AN APPLICATION OF BCI: BRAIN WAVE CONTROLLED ROBOT

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***Abstract*—Brain-Computer Interface (BCI) has been vastly espoused and operated by researchers in the discipline of extracting brain signals and processing them to perform various tasks of social cause (robots and gadgets to help physically challenged people) and entertainment (gaming purpose). With the help of BCI, we have developed a prototype that can be controlled and operated by human brain signals. Electro-Encephalogram (EEG) based brainwave sensor extracts and transmits the raw form of data via Bluetooth communication which is further analyzed in Arduino IDE platform. Alpha wave and beta wave generated in the human brain for various state of mind are responsible for the control of the prototype. No predefined path or map is required for the movement and operation of the prototype but it is overseen by the power generated for an individual frequency of alpha and beta waves after performing Fast Fourier Transformation (FFT).**

The system is designed using non-invasive Neurosky headset for extracting brain signals, HC05 Bluetooth module for receiving raw signal, Arduino Uno for data processing and L293D motor driver with two DC motors for the movement of the prototype.

Keywords*— *Brain-Computer Interface (BCI), Electro-Encephalogram (EEG) signal, Wireless Communication, Fast Fourier Transformation (FFT), alpha and beta waves.

I. INTRODUCTION

Brain-computer interfaces (BCIs) convert brain signals into outputs that communicate a user's intent [1]. People with severe motor disabilities need augmentative communication technologies for the support of their daily life. Those who are totally paralyzed, or "locked-in" cannot use conventional technologies, all of which requires some measure of muscle control. Over past decades, a variety of research has evaluated the application that brain signal recorded from the scalp or from within the brain has developed augmentative technologies that don't require muscle control [2].

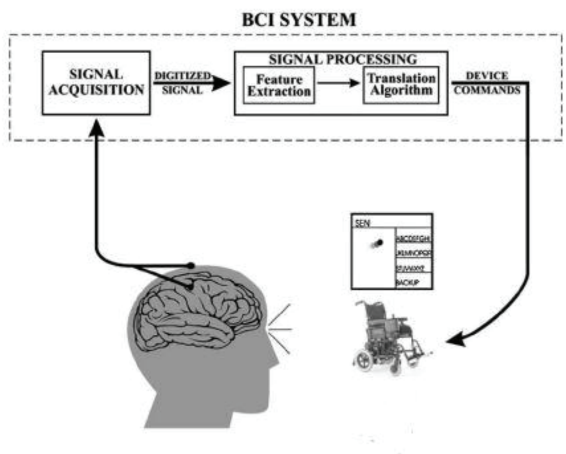


Figure 1 Basic design and operation of any BCI system. Signals from the brain are acquired by electrodes on the scalp, the cortical surface, or from within the brain and are processed to extract specific signal features (e.g., frequency and power of EEG signals, amplitudes of evoked potentials or sensorimotor cortex rhythms, firing rates of cortical neurons) that reflect the user's intent. Features are translated into commands that operate a device (e.g., a simple word processing program, a wheelchair).

[2]

These BCI measures specific feature of brain activity and translates them into a device control signal (Figure 1). In this project, the authors made an Arduino based prototype that has been controlled by human brain wave using the BCI technique. Arduino UNO is chosen because it is a low-cost microcontroller and its availability in the market. The human brain wave has been captured using a Neurosky mind wave headset. The techniques used in this project can be further extended to a wheelchair for paralyzed people.

An electroencephalograph (EEG) is the recorded electrical activity generated by the brain. In general, EEG is obtained using electrodes placed on the scalp with a conductive gel. In the brain, there are millions of neurons, each of which generates a small electric voltage field. The aggregate of these electric voltage fields creates an electrical reading which electrodes on the scalp are able to detect and record. Therefore, EEG is the superposition of many simpler signals. The amplitude of an EEG signal typically ranges from about 1 uV to 100 uV in a normal adult, and it is approximately 10 to 20 mV when measured with subdural electrodes such as needle electrodes [3].

The FFT is a mathematical process which is used in EEG analysis to investigate the composition of an EEG signal. Since the FFT transforms a signal from the time domain into the frequency domain, frequency distributions of the EEG can be observed [3].

EEG can be described in terms of its frequency band on the basis of amplitude of the EEG, which depends on external stimulation as well as internal mental states [4]. The range of EEG can be expressed as Infra low waves (less than 0.1Hz), delta waves (0.1-3 Hz), Theta waves (4-7 Hz), alpha waves (8-12 Hz), Beta waves (12-30 Hz) and Gamma waves (30-100 Hz) [4].

