AI Based Brain controlled Wheel Chair

As a Partial Fulfillment for the award of Degree
Bachelor of Science in Electrical (Computer/Electronics) Engineering

by

Name	Registration Number
Hira Shahid	CIIT/FA18-BCE-024/ISB
Huzaifa Maqsood	CIIT/FA18-BCE-025/ISB
Mehar Dil	CIIT/FA18-BCE-031/ISB

Supervised by

Dr. Omair Inam
(Assistant Professor)
Dr. Mehmood Qureshi
(Assistant Professor)
Department of Electrical and Computer Engineering
CU Islamabad

COMSATS UNIVERSITY ISLAMABAD
JULY 2022

Declaration

We, hereby declare that this project neither as a whole nor as a part there of has been copied out from any source. It is further declared that we have developed this project and the accompanied report entirely on the basis of our personal efforts made under the sincere guidance of our supervisor. No portion of the work presented in this report has been submitted in the support of any other degree or qualification of this or any other University or Institute of learning, if found we shall stand responsible.

Signature:______________
Hira Shahid

Signature:______________
Huzaifa Maqsood

Signature:______________
Mehar Dil

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An Undergraduate Final Year Project Report submitted to the
Department of
ELECTRICAL AND COMPUTER ENGINEERING

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Final Approval

This Project Titled

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has been approved for

COMSATS UNIVERSITY ISLAMABAD

_________________________ _________________________

Supervisor *Co-Supervisor*

Dr. Omair Inam *Dr. Mehmood Qureshi Assistant*

Professor *Assisstant Professor*

_________________________ _________________________

Internal Examiner-1 *Internal Examiner-2*

Dr. Haroon Ahmed *Dr. Omar Ahmad*

Assistant Professor *Assistant Professor*

_________________________ *External Examiner*

Name:

Designation

____

Dedication

We dedicate our thesis with honor to our beloved Parents, family, friends, teachers, and especially to our respected supervisor who immensely supported us through thick and thin .Their support help us to achieve this milestone.

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First of all thanks to Allah Almighty, the most Beneficent, the most gracious who enables us to overcome the difficulties and gave us the ability, power, health and knowledge to complete our thesis.

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Hira Shahid

Huzaifa Maqsood

Mehar Dil

Table of Contents

List of Acronyms

LIS………………………………………………………………....Locked-In Syndrome
ALS……………………………………………………………..Amyotrophic lateral sclerosis
EEG ……………………………………………………………Electroencephalogram
PET ……………………………………………………………Positron Emission Tomography
MRI……………………………………………………………..Magnetic Resonance Imaging
fMRI…………………………………………………………....Functional Magnetic Resonance Imaging
ML………………………………………………………………Machine Learning
AI………………………………………………………………..Artificial Intelligence
AdaGrad…………………………………………………………Adaptive Gradient
RMSprop……………………………………………………...Root Mean Squared Propogation
LR………………………………………………………………Linear Regression
DNN……………………………………………………………Deep Neural Networks
LR………………………………………………………………Logistic Regression
DT………………………………………………………………Decision Trees
LDA…………………………………………………………..Linear Discriminant Analysis
NB………………………………………………………………Naive Bayes
SVM…………………………………………………………..Support Vector Machines
LVQ…………………………………………………………...Learning Vector Quantization
KN………………………………………………………………K-nearest Neighbors
RB………………………………………………………………Random Forest
BCI………………………………………………………………Brain Controlled Interface

List of Figures

List of Tables

Abstract

Around the world, there are almost 6 million population who are born disable or facing disabilities diseases that made them dependent on external help, they always need other's assistance for their mobility. Diseases such as **Strokes** that deactivates the nerves or parts of the body and stroke patients can only move certain parts of their body such as (eyes, tongue and brain). **ALS-** Amyotrophic lateral sclerosis is a progressive nervous system disease that affects nerve cells in the brain and spinal cord, causing loss of muscle control. **Locked-In Syndrome** is a severe neurological disorder characterized by complete paralysis of voluntary muscles, except the control of jaws and eyes. Locked-in syndrome Patients are conscious and can think and reason, but are unable to speak or move. They can only use jaw and eyes movement for communication. They always need external help from other person for their mobility which makes them dependent. They always dependent on nutritional and physical therapies and comfort care to live a healthy life. EEG-based brain computer interfaces have been proposed as a method to facilitate the interaction of disable patients with the external world. In this thesis, we present system of Artificial Intelligence (AI) based brain controlled wheelchair that will be efficient and reliable for Locked-In Syndrome patients to live a healthy and better life. Our designed wheelchair will work on jaw movement that would generate four commands as an output of wheelchair: Forward, Left, Right, Stop. AI based brain controlled wheelchair will include data acquisition using an EEG headset, signal processing, machine learning algorithms and different AI models. The wheelchair is controlled by motor imagery (MI) and jaw clench for its movement.

