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Brain Computer Interface (BCI) Based Smart Wheelchair Control

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ABSTRACT

Electroencephalography (EEG) based wheelchair driving system, one of the major applications of brain-computer interface (BCI) that allows an individual with mobility impairments to perform daily living activities independently. Brainwaves are produced by synchronized electrical pulses from masses of neurons communicating with each other. Brainwaves are detected using sensors placed on the scalp. The brain wave signals are analyzed using Neurosky mind wave mobile. Human brain consists of millions of interconnected neurons. The patterns of interaction between these neurons are represented as thoughts and emotional states. 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 paper, a model has been made to propose a wheelchair, which uses the captured signals from the brain and processes it to control the wheelchair. Electroencephalography (EEG) technique deploys an electrode 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 microcontroller which in turn move the wheelchair.

Index Terms: Electroencephalography (EEG), Brain-Computer Interface (BCI).

1. INTRODUCTION

SPINAL or vertebral column is the most important part in our body where the major functions are to protect the spinal cord, nerve root and also the internal organs. Spinal cord injury occurs when there is any damage to the spinal cord that blocks communication between the brain and the body. When the spinal cord injured, a person's sensory, motor and reflex messages are affected and may not be able to function as usual. The higher the level of injury, the more dysfunction can occur. This may result in partial or complete paralysis of the body as well as complete paralysis of the arms and legs. For persons with a highest level of Spinal Cord Injury (SCI), they are only able to control a muscle movement from a neck and above. To gain an independent mobility, a power electrical wheelchair with an alternative or hands free interface is crucial since normal joystick is not viable anymore. The medium can be developed by utilizing information generated from eyes, tongue, voice and brainwave. Nikhil Shinde and Kiran George proposed a new design of "Brain-Controlled Driving Aid for Electric Wheelchairs". In this paper a BCI based electric wheelchair driving aid design that utilizes mental concentration (EEG signals) and eye blinks (EMG signals) of the user, is used. The design incorporates a safety controller with peripheral safety sensors that override the user command and stop the wheelchair when it detects an obstacle in its path [7].The experimental results show that the average success rate for detecting blinks needed to change the direction of the wheelchair was 85%. Subjects took an approximately 50 seconds to drive a predefined path of approximately 20 feet. This kind of wheelchair can categorize as an intelligent wheelchair as it operate base on computer interface. Imran Ali Mirza, Nikhil Sharma designed a new design which is "Mind-Controlled Wheelchair using an EEG Headset and Arduino Microcontroller". 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 microcontroller which in turn move the wheelchair [2].The information that collected from the action of eyes, tongue, voice or brainwave then will be process to drive the movement of wheelchair to left, right, forward or reverse. The possibility of moving in an autonomous way gives user with severe impairment conditions a remarkable physical and psychological sense of well-being. In recent years, it can be observed a growing of interest in Brain Computer Interfaces (BCI) system for medical and multimedia applications. BCI is a device to provide direct interface between human brain and computer. The users just need to think of movement in order to drive the system. Keun-Tae Kim and Seong-Whan Lee designed a “Towards an EEG-based Intelligent Wheelchair Driving System with Vibro-tactile Stimuli”. This paper uses a Steady-State Somatosensory Evoked Potential (SSSEP) paradigm, which elicits brain responses to vibro-tactile stimulation of specific frequencies, for a user’s intention identification to driving a wheelchair [3]. This wheelchair in mainly based on a subject concentrated on one of vibro tactile stimuli (attached on left-hand, right-hand, and foot) selectively for driving wheelchair (corresponding to turn-left, turn-right, and move-forward).Therefore the usage of BCI is one of the prominent devices for enabling the severe impairment user to control wheelchair based on the signal obtained from the brain.

1.1. Brain Computer Interface (BCI)

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. BCIs are often directed at assisting, augmenting or repairing human cognitive or sensory-motor functions. Figure 1 shows the basic blocks in the BCI interface. Humans’ brain is filled with neurons, individual nerve cells connected to one another by dendrites and axons. Every action like think, move, feel or remember something make neurons are at work. That work is carried out by small electric signals that zip from neuron to neuron as fast as 250 mph. The signals are generated based on the differences in electric potential carried by ions on the membrane of each neuron. The signals then can be detected, interpreted to what they mean and use them to direct a device of some purpose.

