EUROPEAN ACADEMIC RESEARCH
Vol. VIII, Issue 11/ February 2021

Impact Factor: 3.4546 (UIF)
DRJI Value: 5.9 (B+)

ISSN 2286-4822
www.euacademic.org

Design and Implementation of Mind-Controlled Wheelchair Based on Electroencephalography

ABDULMUAIN ALSAKKAF
University of Medical Sciences and Technology
HEISUM M. EWAD
Bahari Ahlia College

Abstract

This paper is proposing wheelchair that can be controlled wirelessly by Electroencephalography (EEG) , where these signals get through the device Neurosky Mindwave and sending them using Bluetooth technology to an Arduino micro-controller which analyses these signals and translates them and provide output signals suitable to be sent to the continuous rotation servo motors that have the ability to rotate in a counter clockwise direction and Anticlockwise in order to move the simplified model for a wheelchair that gives people with quadriplegia ability to move without the need to help others. This system gives a person with quadriplegia the ability to move in all directions and stop when required to do so. Using two signals of the brain that are attention and meditation to move the model wheelchair forward or backward, as well as the decrease in those signals resulting from eyes blinking to move in the right direction or the left. Specific values for attention and meditation and decreases in them has been put, when these values are reached orders are sent to the motors except that it is to stop the motors (the chair is not moving).

Keywords: Neurosky, Arudino, EEG ,Wheelchair

INTRODUCTION

Life has become nowadays rely heavily on machines that facilitate a lot of daily work that we do, and with the increasing reliance on these machines and devices necessary to the invention of devices to be controlled remotely, or the machines are programmed to do specific

tasks, such as machines used in factories or hardware based artificial intelligence, but how can people with special needs and quadriplegic patients to benefit from all this? There are many people who suffer from disabilities and inability to move either partially or fully. According to statistics, approximately 1.2 million people in the United States, and there are more than 11,000 new injuries per year. Half of those injuries are quadriplegic for the year 2019. The number of disability in several countries is high and continues to rise. Estimates with disabilities in the world covering 10 percent of the total population in the world, which is about 650 million people. This number has increased significantly, both in developed countries and developing countries. Despite all of the above, the interest in the category of helping infected people is very few, in addition to that there is no effective medical solution for the quadriplegia, so we wanted to help them in the technical and technological sides by providing appropriate ways to interact and control the things that adapts to each disability, and provide a reliable and functional system that would take humanity one step further in aiding less fortunate handicapped patients by offering them a better and more independent life. With paralysis, life can be a very difficult experience with people requiring assistance for just about everything. The current mobile technology which is most popularly used today, exist in the form of a power chair and is not sufficient because it does not cater to all patients, only patients who have the use of their arms can use these power chairs. There is a need for improved power chairs that would allow quadriplegics to control it using their minds. The control system needs to be designed in a way that would control the speed and direction of a rover or power wheelchair.

Previous study:

This review describes some of previous wheelchair control systems were developed using different methods and techniques. In addition a brief review on brain computer interface, EEG signals.

A. Control Things by Voice

The first was the invention of the wheelchair can be controlled by voice in 1994 through the use of telephone is linked with a micro controller[1], where he works as a translator for the phone converts sounds into commands used by the micro-controller to control the

things. Megha Muralidharan [2] proposed a Voice Recognition Based Intelligent Wheelchair where voice recognition module is used to recognize patient's voice in order to drive a wheelchair. The user can go front, back, right, left using his/her voice. Two ultrasonic sensors are used for obstacle depth detection as well as the system incorporates joystick control using hand movement.

The disadvantage of this system: -

•Responding to commands that are not issued from the user because of the similarity between the sounds.

•There are some people who are paralyzed lose the ability to speak.