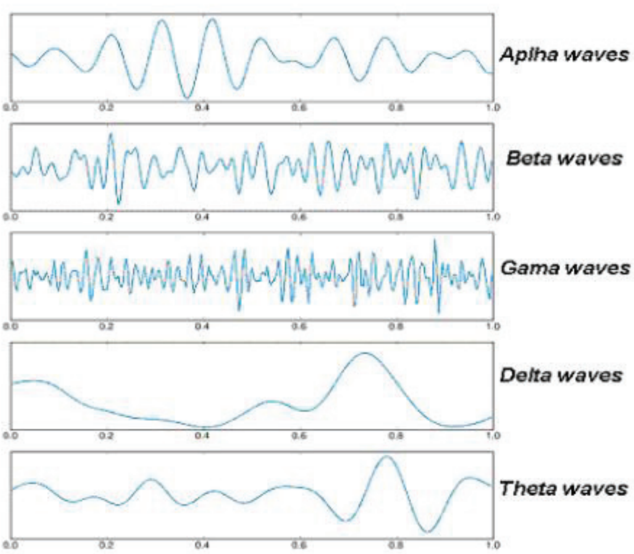


Figure 2 EEG Signal Patterns [3]

Table 1 EEG Signal Range with State of Mind

Brainwave Type	Frequency range	Mental State and Condition
Delta	0.1 Hz to 3 Hz	Deep, dreamless sleeps, non-REM sleep, unconscious
Theta	4 Hz to 7 Hz	Intuitive, creative, recall, fantasy, imagination, dream
Alpha	8 Hz to 12 Hz	Relaxed, but not drowsy, tranquil, conscious
Low Beta	12 Hz to 15 Hz	Formerly SMR, relaxed yet focused, integrated
Midrange Beta	16 Hz to 20 Hz	Thinking, aware of self & surrounding
High Beta	21 Hz to 30 Hz	Alertness, agitation
Gamma	30 Hz to 100 Hz	Motor Functions, higher mental activity

[3]

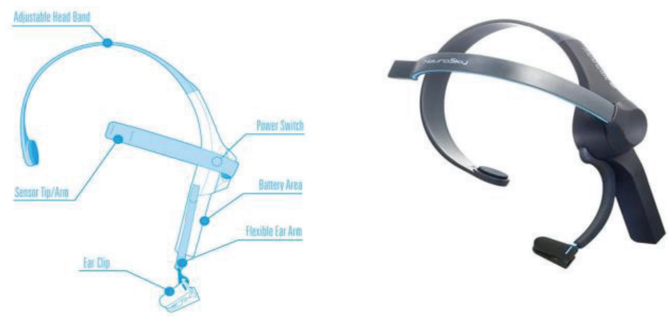
II. HARDWARE REQUIREMENT

The authors have used various electronics components to execute this prototype. Detail description of the hardware components used are as follows:

A. NEUROSKY HEADSET

Neorosky headset is BCI based application which exports and transmits mental state changes and movements followed to control the robot [5].

The mind wave sensor safely measures and outputs the EEG power spectrums (alpha wave, beta waves, etc.). Brain wave sensing device is very important or basic of the whole system, which contains a passive biosensor which is electrode tip for capturing electrical or EEG signal emerging from the brain. It has an ability to convert analog data into digital form and this digitalized data are being transferred to Arduino via Bluetooth communication [6].



[5]

Figure 4 Components of neurosky headset

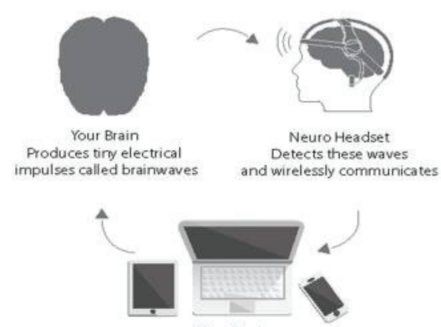


Figure 3 Working Mechanism of neurosky headset

B. HC05 BLUETOOTH MODULE

HC-05 module is Bluetooth Serial port Protocol (SPP)designed for the transparent wireless serial connection setup. It is fully qualified Bluetooth V2.0+EDR (Enhance Data Rate) 3 Mbps modulation with 2.4 GHz radio transceiver and baseband [7]. The authors have used this module for data receiving form neurosky headset.