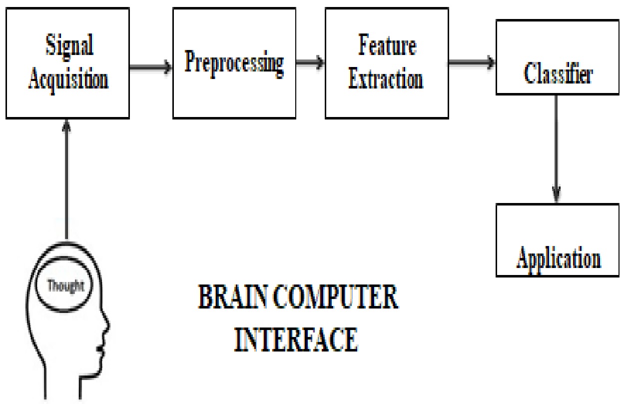

Fig. 1. Brain Computer Interface

The immediate goal of BCI research is to provide communications capabilities to severely disabled people who are totally paralyzed or ‘locked in’ by neurological neuromuscular disorders, such as amyotrophic lateral sclerosis, brain stem stroke, or spinal cord injury. Therefore, BCI is a system that provides direct interface between the human brain and the computer. In order to develop the BCI system, the feasible technique should be studied. BCI systems are broadly classified into invasive and non-invasive techniques. Lee.W.T, Nisar.H, Malik.A.S, Kim Ho Yeap had developed "A Brain Computer Interface for Smart Home Control". The Electroencephalographic (EEG) signals recorded from the brain activity using the Emotiv EPOCH headset where interfaced with the help of mouse emulator to a Graphical User Interface (GUI) on the computer screen [9]. The user will use this GUI to control various devices in a smart home. The user will select his desired application using a raise of an eyebrow (or a smirk, or a combination of actions if needed and to increase the sensitivity of the system), that will cause a mouse click on the desired control.

Monika Rana and Ramandeep Singh proposed a system which will use "Smart Homes for a Better Living Using Bluetooth Communication Based on Atmega Microcontroller". The embedded system is connected to appliance in home and it is ready to receive control through Bluetooth receiver. This paper [5] consists of two parts. (a) Android application, used for communicating with the controlling circuit through Bluetooth channel. (b) Electronic controlling circuitry, consists of a microcontroller, a Bluetooth module, relay driver IC along with relays which will switch electrical loads on the circuit and to switch the power supply. The android device sends a command which is received by the receiver of the Bluetooth module and forwards it through its USART serial interface to the microcontroller. After receiving the command, the microcontroller performs the necessary action.

1.2. Electroencephalography (EEG)

EEG is the first non-invasive neuron imaging technique discovered which is used for measuring the electrical activity of the brain. EEG signals are detected from the scalp and contain noise as a result of electrical interference and movement of electrodes. Applying a large number of EEG channels may include noisy and redundant signals that degrade the BCI performance and also involve a prolonged preparation time that directly impacts the convenience in the use of the BCI. Therefore, selecting the least number of channels that yield the best or required accuracy can balance both needs for performance and convenience.

