometimes called a direct neural interface which is able to detect the user's wishes and commands while the user remains silent and immobilized. There exist various diseases of the nervous system that gradually cause the body's motor neurons to degenerate, Example: Amyotrophic Lateral Sclerosis (ALS), brain stem stroke, or spinal cord injury. Eventually causes total paralysis and the affected individual becomes trapped in his own body, unable to communicate. A Brain-Computer Interface enables communication under such circumstances. Here machine application is controlled according to the thoughts of the affected individual and hence the brain activity is monitored. For this various techniques are available that includes[14], for example, functional Magnetic Resonance Imaging (fMRI), magnetoencephalography (MEG), Positron Emission Tomography (PET), Single Photon Emission Computer Tomography (SPECT), optical brain imaging, single neuron recording (with microelectrodes) and electroencephalography (EEG) .

From these methods, MEG, EEG and single neuron recording give continuous and instantaneous recordings of the brain activity (time resolution about 1 ms). However, MEG is not practical to be used with BCI. The MEG measurements are made using a large device inside a magnetic shielded room. The single neuron recording, on the other hand, requires that the electrodes are inserted inside the skull. Therefore, almost all of BCIs reported to date have been based on EEG. Electroencephalography (EEG) is a method used to measure the electrical activity of the brain caused by the flow of electric currents during synaptic excitations of the dendrites in the neurons and is extremely sensitive to the effects of secondary currents. It is most widely used neuroimaging modality since it has high temporal resolution, relative low cost, high portability, and few risks to the users.

2. Literature Review

The first demonstrations of brain computer interface (BCI) technology occurred in the 1960s when Grey Walter used the scalp-recorded electroencephalogram (EEG) to control a slide projector in 1964 [1] and when Eberhard Fetz taught monkeys to control a meter needle (and thereby earn food rewards) by changing the firing rate of a single cortical neuron [2, 3]. In the 1970s, Jacques Vidal developed a system that used the scalp-recorded visual evoked potential (VEP) over the visual cortex to determine the eye-gaze direction (i.e., the visual fixation point) in humans, and thus to determine the direction in which a person wanted to move a computer cursor [4, 5]. In 1980, Elbert et al. showed that people could learn to control slow cortical potentials (SCPs) in scalp-recorded EEG activity and could use that control to adjust the vertical position of a rocket image moving across a TV screen [6]. In 1988, Farwell and Donchin [7] reported that people could use scalp-recorded P300 event-related potentials (ERPs) to spell words on a computer screen. Wolpaw and his colleagues trained people to control the amplitude of mu and beta rhythms (i.e., sensorimotor rhythms) in the EEG recorded over the sensorimotor cortex and showed that the subjects could use this control to move a computer cursor rapidly and accurately in one or two dimensions [8, 9]. Payam Aghaei Pour, Tauseef Gulrez uses the human ability to control a video game on a mobile device using differential Mu rythms [11]. The J. R. Millan, F. Renkens, J. Mourino, and W. Gerstner develop non-invasive brain-actuated control of a mobile robot by human EEG in combination with advanced robotics and machine learning techniques. The robot executes the commands using the readings of its on-board sensors [12].

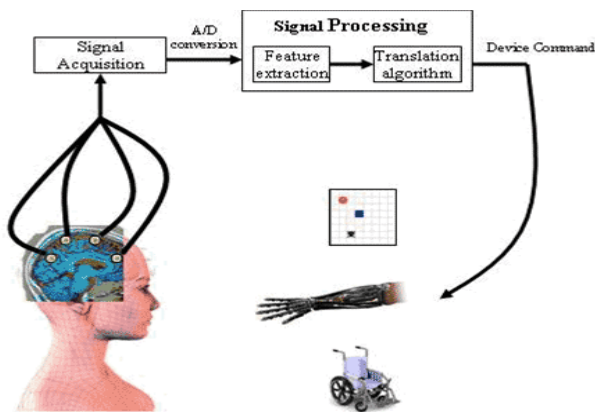## 3. Brain Computer Interface

Brain Computer Interface (BCI), technology is a new and fast evolving field that measures the specific features of brain activity and translates them into device control signals.

Signal is acquired using the electrodes on the scalp. These signals are weak hence amplified and are converted into digital form. Then features are extracted from amplified and digitized version of EEG signals in the signal processing stage. In this stage useful EEG data is separated from noise. These BCI systems measure specific features of brain activity and translate them into device control signals (see Fig. 1). For feature extraction and classification different techniques are included for example, self regulation of EEG µ rythms, slow cortical potentials, P300 evoked potentials, sensorimotor rhythms recorded from the scalp, event-related potentials recorded on the cortex, and neuronal action potentials recorded within the cortex. The application to be control can be wheelchair, robotic arm, cursor, speller or any other device.