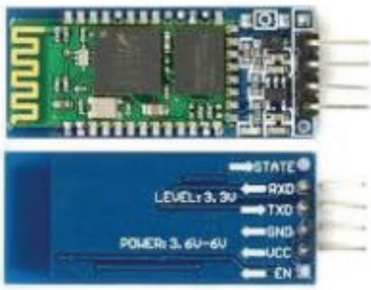


Figure 5 HC-05 Bluetooth module [7]

C. ARDUINO UNO

The Arduino Uno is a microcontroller board based on the ATmega328, developed by Arduino.cc. It has 20 digital input/output pins (of which 6 can be used as PWM outputs and 6 can be used as analog inputs), a 16 MHz resonator, a USB connection, a power jack, an in-circuit system programming (ICSP) header, and a reset button [8].

Figure 6 Arduino Uno [8]

D. L293D DC MOTOR DRIVER

L293D is a typical Motor driver which allows DC motor to drive on either direction. It is a 16-pin IC which can control a set of two DC motors simultaneously in any direction. In a single L293D chip, there is two h-Bridge circuits inside the IC which can rotate two dc motors independently [9].

E. DC MOTOR

An electric DC motor is a machine which converts electric energy into mechanical energy. The working of DC motor is based on the principle that when a current-carrying conductor is placed in a magnetic field, it experiences a mechanical force and the direction of mechanical force is given by Flemmings Left-hand Rule [10].

F. ULTRASONIC SENSOR

Ultrasonic sensor also is known as SONAR is used for measuring the distance between the object and the sensor. It transmits ultrasonic waves and receives it back after being reflected from the surface of an object [11]. The authors have used this sensor to detect the obstacles in the path of the prototype in order to avoid them.

III. SOFTWARE REQUIREMENT

A. ARDUINO IDE

The Arduino Integrated Development Environment (IDE) is it is an official software introduced by Arduino.cc, that is mainly used for editing, compiling and uploading the code in the Arduino Device [12]. It is easily available for operating systems like MAC, Windows, Linux and runs on the Java Platform that comes with inbuilt functions and commands that play a vital role for debugging, editing and compiling the code in the environment. A range of Arduino modules available including Arduino Uno, Arduino Mega, Arduino Leonardo, Arduino Micro, etc. contains a microcontroller on the board that is actually programmed and accepts the information in the form of code [13].

B. MATLAB

MATLAB is a fourth-generation programming language and numerical analysis environment used for matrix calculations, developing and running algorithms, creating user interfaces (UI), data visualization, signal processing, and communication, image and video processing, control system and computational biology [14].

IV. SYSTEM ARCHITECTURE

Figure 7 shows the system architecture of this project. The system is formed by a Neurosky headset (EEG reader), a computer included MATLAB and an Arduino operated prototype. The EEG reader contains a Think Gear ASCII Model (TGAM1) chip that can capture the human brain signal. TGAM1 also provided the signal filter and signal amplification. After that, the EEG signal will be digitized and sent to the Bluetooth transmission module (HC-05). Finally, the EEG signal will be transmitted to the computer for further analysis.

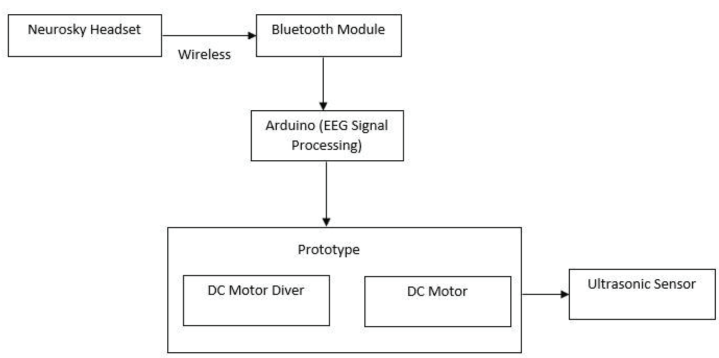


Figure 7 System Architecture

MATLAB on the computer will be used for noise filtering. It will check whether the user is sending a robot controlling command, or the signal is just a natural signal of human. If the signal is belonging to a robot controlling command, MATLAB will also determine which command does the signal represents.