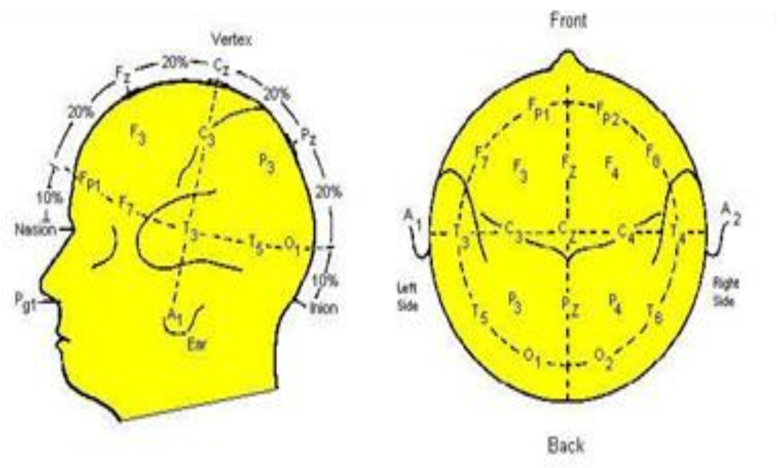

Fig. 2. The International 10/20 Systems of Electrode Placement

1.3. EEG Electrode Brain Channel

Typically, in BCI study, electrode locations are selected arbitrarily from scalp area corresponding to the motor cortical region to record the electrical activity of the brain. It is well known that the variation of the surface potential distribution on the scalp reflects functional activities emerging from the underlying brain. This surface potential variation then can be record and the voltage of electrodes can be measure, which are then filter, amplify, and record. Electrodes conduct voltage potentials as microvolt level signals, and carry them into amplifiers that magnify the signals approximately ten thousand times.

The use of this technology depends strongly on the electrodes positioning and the electrodes contact. For this reason, electrodes are usually constructed from conductive materials, such as gold or silver chloride including a conductive gel that will apply between electrode and scalp to maintain an acceptable signal to noise ratio. The gel based electrode system however have difficulties on the need of long montage time and the need to wash the user's hair after the recording.

Therefore, the dry electrode system will be used to reduce the electrode- skin impedance. Figure 2 shows the location of electrode according to International 10/20 System. Each site has a letter to identify the lobe and a number or another letter to identify the hemisphere location. The letters F, T, C, P, and O stand for Frontal, Temporal, Central, Parietal and Occipital. Even numbers (2, 4, 6, 8) refer to the right hemisphere and odd numbers (1, 3, 5, 7) refer to the left hemisphere. The z refers to an electrode placed on the midline.

1.4. Data Acquisition

Single electrode headsets, such as the Neurosky Mind wave, were inexpensive and simple. Most devices had an accessible Software Development Kit (SDK) so development would be relatively simple. The systems also include built-in electrical noise reduction software/hardware, and utilize embedded (chip level) solutions for signal processing and output. The dry electrodes can measure brain waves millimeters from the scalp and thus can easily be worn over hair. Figure 3 shows an illustration of all of the options for data acquisition devices.

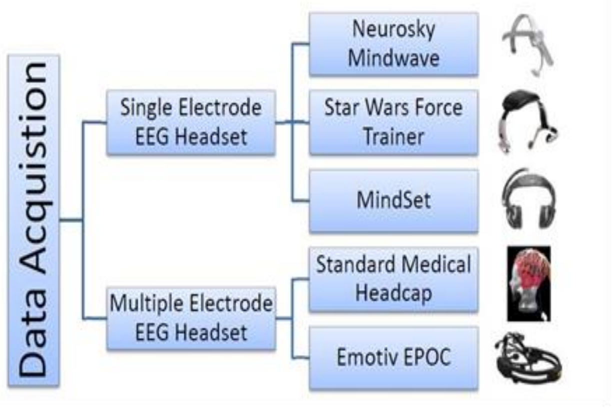

Fig. 3. Data Acquisition Design Option

2. PROPOSED WORK

In recent years, it can be observed a growing of interest in Brain-Computer Interfaces (BCI) system for medical and multimedia applications. BCI is a device to provide direct interface between human brain and computer. The users just need to think of movement in order to drive the system. Therefore the usage of BCI is one of the prominent devices for enabling the severe impairment user to control wheelchair. For this project an Electroencephalogram (EEG) signal generated from single electrode that placed on the forehead will be used as a controller to initiate user-intention command. Meditation levels and eye blinks are detected from the EEG signal. 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. The specific objectives are:

1. To design a Brain Computer Interface based wheelchair for physically impaired people.
2. To acquire and process the EEG signal from non-invasive BCI (Neurosky Mind wave) device using Arduino Software.
3. To analyze the EEG signal in term of attention and meditation level by using their peak and average value.