Figure 1: Brain Computer Interface

4. Neurosky's Mindwave Mobile Device

In brain machine interface user has to monitor his own brain waves in real time to control the given application. Hence for extraction of EEG signal from the brain, Mindwave device released by NeuroSky company is used. The Mindwave reports the wearer's mental state in the form of NeuroSky's proprietary Attention and Meditation eSense™ algorithms, along with raw wave and information about the brainwave frequency bands. The MindWave Mobile safely measures and outputs the EEG power spectrums (alpha waves, beta waves, etc), NeuroSky eSense meters (attention and meditation) and eye blinks. It uses the TGAM1 module and can perform automatic wireless pairing with iOS, Android, PC, or Mac device. The device consists of a headset, an ear-clip, and a sensor arm. The headset's reference and ground electrodes are on the ear clip and the EEG electrode is on the sensor arm, resting on the forehead above the eye (FP1 position) as shown in fig.2. The overview about the NeuroSky Technology is given below:
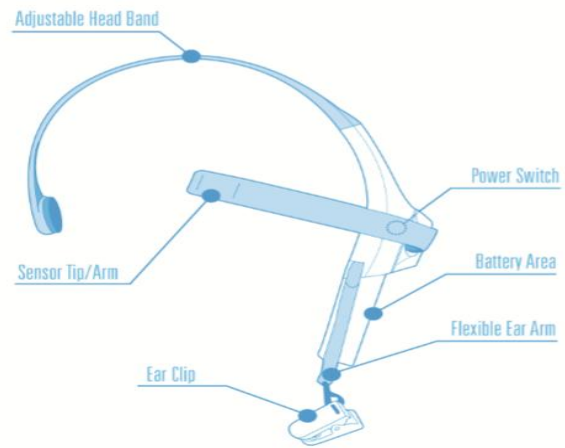
Figure 2: Mindwave headset

4.1 ThinkGear

ThinkGear is the technology inside every NeuroSky product or partner product that enables a device to interface with the wearers' brainwaves. It measures the analog electrical signals, commonly referred to as brainwaves, and processes them into digital signals. Both the raw brainwaves and the eSense Meters (Attention and Meditation) are calculated on the ThinkGear chip. The table 1 below gives a general synopsis of some of the commonly recognized frequencies that tend to be generated by different types of activity in the brain:

Table 1: Frequency ranges of EEG signal

Brainwave Type	Frequency range	Mental states and conditions
Delta	0.1Hz to3Hz	Deep, dreamless sleep, non-REM sleep, unconscious
Theta	4Hz to7Hz	Intuitive, creative, recall, fantasy, imaginary, dream
Alpha	8Hz to12Hz	Relaxed (but not drowsy) tranquil, conscious
Low Beta	12Hz to15Hz	Formerly SMR, relaxed yet focused, integrated
Midrange Beta	16Hz to20Hz	Thinking, aware of self & surroundings
High Beta	21Hz to30Hz	Alertness, agitation

NeuroSky's dry sensor technology is capable of detecting several different kinds of biosignals depending on where the sensor electrode is placed, including EEG, EOG, EMG, and ECG. On the forehead, EEG signals from the brain and EMG signals from eyeblinks and forehead muscles can be detected. Then electrical signal within the device that corresponds to the wave patterns detected is created. For TGAT-based hardware devices (such as TGAT, TGAM, MindSet, MindWave, and MindWave Mobile), the formula for converting raw values to voltage is:

$$\frac{raw\ value\ \times \frac{1.8}{4096}}{2000}$$

This is due to a 2000 gain, 4096 value range, and 1.8V input voltage. The unit is V.

4.2 eSense, Attention eSense, Meditation eSense

eSense™ is a NeuroSky's proprietary algorithm for characterizing mental states. To calculate eSense, the NeuroSky ThinkGear technology amplifies the raw brainwave signal and removes the ambient noise and muscle movement. The eSense algorithm is then applied to the remaining signal, resulting in the interpreted eSense meter values. The eSense meter values do not describe an exact number, but instead describe ranges of activity. The eSense attention meter indicates 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 level. The eSense meditation meter indicates the level of a user's mental "calmness" or "relaxation". Its value ranges from 0 to 100. Note that meditation is a measure of a person's mental states, not physical levels, so simply relaxing all the muscles of the body may not immediately result in a heightened meditation level.

5. Overview of Implemented System

The block diagram of implemented system is shown in figure 3. The main objective of the given system is to control the wheelchair movement using the thoughts of the individual. For this project first of all the electrode is required which pickups the brain signals. The mindwave device will pick up the raw brain signal which is the EEG signals. The signal obtained from this electrode is transmitted using bluetooth. The data which is transmitted is to be processed for which either PC or laptop can be connected with an installed mindwave software is required. Mindwave device has its own dongle which will acquire this wireless signal transmitted by the electrode. The data is received in jsn format. This is one of the protocol for serial communication used popularly nowadays. To process the data processing java software is used. The graphical display of brainwave signal is obtained on the mindwave software which can be studied by the user. It gives visual indication about eye blinking, attention level, meditation level (Refer fig.4) and the graph which is obtained from this waveform again having subtypes as lower alpha, higher alpha and so on as given in table no.1.
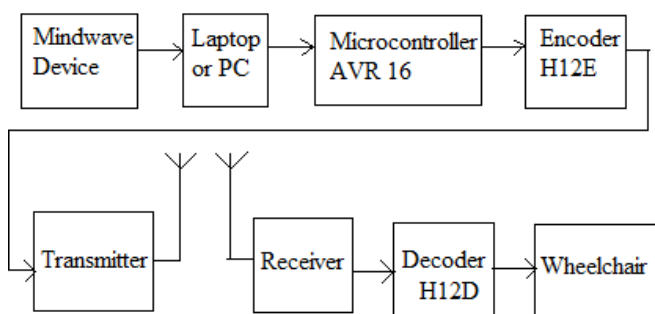
Figure 3: Mindwave device wheelchair control block diagram