B. Control Things through Eye Movements:

Through filming Eye camera and analyze coordinates iris and track the movement of the eye if moved iris to the rightis translated into a specific command is used the same way to all directions (right , left, above, below) and has been designed with the first device the track eye movement in 1980, then appeared computer applications to track the movement of the eyes and used these programs , the movement of the cursor on the computer to help the disabled and people with quadriplegic, and now has become much easier and using the program MATLAB ,which can image processing is simplified and also can be used as a mobile phone and programs waged in the phone to track the movements of the eyes, as was the use of phone system Android to help people with quadriplegic to send short messages when you need to help[3]. In 2011 an Italian group of engineers published a paper [4] ,discussing the disadvantages of eye-controlled electric powered wheelchair (EPW) systems. This paper brought to our attention that when the user is attempting to move the wheelchair by gazing at the screen, he would not actually be seeing where he is going. This general flaw in eye-controlled EPW systems encourages the addition of a video screen on the display.

C. Control things through the brain

There are two ways to rely on the brain to control either through the nerves related to the brain or by measuring the electrical signals of the brain directly and translated into specific orders, which were first used technique to measure electrical signals from the brain in the late nineties was the invention of the first wheelchair controlled by signals

the brain in 2007 by Toyota Motor Corporation, which technique was used to measure the imam brain signals [5].

The disadvantage of this system:

- The need to use a computer intermediary to translate the signals that are measured.
- The link between device to measure brain signals and computer is wired.

1. Brain computer interface (BCI):

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.

BCI System parts Forming a BCI system requires following three main steps as shown in Figure(1) signal acquisition signal processing data manipulation "using these obtained signals to control in external devices or computer depending on the application".

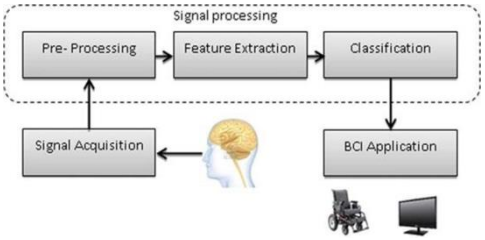

Figure1. BCI system

A. Signal Acquisition Signal acquisition process is required to capture the brain electric signals. The electric signals could be recorded from the scalp, the surface of the brain, or from the neural activity. Since the capture signals strength are usually low, they need to be amplified. Then, to be used by computer applications, they need to be digitized.

B. Signal Processing In this step, obtained signals in step1 are analyze to get the control signals. Signal processing could be done through some other sub operations as follows:

- Preprocessing The first part of signal processing is preparing the recording electric signal form processing like enhancement to make the features clear for detection. Some filtering techniques could be used in the preprocessing operation.
- Feature extraction Simply, feature extraction means extracting specific signal features. EEG recordings not only contain electrical signals from the brain, but also several unwanted signals. Those unwanted signals may bias the analysis of the EEG and may lead to wrong conclusions. Therefore, the digitized signals are subjected to feature extraction procedures.
- Signal Classification: "translation algorithm" ,The next stage, the translation algorithm, in which it translates the extracted signal features into device commands orders that carry out the user's intent.The signals are classified on both frequency and on their shape; the classification algorithm might use linear methods or nonlinear methods.[6]

2. EEG Signals

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:

a. Delta Signal.

It is captured within the frequency range of 0.5–3.5 Hz. It tends to be the highest in amplitude and the slowest waves. It is seen normally in adults in slow wave sleep as well as in babies.

b. Theta Signal

The frequency of this signals ranges from 3.5 to 7.5 Hz. Theta is linked to inefficiency and daydreaming. In fact, the very lowest waves of theta represent the fine line between being awake or in a sleep.

c. Alpha Signal

This signal frequency ranges from 7.5 to 12Hz .Hans Berger named the first rhythmic EEG activity he saw, the "alpha wave".Range seen in the posterior regions of the head on both sides,mbeing higher in amplitude on the dominant side. It is brought out b closing the eyes

and by relaxation. Several studies have found a rise in alpha power after smoking marijuana.

d. Beta Signal

Beta is another brain signal in which its frequency ranges from 12 Hz to about 30 Hz. It is seen usually on both sides in a symmetrical distribution and it is most evident frontally. Beta waves are often divided into 1 and 2 to get more specific range. The waves are small and fast when resisting or suppressing movement, or solving a math task. It has been noticed in these cases that there is an increase of beta activity.

e. Gamma Signal

It is a signal with frequency range of 31 Hz and up. It reflects the mechanism of consciousness.[7]

SYSTEM DESIGN

The Fig. 2 show the overall system, where the controlling input signals come to the microcontroller (Arduino mega 2560) from the mind wave sensor (neurosky).The microcontroller receives these signals as packets and interprets them to give the required output signal. The signals are transmitted to servo motors which move the module to the required direction (that will be described in the coming sections).

