Mind-Controlled Wheelchair using an EEG Headset and Arduino Microcontroller

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***Abstract* — Improving the quality of life for the elderly and disabled people and giving them the proper care at the right time is one the most important roles that are to be performed by us being a responsible member of the society. It's not easy for the disabled and elderly people to maneuver a mechanical wheelchair, which many of them normally use for locomotion. Hence there is a need for designing a wheelchair that is intelligent and provides easy maneuverability. In this context, an attempt has been made to propose a thought controlled wheelchair, which uses the captured signals from the brain and eyes and processes it to control the wheelchair. Electroencephalography (EEG) technique deploys an electrode cap that is placed on the user's scalp for the acquisition of the EEG signals which are captured and translated into movement commands by the arduino micro-controller which in turn move the wheelchair.**

***Keywords* – Neuroscience, Brain Computer Interface (BCI), EEG, Micro-controller.**

I. Introduction

Wheelchair users are among the most visible members of the disability community; they experience a very high level of activity and functional limitation and also have less of employment opportunities. Elderly people are the group with the highest rates of both manual and electric wheelchair use. Wheelchair users report difficulty in basic life activities, and perceived disability. It's not easy for the physically challenged and elderly people to manoeuvre a mechanical/ electric wheelchair.

In recent times there have been a wide range of technologies that help aid the disabled physically challenged. These control systems are designed to help the physically challenged specifically. These competitive systems are replacing the conventional manual assistance systems. The wheelchair too has developed significantly with a variety of guidance systems alongside like using the joystick and a tactile screen, and systems based on voice recognition.

These systems however are of use to those with a certain amount of upper body mobility. Those suffering from a greater degree of paralysis may not be able to use these systems since they require accurate control. To help improve the lifestyle of the physically challenged further, this work aims at developing a wheelchair system that moves in accordance with the signals obtained from the neurons in the brain through the mounted headset.

Since the brain comprises of a plethora of neurons which process the data, this work aims at exploring the signals collected from EEG to help manoeuvre the wheelchair.

Brain Computer Interface (BCI) is a technique that provides direct interface between the human brain and the computer. BCI techniques are broadly classified into invasive and non-invasive techniques. Non-invasive techniques have become more popular and more research is being done on this topic. There are various non-invasive BCI techniques such as Electroencephalography (EEG), Electro-Oculography. EEG technique makes use of an electrode cap that is placed on the user's scalp for acquiring the EEG signal, which relates the scalp potential differences to various complex actions [5]. Classification of the EEG signal has been made into several bands like alpha, beta, delta, theta and mu suppression, each corresponding to various states of being like relaxing, ranging over 8-14 Hz; concentrating, ranging over 13-30 Hz; deep sleep, from 0-4 Hz; meditating from 4-8 Hz; moving your hands or legs or just by imagining these motor actions respectively [2]. As it is non-invasive in nature, it has an advantage over traditional BMI, not being hazardous to health. With the advent of technology, EEG acquisition devices are made more compact, handy and wireless. Using the above mentioned technique, a simple thought controlled wheelchair system has been proposed in this paper.

II. Working Principle

The aim of this work is to use parameters gathered by the headset to move the wheelchair in the directions the user wants, the main being attention and meditation. The proposed methodology involves using the wheelchair to move around using neuron signals.

Signal acquisition

Signal acquisition and processing techniques and devices acquire and process the ionic electrical signals generated by the neurons in the brain.

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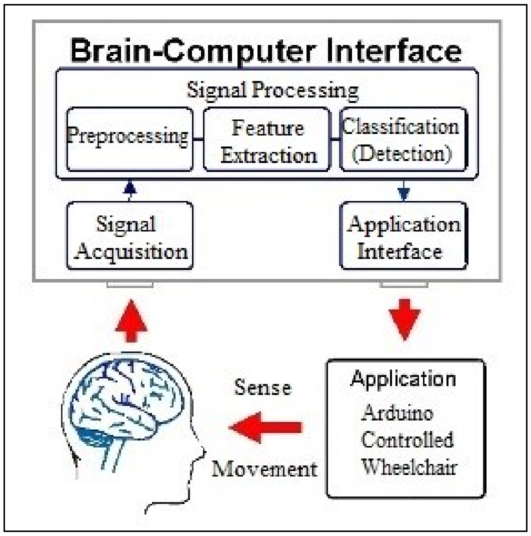