CHAPTER 1

Introduction:

Electroencephalogram is a way to evaluate the electrical activity of brain. As we understand that neurons communicate, they produce electrical impulses. EEG test basic job is to record the patterns of brain wave. Electrodes which are metal discs usually small and flatter attached to scalp with wires which then evaluate the electrical impulses inside the brain and based on them it sends signals to computer to which it is being connected for recording the results. Generally in the field of medical science there can be certain medical disorders present in human brain can be detected using double EEG headset. It gives one result which can be further evaluated in study to get to know more about certain medical conditions such as epilepsy, head injury, inflammation of brain, stroke, memory problems, dementia, sleep disorder, brain tumor, Locked-In Syndrome [1] and Amyotrophic lateral sclerosis [2] .Thus we can say that majority of the important problems related to health can be detected using headsets and its detection is vital for solving health problems and curing diseases. In EEG headsets, sensors that are used to direct electrical activity are called electrodes.There's another technique that is called MRI (magnetic resonance imaging) which is a blood flow based neuroimaging technique but comparing to EEG , the EEG is non invasive and provides real time information of neuronal activities at the very shortest of time observable to the human. EEG is also pretty low cost in comparison to other devices such as MRI, X rays etc and relatively it is very easy to implement.

Looking through the advancements in the technology and brain controlled devices being implemented, a new invention was made in field of medical for purpose of helping paralyzed patients in their mobility by inventing a mind controlled wheel chair. A mind-controlled wheelchair is a mindmachine interfacing device that uses thought (neural impulses) to command the motorised wheelchair's motion. The first such device to reach production was designed by Diwakar Vaish,[Singhdeo, Saswat] (2016-03-31) [3]. Head of Robotics and Research at A-SET Training & Research Institutes [4][5]. This brain controlled wheel working with an electroencephalogram (EEG) worn on the user's forehead detects neural impulses that reach the scalp allowing the micro-controller on board to detect the user's thought process, interpret it, and control the wheelchair's movement. The wheelchair is of great importance to patients suffering from locked-in syndrome (LIS), in which a patient is aware but cannot move or communicate verbally due to complete paralysis of nearly all voluntary muscles in the body except the jaws and eyes. Such wheelchairs can also be used in case of muscular dystrophy, a disease that weakens the musculoskeletal system and hampers locomotion (walking or moving). Each time advancement in this field helps disable and paralyzed patients to tackle the problem of their dependency for their mobility.

1.1 Problem Statement and Motivation:

There is no cure or proper treatment for Locked-In Syndrome [1], therefore LIS patients always rely on external assistance for their mobility and daily life tasks. LIS Patients are always dependent on support and physical therapies, nutritional support, comfort care and prevention of respiratory complications to live a better and healthy life.

1.2 Objective:

The objective of this thesis is to devise a way for assisting the Locked-In Syndrome Patients in their mobility and removing their external dependency while maintaining the standards of living a healthy and better life. We will design more reliable and efficient Artificial Intelligence (AI) based Brain Controlled Wheelchair that will aid LIS Patients in their mobility and in carrying out daily life tasks more efficiently.

1.3 Thesis Contribution:

The work presented in this thesis will have contributions in the field of medical using advanced technology under Artificial Intelligence (AI) employing simple models that will assist LIS patients in their mobility. The main contributions are listed below:

a. As LIS patients are unable to move around on their own and suffers from whole body paralysis. Thus, they always require external assistance in their movement and to perform daily life tasks As we know their jaw and eyes movement are intact from paralysis and have sensation in some of their body organs so utilizing them we will design a wheelchair which help them in their mobility by moving around without any external assistance.

b. Jaw Movement in LIS patients will be detected using EEG headset which is placed on one's head and used to detect brain's electrical activity. This brain activity is recorded in EEG headset which will further be used for processing and driving a wheelchair.

c. Signals captured from EEG headset will be classified using AI based machine learning techniques. These techniques will classify brain waves in to signals which will act as input for driving wheelchair.

d. EEG Headset integration will be done with Arduino UNO using different signal classifications methods and using different softwares.