2.1. Problem Statement

Every year, around the world, between 250000 and 500000 people suffer a spinal cord injury (SCI) and severe impairments. The majority of spinal cord injuries are due to preventable causes such as road traffic crashes, falls or violence. The damage of spinal cord and nerve root may effect from incomplete to total dysfunction. Conventionally, most people with severe impairments conditions are unable to control their electrical wheelchair using a standard joystick. A complete paralysis of the body severe impairment people as well as complete paralysis of the arms and legs cause the power wheelchair with alternative interface is needed. Limited physical movement above the fourth cervical vertebra typically no single alternative interface provides a comprehensive solution to the control wheelchair. Therefore this project will develop the BCI system based on EEG signal to control wheelchair so that the patients can use their brain to move the wheelchair without any assistant. Figure 4 shows the proposed system block diagram.

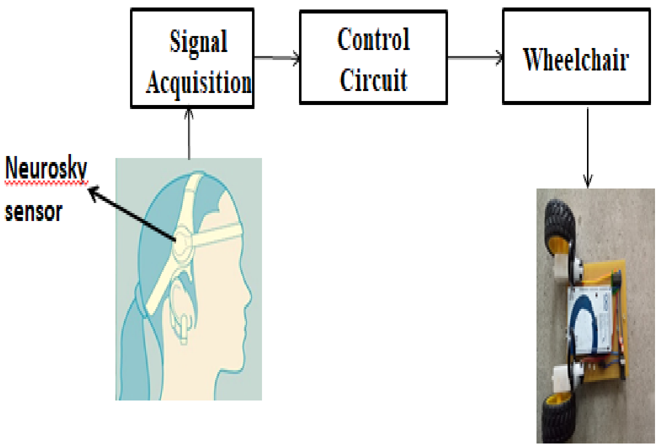

Fig. 4. Block Diagram of Proposed System

2.2. Scope and Advantages

The scopes of this study are:

1. Use the Neurosky Mind wave of single electrode EEG headset to capture the brain signal.
2. Constraint of six basic wheelchair's movement which are start, stop, left, right, forward and reverse.
3. Use Arduino software to analyse the collected data.

2.3. Advantages of Proposed System

1. Easy to handle, since uses the simple concentration and blink to control.
2. Suitable for all kind people especially Elderly people and physically disabled people.
3. Less power consumption.
4. Wireless control.
5. Less interference due to encoding techniques.
6. Less deviation and high sensitivity.
7. Flexible hardware changes.

3. HARDWARE DESCRIPTION

Hardware requirements for the proposed system:

1. NeuroSky Mindwave Mobile Headset
2. HC-05 Bluetooth Module
3. Ardunio Mega &nano
4. Model of Electronic Wheel chair

3.1. Neurosky Mindwave Mobile

NeuroSky, Inc. is a manufacturer of Brain-Computer Interface (BCI) technologies for consumer product applications, which was founded in 2004 in Silicon Valley, California. Figure 5 shows the Neurosky Mindwave Mobile. The company adapts Electroencephalography (EEG) and Electromyography (EMG) technology to fit a consumer market within a number of fields. NeuroSky technology allows for low-cost EEG-linked research and products by using inexpensive dry sensors.

Fig. 5. NeuroskyMindwave Mobile

The systems also include built-in electrical “noise” reduction software/hardware, and utilize embedded (chip level) solutions for signal processing and output. When NeuroSky has released direct-to-consumer products, such as the MindSet and the MindWave, they are typically designed for maximum flexibility of use through third party and open source content. The NeuroskyMindWave Mobile safely measures and outputs the EEG power spectrums in the form of alpha waves, beta waves, etc., NeuroSkyeSense 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.

3.2. HC-05 Bluetooth Module

HC-05 module is an easy to use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup. 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. 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.

3.3. Arduino Mega & Nano

3.3.1. Arduino Mega 2560

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button.

It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega 2560 board is compatible with most shields designed for the Uno and the former boards Duemilanove or Diecimila. The ATmega2560 on the Mega 2560 comes preprogrammed with a bootloader that allows you to upload new code to it without the use of an external hardware programmer.