Figure 1: BCI Working Principle

As a whole, there are two types of acquisition techniques:

i) Invasive acquisition

This technique acquires the brain signals through electrodes that are implanted directly in the brain tissue. Surgery is required to implant the electrodes on the cortex. This technique gives excellent quality of signals with very less delay. However, as the electrodes are pieces of wire and metal pins they are not completely reliable when placed inside the brain. Additionally, the invasive acquisition technique may prove to be an ethical controversy [12].

ii) Non-Invasive acquisition

The non-invasive technique on the other hand uses the electrophysiological signals from the scalp and takes measurements using that technique. The electroencephalogram is most commonly used due to its simplicity and ease in using other than meeting with the requirements for BCI systems [7]. In this paper, electroencephalogram is used as the signal capturing technology [12].

Feature Extraction

Classification

There is a certain amount of discrepancy in classifying the waves, since the signals are continuously being captured by the many electrodes present on the scalp. These waves are therefore classified into the following types:

i) Alpha Waves: These waves generally range from 8Hz to 13Hz with a very low voltage of about 5µV to 30µV. These waves are generated by the brain when it is in an empty or inactive state

ii) Beta Waves: These waves generally range from 13Hz to 30Hz with a voltage of about 30µV. They are released by the brain is active and thinking, or solving a problem.

iii) Theta Waves: These waves generally range from 4Hz to 7Hz with a voltage of about 20µV. These waves are generally generated by the brain under stress, emotional tension, disappointment etc. These waves are also generated when the user is in deep meditation or unconscious.

iv) Gamma Waves: These waves are released by the brain when the user is conscious and are generally of a frequency of 35Hz or greater.

v) Mu Waves: These waves generally range from 8Hz to 12Hz. They are generally released when the brain responds to spontaneous activities such as motor activities etc.

These waves will further be processed by the headset to find out the task that the brain is performing.

Application Interface

The different blocks in the interface are explained as shown in the figure (Figure 1).

A. Connecting EEG headset to BCI

EEG is the recording of electrical activity along the scalp. EEG measures voltage fluctuations resulting from ionic current flows within the neurons of the brain. In clinical contexts, EEG refers to the recording of the brain's spontaneous electrical activity over a short period of time, usually 20–40 minutes, as recorded from multiple electrodes placed on the scalp [5] [6]. The Mind Wave Headset is used to get the EEG recordings. The headset takes decades of laboratory brainwave technology and puts it into a bundled software package. It safely measures brainwave signals and monitors the brain activity. A Brain–Computer Interface (BCI), often called a Mind-Machine Interface (MMI), or sometimes called a Direct Neural Interface (DNI), Synthetic Telepathy Interface (STI) or a Brain–Machine Interface (BMI), is a direct communication pathway between the brain and an external device [7]. The signals from the EEG headset would be given to a Brain computer Interface [5] [6].

B. Interfacing BCI to Arduino

The BCI processes the inputs from the EEG headset which has to be interfaced with Arduino Micro Controller. Arduino is a single-board microcontroller, intended to make the application of interactive objects or environments more accessible. The hardware consists of an open-source hardware board designed around an 8-bit Atmel AVR (Advanced Virtual RISC) microcontroller [2]. The Processed inputs in the BCI is send to the Arduino Microcontroller with the help ThinkGear.net library with the help of C# programming [2].

C. *Sending Signals from Arduino to Wheelchair*

The Arduino Receives the Signals from BCI which has been programmed into it. An Arduino based wheel chair is built using a Servo Motor. A servomotor is a rotary actuator that allows for precise control of angular position, velocity and acceleration [4]. It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors [3]. The Arduino Microcontroller is programmed using Arduino Programming language to send the BCI output to perform forward backward and rotational movements in the wheelchair [3].