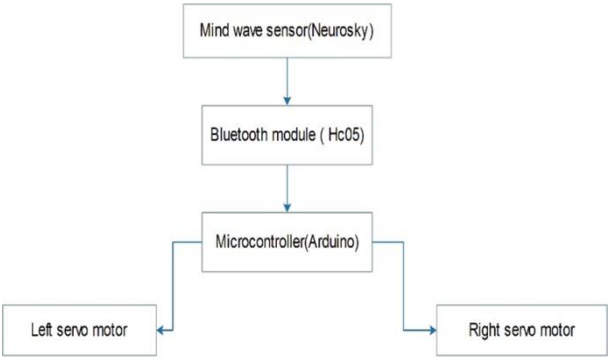

Figure 2. Block diagram for system design

A. Neurosky mind wave Headset

The last century of neuroscience research has greatly increased our knowledge about the brain and particularly, the electrical signals emitted by neurons firing in the brain. The patterns and frequencies

of these electrical signals can be measured by placing a sensor on the scalp. The Mind set contains Neurosky Think Gear technology, which measures the analog electrical signals, commonly referred to as brainwaves, and processes them into digital signals to make the measurements available to games and applications.

1. ThinkGear

Think Gear is the technology inside every NeuroSky product or partner product that enables a device to interface with the wearers' brainwaves. It includes the sensor that touches the forehead, the contact and reference points located in the ear clip, and the on-board chip that processes all of the data. Both the raw brainwaves and the eSense Meters (Attention and Meditation) are calculated on the Gear chip.

2. ATTENTION eSense

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 o , or anxiety may lower the Attention meter level

3. MEDITATION eSense

eSense Meditation meter indicates the level of a user's mental "calmness" or "relaxation". Its value ranges from0 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. However, for most people in most normal circumstances, relaxing the body often helps the mind to relax as well. Meditation is related to reduce activity by the active mental processes in the brain. It has long been an observed t that closing one's eyes turns o the mental activities which process images from the eyes. So closing the eyes is often an effective method for increasing the Meditation meter level. Distractions, wandering thoughts, anxiety, agitation, and sensory stimuli may lower the Meditation meter levels. [8]

B. Motors and power supply

Two 7 V servo motors is used at the left and right of the wheelchair and wheels are coupled with the motors. One 12 V 2400 mAh Lithium Polymer (LiPo) battery is used as power supply.

C. Pairing HC-05 Bluetooth module with neurosky mindwave

User can change the default setting of HC-05 Bluetooth module with the AT command via 'Mode' pin. If the 'Mode' pin pulled high, the module enter the AT command mode. The breakout board provides two LED to indicate the status of the module, the RED led indicate the link activity status, and the GREEN led indicates the pairing status.

D. A mechanism to read and translate brain signals:

To facilitate the explanation of how brain signals are read and measured from Neurosky mind wave we will divide that into a number of sub-sections as follows:

1. Achieve synchronization between Arduino mega 2560 and Neurosky

The brain signals measuring device (Neurosky) Provides protocol for (eSense) technology that through this technique the intensity of attention and meditation can be obtained, and this Protocol works to send (Packets of Bytes), so it is possible to analyze this Packets by reading bytes consisting those packets by the Arduino and prefers to use high-speed Arduino, due to the large number of data sent, and this protocol can be obtained from development tools of the brain signals measuring device (Mindset Development Tools) available in company's website, and this protocol gives an explanation for each Packet sent and the values of the bytes constituting the packets, the packets consists of three parts:

• Synchronization part - (Packet Header): It consists of three bytes, two bytes to achieve synchronization (Sync), and one to determine the length of the main part (Plength), and the value of that two bytes used for synchronization must be (170), as well as require that the length of the main part (Length) is less than (169) In the case of the greater length packet is rejected.