1.4 Datasets:

All the machine learning techniques and signals acquired from EEG headset used are tested using following datasets:

a. The offline datasets we used for validation of our signals are acquired from McGill University Faculties of Arts, Science and Engineering, University of Montreal, Canada. 8 Channel NeuroSky Mindwave Brainlink EEG headset as an input is used. Sample Rate = 255Hz. 60 Hidden neurons. 2 Output Neurons.[6]
b. Data sets from github are used, which were collected using thirty five group of people of different ages.[7]

1.5 Thesis Outline:

Futher on the thesis is structured as:

- Chapter 2: Literature Review.
- Chapter 3: Methodology.
- Chapter 4: Results and Conclusions.

CHAPTER 2

Literature Review

2.1 Historical Background:

Looking through the advancements in the technology and brain controlled devices being implemented, a new invention was made in field of medical for purpose of helping paralyzed patients in their mobility by inventing a mind controlled wheel chair. A mind-controlled wheelchair is a mind-machine interfacing device that uses thought (neural impulses) to command the motorised wheelchair's motion. The first such device to reach production was designed by Diwakar Vaish,[Singhdeo, Saswat] (2016-03-31) [3]. Head of Robotics and Research at A-SET Training & Research Institutes [4][6]. This brain controlled wheel working with an electroencephalogram (EEG) worn on the user's forehead detects neural impulses that reach the scalp allowing the micro-controller on board to detect the user's thought process, interpret it, and control the wheelchair's movement. The wheelchair is of great importance to patients suffering from locked-in syndrome (LIS), in which a patient is aware but cannot move or communicate verbally due to complete paralysis of nearly all voluntary muscles in the body except the eyes. Such wheelchairs can also be used in case of muscular dystrophy, a disease that weakens the musculoskeletal system and hampers locomotion (walking or moving).

We learnt how to use machine learning for interfacing brain and Computer and help this advancement of technology in medical field such as brain controlled wheel chair through use of different parts of body has been made. Each time advancement in this field helps disable and paralyzed patients to tackle the problem of their dependency for their mobility. The advanced way of controlling wheel chair through machine learning and non-brain source signals are used, such as eye-blinking, teeth clenching, jaw squeezing, and other movements. Thus, paralyzed patients have been much benefited through this invention. Especially people with ALS and Locked-In syndrome are much more in ease and are feeling independent through this invention for their mobility.

In the paper "T. Carlson, R. Leeb, R. Chavarriaga and J. del R. Mill´an with the Chair in Non–Invasive Brain–Machine Interface "[8] , they have used BCI with proficiency based on imaginations of movements and then recording the electrical activity of brain using EEG from which features are extracted, interpreted and classified using machine learning techniques and actions for moving left or right are being decided and then implemented on brain controlled wheelchair helping the user in their mobility.

Seeing advancement in technology in contrast to medical field, we thought to work on designing a brain controlled wheel chair which will be working on Artificial Intelligence and helping Locked-In Syndrome, ALS and Paralyzed patientis in their mobility.

2.2 Brain Signals:

Brain signals [8] are produced by electrical pulses when large number of neurons communicate with one another. Many nerve cells in our brain produce very small electrical signals that form specific pattern. Our behavior, thoughts and emotions is actually the communication between neurons with our brain. Brain is aware of what is happening inside us to it changes brain signals (see figure 1) accordingly.

,


Figure 1: Brain Signals

Brainwaves speed is measured in Hertz(Hz) and they are divided into bands delineating fast waves, and slow waves.

2.2.1 Neurons:

One of the elementary part of the nervous system is neuron, Neurons are actually nerve cells and are responsible to carry information throughout the body inform of electro-chemical signals. Brain's working totally dependent on functionality and structural properties of interconnected neurons. Communication in human body is also possible through brain signals in brain, as brain is responsible for transferring messages from one neuron to another and further to muscles and different organs of the body.

Types of Neurons:

There are three types of neuron which are inter, sensory and motor neuron. To carry information from sensory receptors to the brain, sensory neurons plays an important role. Motor neurons carry information to the muscles of the body from the brain where inter neuron carry information between neurons of the body.