III. TOOLS AND TECHNOLOGY

Hardware

- NeuroSky Mindwave Mobile Headset
- HC-05 Bluetooth Module
- Arduino Uno
- Electric Wheelchair

Software:

- Brainwave Visualizer(Android App)
- EEG Analyzer(Android App)

IV. IMPLEMENTATION OF PRINCIPLE

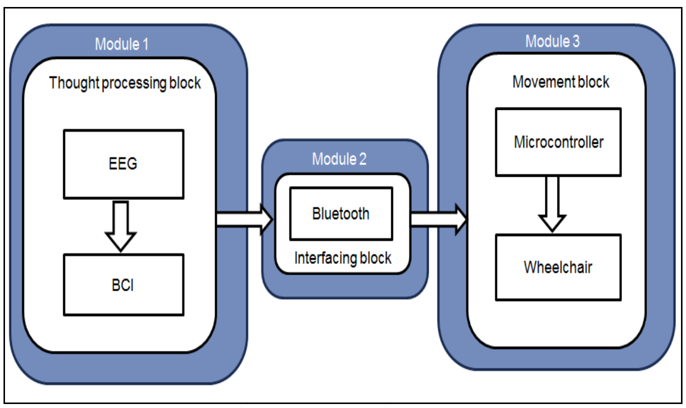

Figure 2: Proposed system

A. *Neurosky Mindwave Mobile Headset*

The MindWave Mobile safely measures and outputs the EEG power spectrums in the form of alpha waves, beta waves, etc., NeuroSky eSense meters (attention and meditation) and eye blinks. 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). It uses a single AAA battery with 8 hours of battery life [10].

B. *HC-05 Bluetooth Module*

HC-05 embedded Bluetooth serial communication module (can be short for module) has two work modes: order-response work mode and automatic connection work mode, and three work roles (Master, Slave and Loopback) at the automatic connection work mode [8] (Figure 2). When the module is at the automatic connection work mode, it will follow the default way set lastly to transmit the data automatically.

When the module is at the order-response work mode, user can send the AT command to the module to set the control parameters and sent control order. The work mode of module can be switched by controlling the module PIN (PIO11) input level [11].

C. *Arduino Uno*

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. The main reason for selecting this specific model of arduino was that it satisfied our basic requirement of connection to motor shield and Bluetooth shield. Each of the 14 digital pins on the Uno can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms [9].

D. *Electric Wheelchair*

The wheelchair will perform the basic forward, right and left rotation movements using the code programmed into the arduino microcontroller.

V. OBSERVATIONS

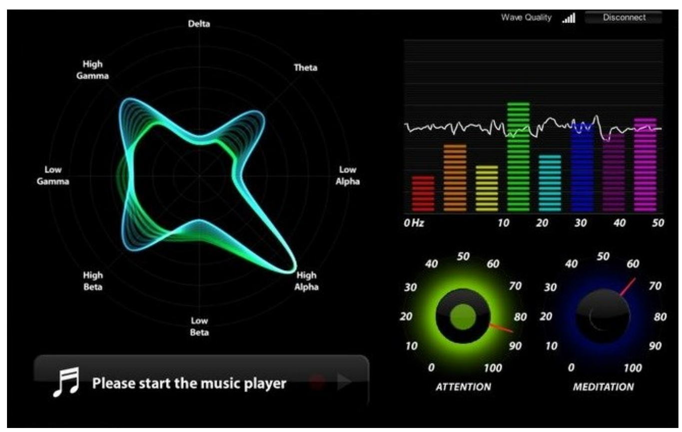

Figure 3: Measurement of attention parameter

The graph to the left and top-right show the value of brain waves currently captured. The dials show the attention and meditation level of the user. There is a specific value range through which they show. Each specific level and when the reading finally reaches 100 is accompanied by a ping like sound. We can find out the dynamic attention level of the user as shown in the figure (Figure 3).

The meditation dial works in a similar way.

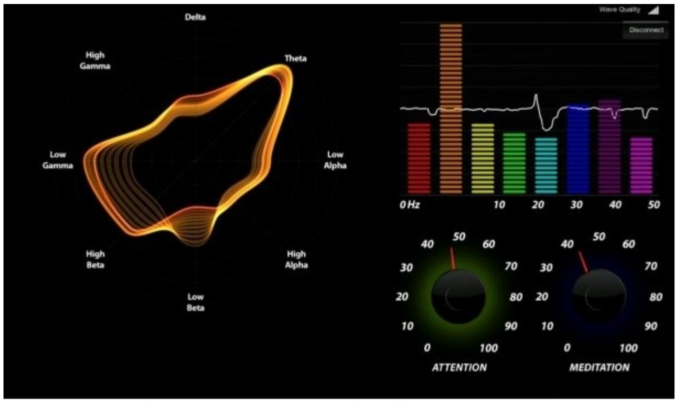

Figure 4: Measurement of meditation parameter

The attention and meditation at the same time can be recorded as shown in the figure and both can peak to 100 while giving off different ping sounds (Figure 4).