As previously mentioned wheelchair is controlled using the thoughts of a person. The wheelchair moves in different directions and performs different operations such as forward, left, right and stop movements. So for control of wheelchair, the signal of blinking of eye and attention and/or meditation level are monitored continuously. The command for given operation selection is given by the eye blinking signal. Once command is selected then for execution of command attention and meditation levels are controlled. So when either attention or meditation level is greater than the reference value, selected operation is executed and wheelchair moves in that particular direction.

So after processing the EEG signal in the software whatever the information signal is obtained is to be interfaced with controller. For interfacing of microcontroller and laptop USB to serial converter is used. The CP2102 is highly integrated USB to UART bridge controller providing a simple solution which includes a USB 2.0 full speed function controller, USB transreceiver, oscillator, EEPROM and asynchronous serial data bus (UART) with full modem control signals. The hardware part of transmission section of the system consists of AVR 16 controller with encoder IC HT12E. The HT 12E Encoder ICs are series of CMOS LSIs for remote control system applications. They are capable of encoding 12 bit of information which consists of N address bits and 12-N data bits. The HT 12D ICs are series of CMOS LSIs for remote control system applications. This ICs are paired with each other. For proper operation a pair of encoder/decoder with the same number of address and data format should be selected. The decoder receives the serial address and data from its corresponding encoder, transmitted by a carrier using an RF transmission medium and gives output to the output pins after processing the data. The data is transmitted using wireless transmission for which RF is used. The RF frequency of transmitter and receiver is 534 MHz. The received data is decoded by decoder IC HT12D and then it is given to relay, relay driver and motor to control the wheelchair. There are four relays in which a pair of relay controls one motor. There are two motor of 12V, permanent magnetic dc reduction motor having 30 rpm speed. Also to detect an obstacle on the path there is an IR sensor on the front of the wheelchair. So when obstacle is detected the relay will cut supply to the motor. Hence motor turns off and wheelchair stops.

6. Result

The accuracy of operation depends on how precisely the command is executed. For low strength of blinking and attention or meditation command selection and execution is very fast but error probability increases, as inherent signal at particular instant may interfere with desired action. So to get maximum accuracy reference level of blink eye signal is selected above 50% while meditation and/or attention reference is selected above 70%. Still values are varied from person to person and we can get even 100% accuracy by varying the reference level value.

Table 2: Blink level relative scale

Strength (%)	Accuracy	Speed of execution
10-30	Low	Very High
30-50	Medium	
50-70	High	High
70-100	Very high	

Table 3: Attention or meditation level relative scale

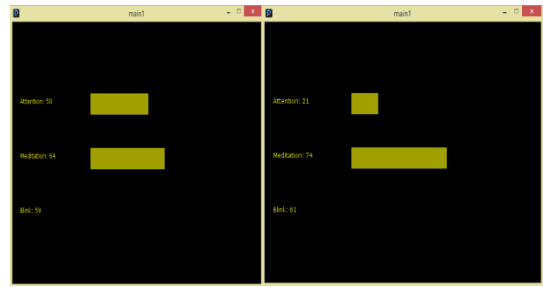| Strength (%)	Accuracy	Speed of execution
10-30	Low	Very High
30-50	Medium	High
50-70	High	Medium
70-100	Very high	Slow

(a)

(b)
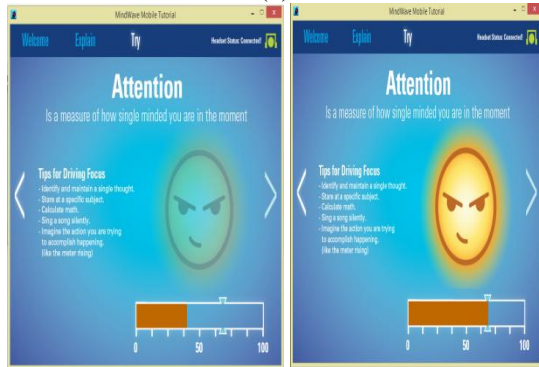
(c)

(d)

(e)

Figure 4: a) Graphical display of EEG acquisition by Neurosky Mind wave b) Eye blink display c) Attention level d) Meditation level e) Processing output display

Conclusion

The mind wave device headset is used that gives measure of brain activity in terms of blink detection and eSense meter values. The BMI translates the user wishes or commands into device commands that accomplish the user's intent. The wheelchair can merely be controlled by human thinking with almost 100% accuracy. According to strength of brain signals for particular individual speed of execution is varied and also it can be controlled. Thus implemented system provides new world of interactivity to the people suffering from so called locked-in syndrome, but cognitively intact and alert.

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