• The main part of your data - (Packet Payload): It contains data attention and meditation, and the length of this part ranging from (0) when there is no data, to (169) .
• Part for summation checking (Packet Checksum): It contains one byte used to validate the data. Transmitted using the algorithm (Checksum) and this is done through the following steps:

1. Summation of all data bytes located in the main part of the package.
2. Taking eight bits of the output of a combination, starting from the least significant bit - (LSB).
3. Taking out complementary for the first eight bits (reverse every bit).
4. Compare the eight bits with the (checksum byte) that is the last byte in the packet sent.

The Table1 below illustrates basic Parts of package that sent, in addition to the meaning of bytes and values for each part of the package.

Table 1. Parts of package sent and their meaning

Example	Example	Example		Meaning
Synchronization Part (Packet Header)	Synchronization bytes (2 Bytes)	2d B 170	1st B 170	Always be equal and the value is (170) to achieve synchronization
	Byte of the length of data(1Byte)	4		This means that the main part consists of four bytes
Main data Part (Packet payload)	Attention Bytes (2Bytes)	2nd B 55	1st B 4	The first byte: for the Attention and always equal(4) The second byte: for the high attention, and its value from 0 to 100
	Meditation bytes (2Bytes)	2nd B 30	1st B 5	The first byte: for the meditation and always equal(5) The second byte: for the highly meditation, and its value from 0 to 100
Main data Part (Packet payload)	Poor signal bytes (2 bytes)	2nd B 0	1st B 2	The first byte: for Poor signal and always equal(2) The second byte: for the degree of poorness and its value from 0 to 255
Checksum Packet	Checksum Byte (1 byte)	160		The total of data bytes (payload) to verify of their correctness

And there is additional information can be obtained in the main part of the package private data, and examples of these information: in the case of connection, an interruption of the connection between the measuring device, an error occurs in the package (Bluetooth Model) brain signals and tool Bluetooth sent receptor, in addition to identifying important bytes that contain attention and meditation data. The sending bytes is used to representation code that performs a specific function, and can be represent these bytes by hexadecimal or decimal number the following table Show some of important Meaning byte values used to denote specific information.

Table 2. Function of some of bytes

The Byte value decimal system DEC	The Byte value hexadecimal system HEX	Functions
170	0xAA	used to achieve synchronization
-70	0x46	An error occurs
128	0x80	2Bytes are skipped When data are read
131	0x83	24Bytes are skipped When data are read
194	0xC2	Start connecting
208	0xD0	The Neurosky is connected
209	0xD1	No device is found
210	0xD2	The Neurosky is disconnected

After we know about the (eSense) technology protocol in the Neurosky device, the appropriate code to implement this protocol must be written in Arduino C language and also to read attention and meditation data that used to control the wheelchair model, Therefore, we have designed an algorithm that fit the protocol used by the device to measure brain signals as well as we were able to read attention and meditation data and the degree of the weakness of the transmitted signal. Figure.3 shows algorithm that is designed to achieve communication and synchronization between the Arduino and Neurosky as well as to read bytes and a measure brain signals that will be used to control the wheelchair model.