The prototype is consisting of various components. They are Arduino Uno, one Bluetooth HC-05 module, two DC motors, one L293D DC motor driver, ultrasonic sensor. When the Bluetooth HC-05 module received the controlling command from the computer, the Arduino board will consider the data received from the ultrasonic to make the final decision of the prototype movement. The ultrasonic sensors will detect the obstacles and avoid them automatically.

If the command from the human brain is received, the robot will follow the command with forward and backward movement along with sidewise movement. Program in Arduino Uno process the EEG data using FFT algorithm with $2^9 = 512$ points FFT, which converts time-domain data in the frequency domain. The FFT results are used to compute the signal power of each band which further is used to control the movement of the prototype.

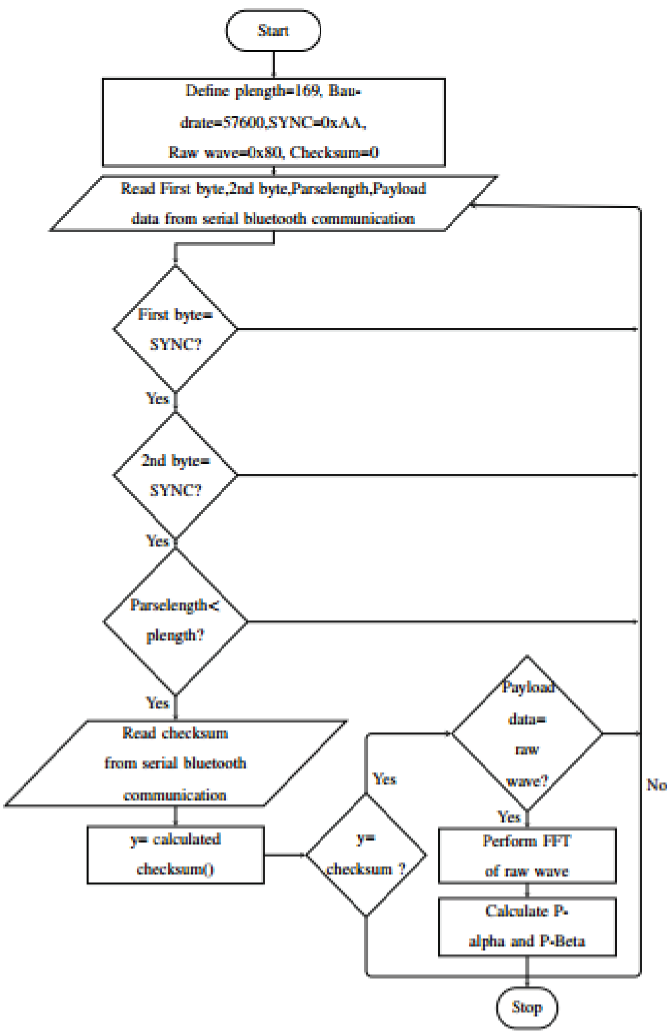


Figure 8 Flow Chart

Figure 8 is the flow chart how prototype operates.

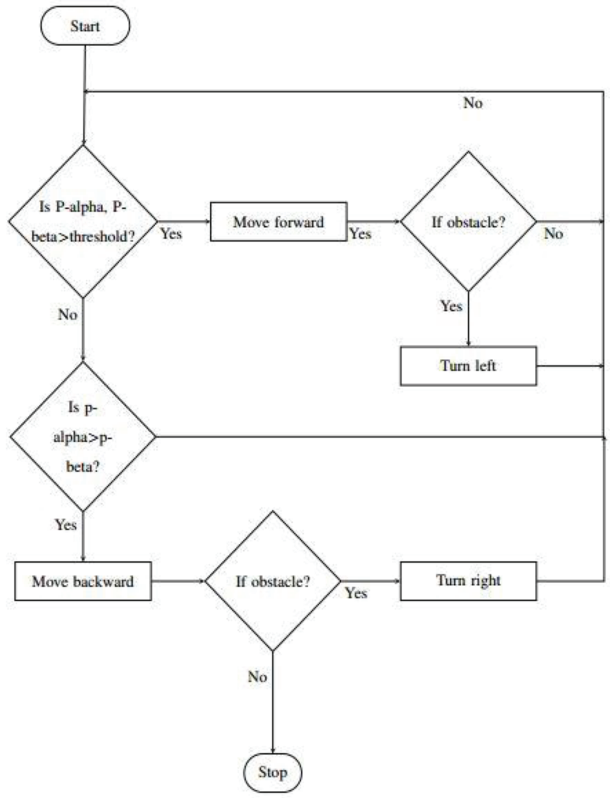


Figure 9 explains the control mechanism of the prototype.