Figure 2: Nano Scale Neuronal Activity

Neurons are capable to receive and transmit information. To commune, neurons need to transmit information with in the neuron and from one neuron to the next.

During any brain activity, when neurons communicate with each other during communication a minute electric voltage is produced. Brain signals are actually electrical signals with frequencies ranging from 0.5 to 60Hz.

2.3 Types of Brain Waves:

Brain waves [9] of 5 types, each have in between the certain play frequency range which are mentioned below:

Specific frequency each different brain wave has definite effect which is listed below:

Name	Frequency Range	Body Action Association
Alpha Waves	7-13Hz	Calm/Relaxed
Beta Waves	13-39Hz	Consciousness,Inattentive, Active Processing and Cognition
Gamma Waves	>40Hz	Solving Problem, Alert
Theta Waves	4-7Hz	Loss of Body Awareness
Delta Waves	<4Hz	Relaxation

Table 1: Classification of Brain Waves

In normal brain, brain waves lies in between these specified ranges and depending on the state of mind we have the correct strong dominant brainwave.

2.4 Detection of brain waves:

2.4.1 Electroencephalogram (EEG):

Electroencephalogram is a technique to record the brain signals by placing electrodes on the scalp. It can also be used to detect certain diseases including drowsiness, epilepsy, brain tumours locked in syndrome, strokes etc.German physiatrist hansberger (1873-1941) recorded the human first time in 1924. Berger [9] invented electroencephalogram (giving the device its name), an invention described as one of the most remarkable,momentous and surprising revolution in the history of clinical neurology,

A normal routine EEG recording can be recorded in 20 to 30 minutes by placing electrodes on the scalp [3][10] . The main aim is to observe the different brain spells to distinguish epileptic seizures from other types of spells such as migraine, sub-cortical movement syndromes and disorders. EEG can also help to see the brain electrical activity of the patients who are facing different disorders such as strokesand facilitate and understanding the illness and helps in treatment.

The brains electrical activity is maintained by billions of neurons. As neurons are electrically charged by membrane transport proteins that'll pump ions across their membranes. As similar charges repel each other so ions of the familiar charge repel each other at the same time and when many ions are pushed out of many neurons they can push their neighboring, who push their neighbouring neurons and so on, in awave. This processes called volume conduction.

As the wave of ions reaches the electrodes that we have placed on the scalp they can push or pull electrons on the metal in the electrodes. Since metal conducts push and pull of electrons the difference in pull or push voltages between any two electrodes can be measured by a voltmeter. Recording of this voltages over the time will give as the EEG.

Areas of cortex for requiring EEG data:

As EEG data is required from brain electrical impulses that it is important to electrodes required data can be placed at best possible position to get a stronger brain signals [11].

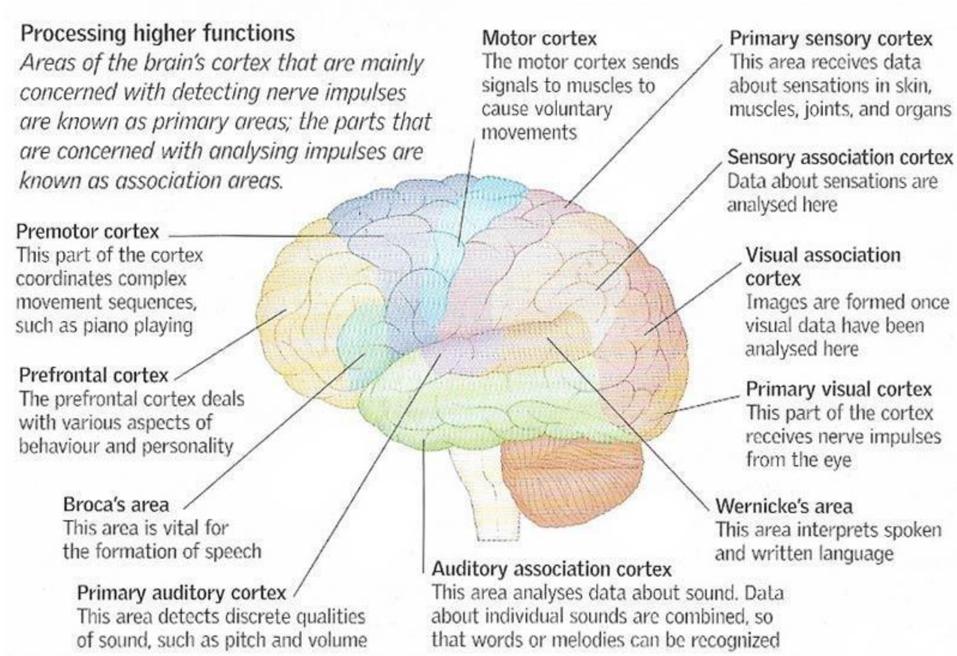


Figure 3: Brain regions detecting electrical activity inside it [11]

a. Occipital Cortex:

This part of brain is responsible for measuring visual data and its processing. Impulse is regarding to the visual function such as videos or pictures blinking focuses on this region of brain. **b. Parietal Cortex:**

Parietal cortex play is responsible for motor function task and it gets activated due to motor imagery and impulses occur in brain when we we are encountering objects.

c. Temporal Cortex:

It is related to language processing and speech generation and it is important part of brain in EEG.

d. Frontal Cortex:

Frontal cortex is responsible for all executive functions, it is like real processor of brain and a very important organ for intellect. Planning, organizing and control functions all are handled by this region of brain.

Characteristically we can know from the brain electrical activity original and can analyse which frequency is driving the current activity.

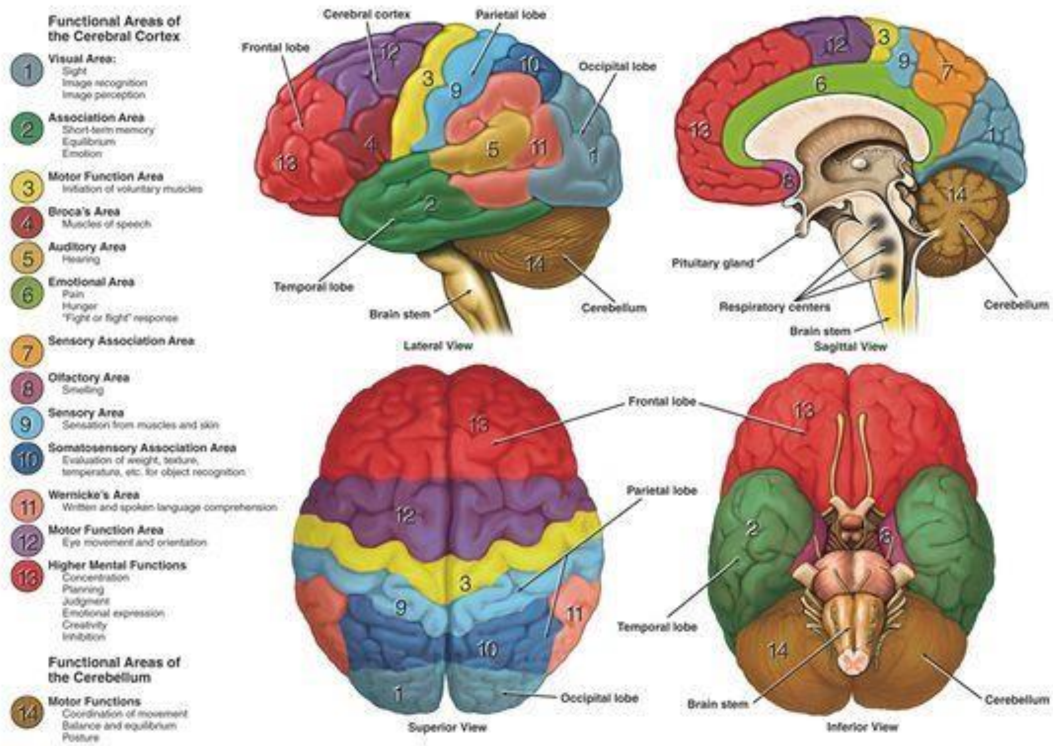


Figure 4: Visual Representions of Brain Regions Detecting Signals Based On Emotions[12]

2.4.2 Methods for recording brain waves:

We can use many methods to record brain signals encephalogram (EEG), magnetic resonance imaging (MRI), functional magnetic resonance imaging (fMRI) and positron emission tomography (PET). We are prefferably using EEG [2][12] methodology in which we can directly conduct electrical activity of brain or use head sets. As in conventional scalp EEG if we use electrodes with a conductive gel or paste and place them directly on brain using get we can conduct brain electrical activity. It is done by placing electrodes on scalp by applying conductive gel or paste which reduces the skin impedance is due to dead skin cells.