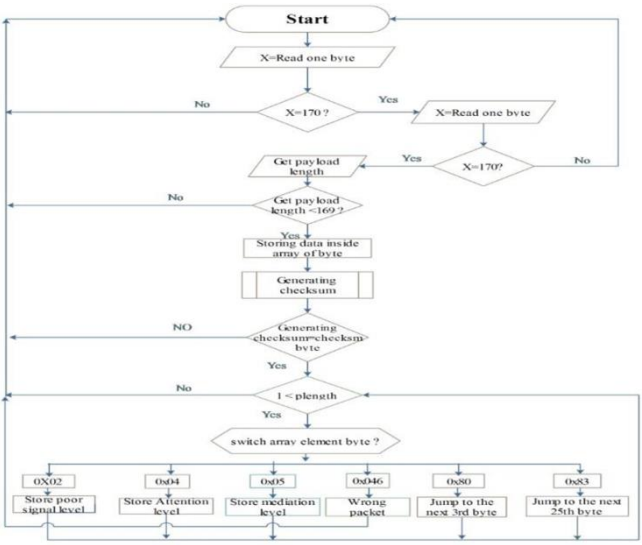

Figure 3. Achieve synchronization between Arduino and Neurosky

2. Determining the occurrence of eyes blinking without using a computer:

As we mentioned earlier that the brainwaves(Row Waves) that can be read by the(Neurosky Mind-set) used to read the ideas and determine the movement of the eyes can be analyzed only by computer , while the electrical signals of the brain that used to determining the attention and meditation, which are measured in the same device can be analysis by controller , So it was available in this project, only two signals, the attention and meditation ,that will control the movement of the model forward and backward, but when you connect the device to the computer to read brainwaves and brain electrical signals to get additional signals can be read and analyzed by Arduino to control the movement of wheelchair model, when the eyes are blinking there is sudden change and decrease the intensity of brain signals, we knew previously that the technology eSense used in the device Neurosky that can be analyzed by the controller can measure the intensity of attention and intensity of meditation and the intensity of poor signal, therefore by relying on the reading the level of signal and analysing by the controller to determine eyes blinking and the intensity of the eyes blinking , to determine the direction movement (right, left) of wheelchair model

SYSTEM IMPLEMENTATION

After achieving synchronization between Arduino and the Neurosky mind wave device, and obtaining the signals from that device we can convert these packets of data received from the Neurosky mind wave device in the following manner:

A. Convert brain signals into commands

To translate the signals into commands must first know the number of commands required to control the car model, there are five orders as follows:

1) Forward instruction
2) Backward instruction.
3) Turn right instruction.
4) Turn left instruction
5) Stop instruction.

While the number of brain signals that can be measured and analyzed by the controller are three signals as follows:

a) Attention signal.
b) Meditation signal.
c) Eye blink signal.

So some of command can be adjusted and integrated to control a wheelchair model by using the three brain signal be analyzed by the controller, and the command became after Modified as follows:

1. Moving forward instruction.
2. Moving backward instruction.
3. Determine the direction instruction (right, left, front).
4. Stop instruction.

We will discuss separately each order and see how it is translated to fit the brainwave signal with the command to be executed.

•Command for moving the motor forward

The attention signal is the appropriate signal for moving the motor forward, Because the attention signal commensurate with the thinking to move forward, As mentioned earlier that the intensity of attention ranging between (1-100), to simplify dealing with these numbers mathematically and to control rotation speed motor we convert these numbers to decimal numbers dividing by 100 Therefore Initial value is specified for the intensity of attention when the

intensity level is greater than this specific Initial value command is sent to the motors for forward rotation, these initial value of intensity of attention was determinate equal to (0.45) .

But after the experience of these device by more than one user ,the level of attention varies from one person to another, therefore we can adjust the initial value by using rheostat that one of the parties was reached resistance to analogue ports of the Arduino and other to the ground and we can read the changing in initial value by Arduino program using the command (analog read()) ,also we can know the high and low value by observing the Arduino program serial monitor using command (serial .print) .

To determine the initial value and make it between the high and low value we use the equation:

$$\text{Intensity attention Initial value} = \frac{\text{measure values} - \text{lowest values}}{\text{Highest values}}$$

The figure.4 below show flowchart of algorithm to control moving the motor forward

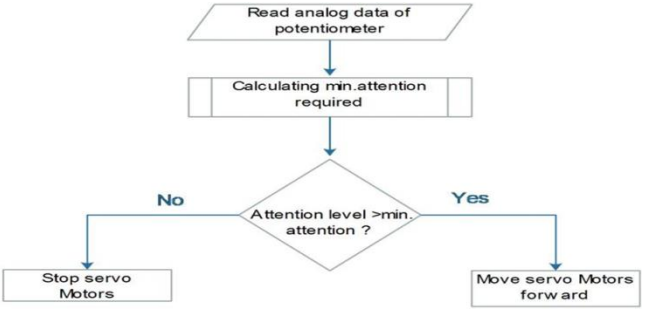

Figure 4. Algorithm to control moving the motor forward

• command for moving the motor backward

The meditation signal used for moving motor backward, these signal has the same characteristics of the attention signal where the level of the attention signal from 0 to 100 .In the same way which convert the intensity of attention to decimal number , the levels of meditation converted by divided by 100 .also the initial value of the intensity of meditation is determine as the lowest meditation signal that can move the motor backward ,also the level of meditation varies from one person to another , but because all the analog ports are used the