Figure 9 Flow Chart for Control of Prototype

V. EEG SIGNAL THROUGH NEUROSKY HEADSET

Neorusky headset has been espoused for EEG signal extraction from human brain as a primary source of data for the rheostat and operation of the prototype. Figure 10and 11 shows the different set of data obtained from neurosky headset.

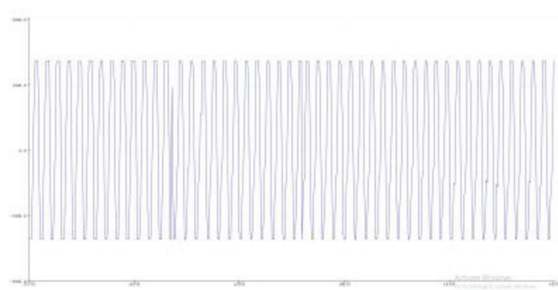


Figure 10 Random Signal when headset is not placed in head

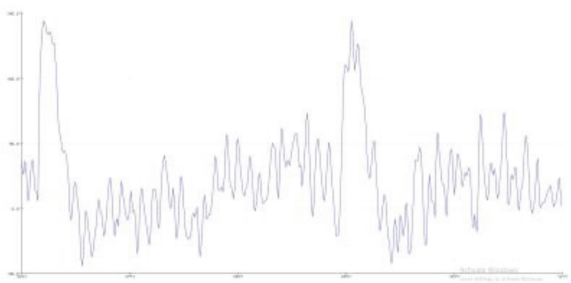


Figure 11 Raw EEG Signals

VI. CONTROL OF PROTOTYPE

Control signals are generated by performing FFT of raw EEG signals. Alpha waves (Meditative state) and beta waves (Attentative state) are major sources for control waves.

Following figure 13 and 14 shows the FFT of both alpha and beta waves.

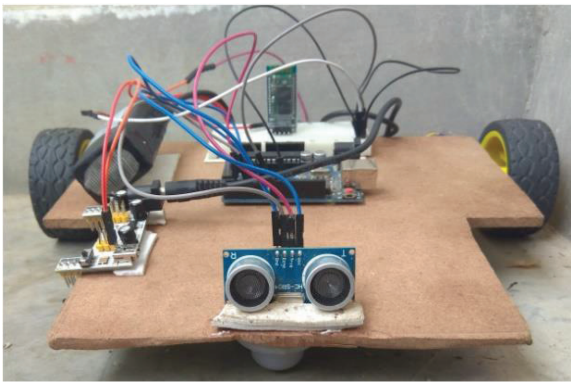


Figure 12 Photo of Prototype

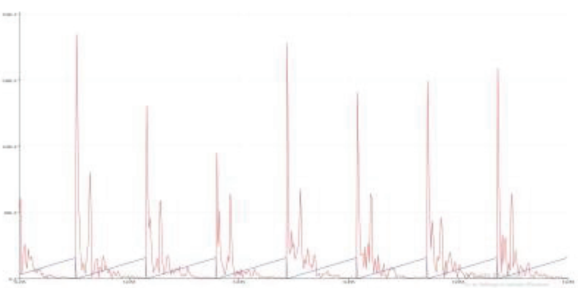


Figure 13 FFT at Attentative state

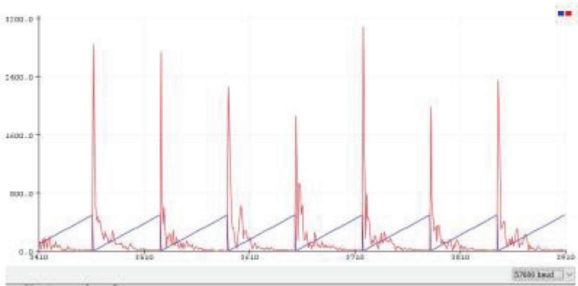


Figure 14 FFT at Meditative State

VII. CONCLUSION

This project has provided a new method for developing a prototype which further can be developed in the form of a wheelchair for paralyzed patients using a low-cost brainwave reading headset. This project has implemented an Arduino robot to simulate a brainwave-controlled prototype for paralyzed patients with an improved controlling method. The robot can move freely anywhere under the control of the user and it is not required to predefine any map or path. An accurate and natural controlling method is provided, and the user can stop the robot any time immediately to avoid risks or danger.

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