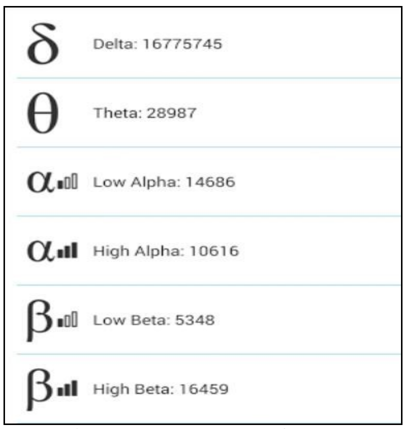

Figure 5: Measurement of waves

The three main types of brain waves that will be monitored using the headset are alpha, beta and gamma. But theses waves too have a sub compartment that can be useful while setting threshold values (Figure 5).

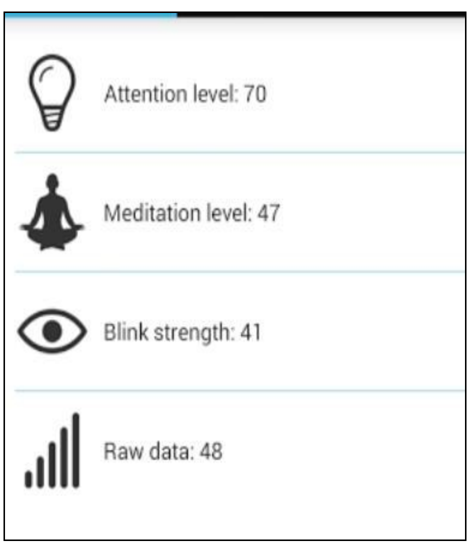

Figure 6: Measurement of blinks

The third parameter that can be measured using the headset is the blinking of the eye. The application provides details about which eye is blinking and the strength and frequency of the blink (Figure 6).

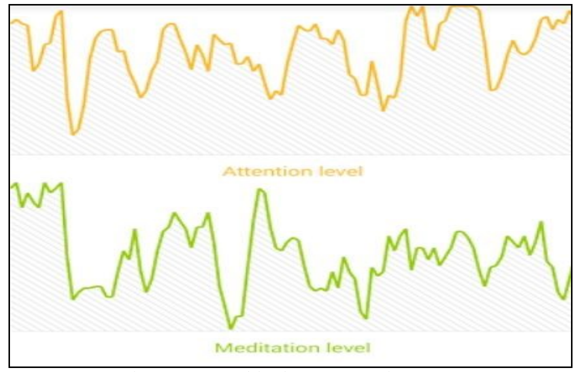

Figure 7: Graphical representation

This shows the android brainwave visualizer application in action which again measures the attention and meditation level in the form of continuous waves (Figure 7).

VI. Summary

There are many research institutions around the world using EEG caps to drive wheelchairs, and there may well be commercial products reaching the market in a few years as a result of these efforts. The brain-controlled wheelchair has not yet been widely adopted, and any commercial device would need proper safety trials and FDA approval before release [1]. But there are high hopes for the future of brain-controlled chairs and prosthetics. Ultimately, even profoundly disabled people will be able to gain some independence through the use of mind controlled chairs and prosthetics. Using the system proposed in this paper the signals were sent from the headset to the arduino in order to instigate movements in the wheelchair based on the inputs from the brain. Although this system is very raw it is a step towards brain-controlled movement.

The movement of the wheelchair will be solely configured to the signals generated by the mind thus negating any physical force required. User based or specific modules can be created thus generating a unique footprint. It uses upcoming and ever evolving technology that will enable easy and manageable iterations. The components used are very low cost yet have an optimum performance level.

External help maybe required by people who suffer from paralysis of the upper torso for placement/adjustment of the headset. Exact thoughts cannot be measured using the current headset.

VII. Further work

An obstacle in the way could be detected automatically by the wheelchair forcing it to stop. Acceleration sensors could be added onto the wheelchair to calculate the amount of acceleration tilt to help navigate on ramps and slopes. The wheelchair could be integrated with head movements to control factors such as speed and brakes.

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