rheostat cannot be used to determine 40 the initial value of the meditation signal , so After the experiment for many person the initial value of the meditation determined equal to (0.85) , because of interference between the attention and meditation signals we design mechanism that can separate between tow signals and determine the required signal that user means and these mechanism is

- Store the value of the intensity of attention signal in variable and the intensity of meditation in other variable.
- Compare between the values if intensity of attention signal greater than the intensity of meditation that mean the user in attention state and command for moving forward send to motors ,or if the intensity of meditation greater than intensity of attention that mean the user in meditation state and command for moving backward send to motors .
- In the backward state, compare between the initial value of meditation and the meditation value ,if the meditation value greater than initial value the motors move backward and if not the motors will be stopped.

The figure.5. Show the algorithm used to implement this mechanism:

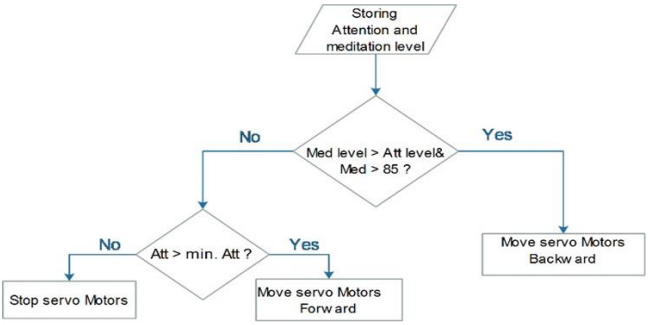

Figure 5. Algorithm to control moving the motor backward

• Commands for determining the direction of movement wheelchair model:

Because of a few signal brain that can be analyzed by the Arduino we can dispense with signals that can move the car model toward the left or right, and to achieve these goals we have been replaced these commands by command determines the direction first then moving the motors forward . The eye blinks signal used to identify the

directions (front, right, left), but the signal of every eye cannot be distinguished separately, so direction has been determined as follows in figure.6 algorithm used determines the direction by eye blinks signal.

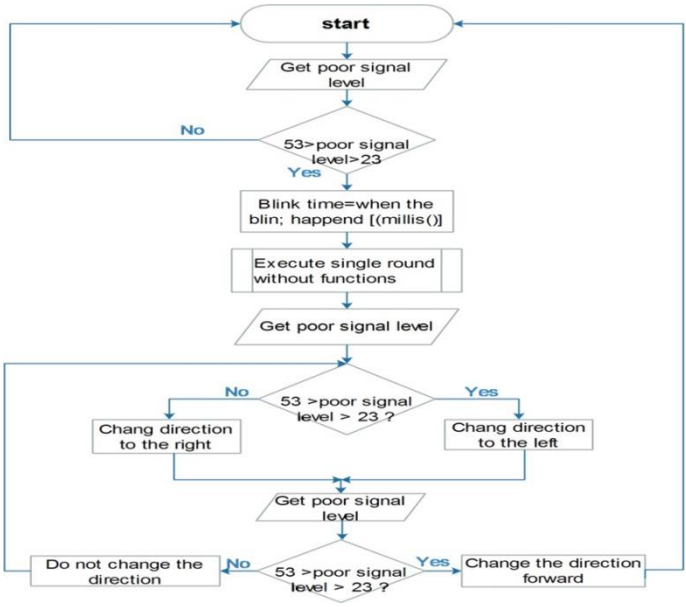

Figure 6. Design of the algorithm determines the direction by eye blinks signal

- **Command for motors stopping**

The motors in the stop state when there is no enough attention or meditation signal to move them, that mean there is no need for a new signal to make the motor in stop state, just need to reduce the level of attention and meditation signal less than the initial value of the intensity of attention in forward rotation state and less than the initial value of the intensity of meditation in backward rotation state.