3.2.2.Arduino Nano

The Arduino Nano is a small, complete, and breadboard-friendly board based on the ATmega328 (Arduino Nano 3.x). It lacks only a DC power jack, and works with a Mini-B USB cable instead of a standard one. The Arduino Nano can be powered via the Mini-B USB connection, 6-20V unregulated external power supply (pin 30), or 5V regulated external power supply (pin 27). The power source is automatically selected to the highest voltage source. Each of the 14 digital pins on the Nano can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions.

4. MODEL OF ELECTRONIC WHEELCHAIR

4.1. Working Principle

Wheel chair consist of two LED, Red LED is used to indicate the sensor is ready or not and Green LED is used to select the wheelchair direction.

- Forward
- Backward
- Left
- Right

After the selection of direction, Green LED is off and tries to make the attention. The wheelchair moves the selected direction. Attention goes less than threshold value, wheelchair is stopped. Again choosing the direction is done by the help of Green LED. Figure 6 shows the circuit diagram of a wheelchair.

4.2. L293D-Motor Driver

The L293D works on the concept of typical H-bridge, a circuit which allows the high voltage to be flown in either direction. L293D is a driver circuit which allows the rotation of both the motors simultaneously either clockwise or anticlockwise direction.

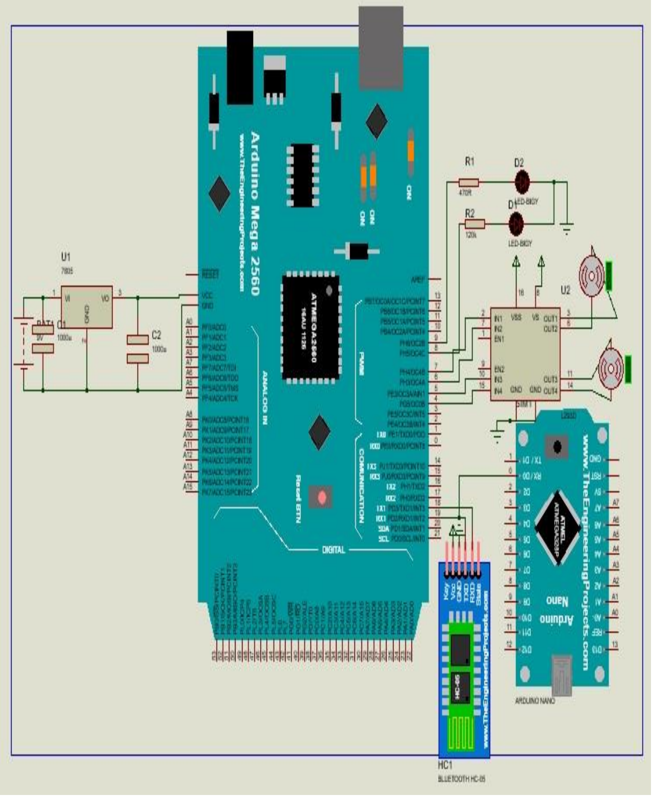

Fig. 6. Circuit Diagram of Wheelchair

In a single L293D IC there two H-bridge circuits which can rotate two DC motors independently. Due to its size and voltage requirement, it is frequently used in robotics applications for controlling DC motors, including in

Arduino projects. Figure 7 shows the L293D pin configuration. The L293D is also a key component in larger 'motor driver' boards available premade for hobbyists.

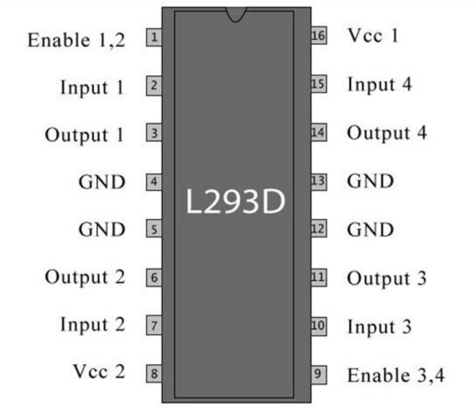

Fig. 7. L293D Pin Configuration

4.3. DC Motor

Two DC motors are attached to the rear wheels of the wheelchair simulator. These motors rotate with the speed of 100 revolutions per minute. For the movement of wheelchair in forward or backward direction both the motors will rotate but in opposite directions. For left or right movement one motor is in one direction and another motor is in opposite direction.