b.prototybe

The figure.7 bellow show the parts of prototype

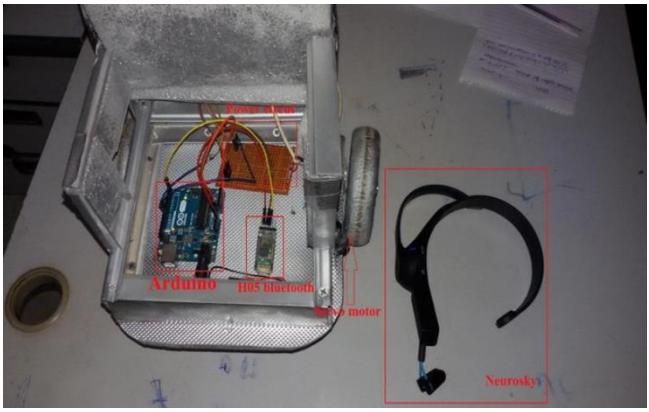

Figure.7. parts of the system

RESULTS AND DISCUSSION

a. Received packets from neurosky

The Neurosky mind wave sends the packets to the Arduino wirelessly by Bluetooth, figure.8 show serial monitor of receiving packets from Neurosky.

Figure 8. Receiving packets from Neurosky on serial monitor

b. Commands that Arduino send to the servo motors

We will have five commands that Arduino send to the servo motors of wheelchair simple model

1. Movement wheelchair model forward :

When the attention value is greater than specified initial value (45), Arduino send command for servo motors to move wheelchair model forward.

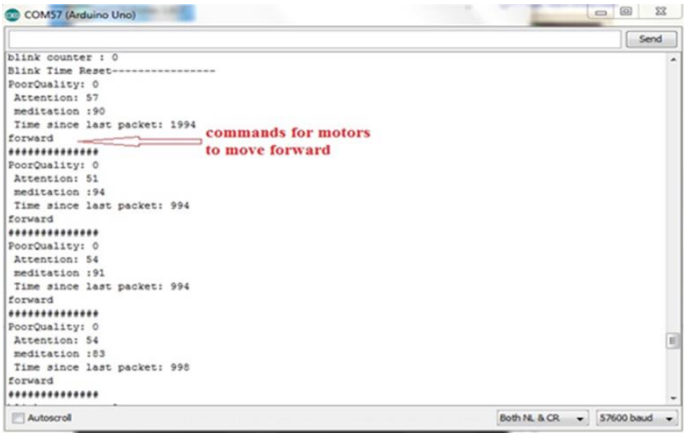

Figure 9.command forward on serial monitor

2. Movement wheelchair model backward

When the meditation value is greater than specified initial value (75), Arduino send command for servo motors to move wheelchair model backward.

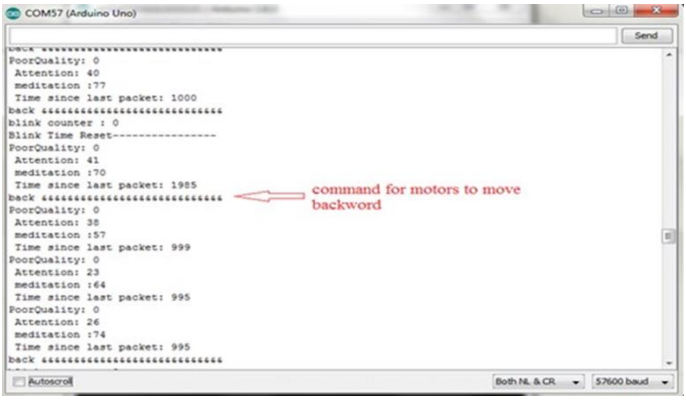

Figure.10. command backward on serial

3. Movement wheelchair model right direction:

If one eye blink is detected the left motor will be stopped and the right motor rotate only that make wheelchair model move right direction.

Figure 11. command right direction on serial monitor

4. Movement wheelchair model left direction

If two eye blinks detected consecutively, the right motor will be stopped and the left motor rotate only that make wheelchair model move left direction.