5. RESULT AND DISCUSSION

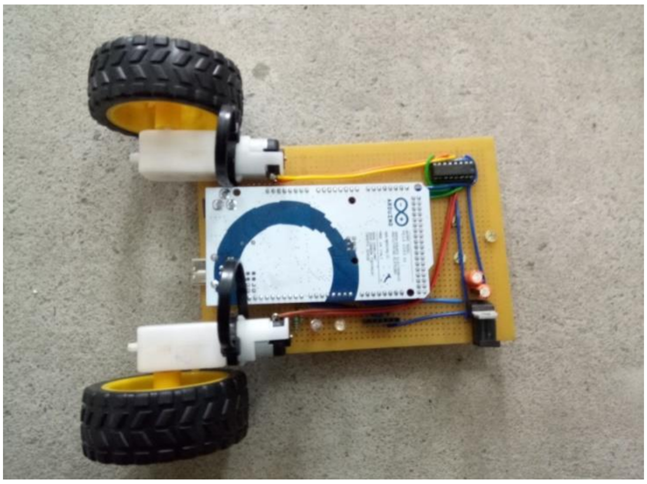

Fig. 8. Model of Wheelchair

Wheel chair consist of two LED, Red LED is used to indicate the sensor is ready or not and Green LED is used to select the wheelchair direction and figure 8 shows the model of wheelchair. Figure 9 indicates that the device is ready.

1. Forward
2. Backward

3. Left
4. Right

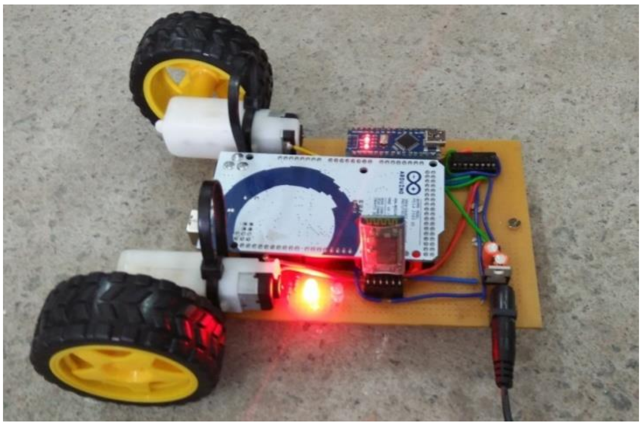

Fig. 9. Indication of the Device is Ready

After the selection of direction, Green LED is off and tries to make the attention. The wheelchair moves the selected direction. Attention goes less then threshold value, wheelchair is stopped. Again choosing the direction is done by the help of Green LED. Figure 10 shows that the both LED are in on condition.

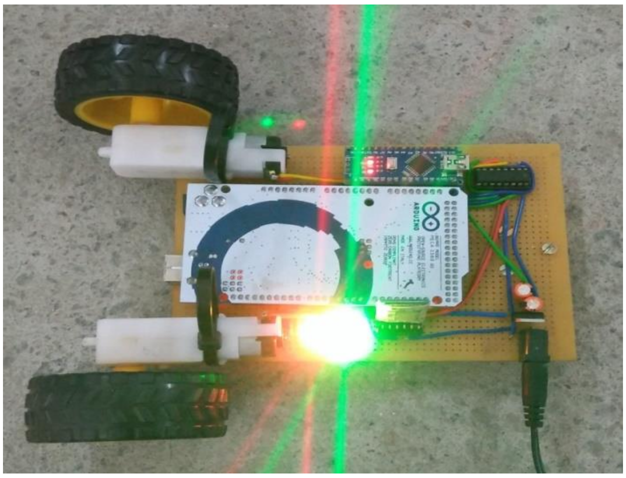

Fig. 10. Red and Green LED is on Condition

6. CONCLUSION

Using this proposed system 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. With the Implementation of above hardware architecture a wheelchair could be controlled successfully. This wheelchair uses two motors for its movement. 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. 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.

7. FUTURE 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. Arduino efficiently controls drivers and drivers are able to communicate with motors. With more modifications this system could be converted to real system which can support the lives of amputees.

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