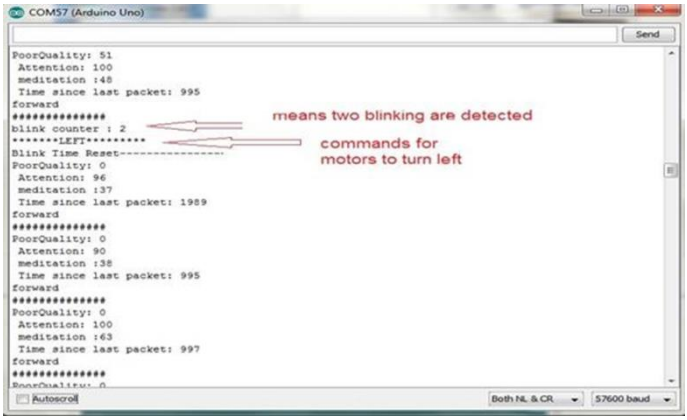

Figure 12. command left direction on serial monitor

5. Stop wheelchair model movement

When the level of attention less than the initial value(45) and the level of meditation less than initial value (75) motors of wheelchair model will stop.

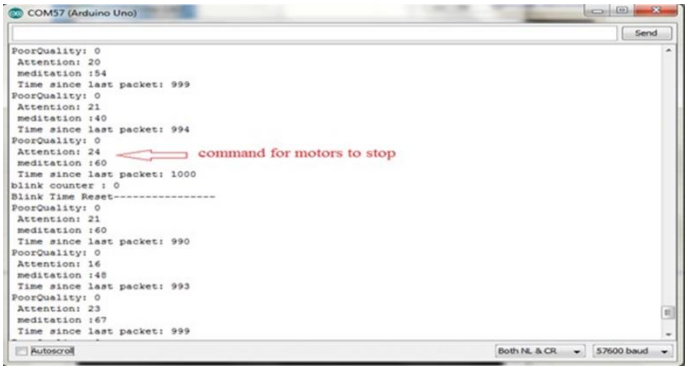

Figure.13 command stop on serial monitor

CONCLUSION

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 result of these efforts.

In this work, the design of a mind controlled wheelchair for provide mobility to all disabled people regardless of whether or not they have use of any limbs is shown. . In general the point is to control and operate electrical motors with waves produced by the human brain, The patient will be able to move the wheelchair in four directions by keep attention level for forward, meditation level for backward and the eye blink pattern for left and right .

There are many possibilities for future research of technology development of the wheelchair movement control system. 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.

REFERENCES

[1] Mazo, M., Rodríguez, F.J., Lázaro, J.L., Ureña, J., Gracía," Wheelchair for physicallydisabled people with voice, ultrasonic", Kluwer Academic Publishers, Autonomous Robots, 2, 203-224 (1995)

[2] Megha Muralidharan, P.T.Jabir, Vinod Pottakulath, "Voice Recognition Based Intelligent Wheelchair", International Journal of Innovative Research in Science, Engineering and Technology, Volume 5, Special Issue 5, April 2016

[3] Barea, R., Boquete, L., Mazo, M. & López, E.(2002). System for assisted mobility using eye movement based on electrooculography . IEEE transactions on neural systems and rehabilitation engineering, Vol. 10, No 4,December 2002 .

[4] Gneo, M., Severini, G., Conforto, S., Schmid, M., & D' Alessio, T. "Towards a Brain-Activated and Eye-Controlled Wheelchair" international Journal of Bioelectromagnetism, 44-45. (2011).

[5] Escolano, C., Antelis, J. & Minguez," Human brain-teleoperated robot between remote places", IEEE International conference on robotics ,2009 .

[6] Rabie, S. Refat, Marwa and Rasha ," Basics of Brain Computer Interface", Springer International Publishing Switzerland, (2015) .

[7] Erik Andreas Larsen, Classification of EEG Signals in a Brain- Computer Interface System, June(2011)

[8] MindWave Mobile: User Guide, Brain-Computer Interface (BCI) technologies,(2015).