Many systems typically use electrodes each of which is attached to individual wires and stemp systems uses caps or nets into which electrodes are embedded, that is particularly common strings of electrodes or high density arrays of electrodes are needed.

2.5 Electroencephalogram (EEG):

Electroencephalogram is a way to evaluate the electrical activity of brain. As we understand that neurons when communicate produce electrical impulses. EEG test basic job is to record the patterns of brain wave. Electrodes actually that are metal discs usually small and flatter attached to scalp with wires which then evaluate the electrical impulses inside the brain and based on them it sends signals to computer to which it is being connected for recording the results. Generally in the field of medical science there can be certain medical disorders present in human brain that can be detected using double EEG headset. It gives one result which can be further evaluated in study to get to know more about certain medical conditions such as epilepsy, head injury, inflammation of brain, stroke, memory problems, dementia, sleep disorder, brain tumor, Locked-In Syndrome [1] and Amyotrophic lateral sclerosis.

Thus we can say that majority of the important problems related to health can be detected using headsets and its detection is vital for solving health problems and curing diseases. In EEG headsets, sensors that are used to direct electrical activity are called electrodes.

There's another technique that is called MRI (magnetic resonance imaging) which is a blood flow based neuroimaging technique but comparing to EEG , we know the EEG is non invasive and provides real time information of neuronal activities at the very shortest of time observable to the human. EEG is also pretty low cost in comparison to other devices such as MRI, X rays etc and relatively it is very easy to implement.

We know , in human brain cognitive task produce a very specific pattern and due too rapidly changing pattern of human brains for a fact we can understand whether one is cognitively right or is there any presence of cognitive dysfunction. Due to the real cognitively time behaviour of EEG and its ability to give results right along, there is a lot of working going on EEG and many new application based on EEG are emerging with time and most of them are already been built.

A few decades ago, EEG recordings were only restricted to clinical setup and neuro scientific researchers under strict laboratory conditions. There used to be at least 64 or more electrodes that worked at different places of human brain but nowadays it has become quite smart and modern as new devices are invented which are portable, efficient and low cost and have less number of electrodes in them where we can easily do our tasks using minimum labour by sitting at any place we want to work.

It is evident as knowledge is expanding and advancement are made in processors and computer technology it is allowing us to research all over the globe to gain better inside about the brain of human being and its electrical structure.

Apart from the detecting problems in the electrical activity from the brain there is also a lot of work nowadays going on in EEG in order to make real world applications with the help of brain signals like controlling vehicles, video games, moving hands etc . All these kind of applications fall in the category of brain computer interfaces which is discussed below:

Below are some few fields which have been emerged in EEG:

2.5.1 EEG headset:

As there is much development in the technology in recent few years so as in electroencephalogram technology. It has been upgraded to a level where new devices has been introduced in this field. These devices helps to conduct the brain activity in form of brain signals and has made life more easier. These electroencephalogram devices had made revolutionary changes in the field of engineering technology and medicine.

Recently many cases of lock in syndrome, amyotrophic lateral sclerosis and strokes have been reported and becoming common due to genetic issues, bad diet, stress, anxiety and many more reasons. Thus to deal with them many methods and ideas had been introduced in the field of biology with the help of technology and the most common solution to amyotrophic lateral sclerosis and lock in syndrome patients play as using technique of electroencephalograph method acquiring devices. Hence one of the most known device is among EEG Headset is Neurosky Mindwave EEG headset is very famous due to its advanced features and revolutionary technique but on the other side it is very expensive hence other low cost EEG headset devices are also recently inyroduced in the market i.e. Brainlink Mindwave headset which is another EEG headset and very low cost device in this technology and seeking attention from many people in the field of technology as well as playing its part like other costly headsets.

Figure 5: How to wear EEG Headset

2.5.2 Neuromarketing:

Economist take help from EEG research to identify the consumer mindset of taking decisions during shopping or purchasing some product, this field is actually called neuromarketing[13]. This is actually done by determining the areas which are active during the time of taking decisions when we are purchasing some products or services or we can also explored the mindset through EEG. Currently researchers are interested in exploring the decision making of the customer in real time in the field of shopping.

2.5.3 Human Factors:

Human factors [14] is the field in which through EEG research we are now capable to specify the personality traits and identify whether the person has social anxiety or not whether the person is expressive or not. Nowadays human machines interplay the most favorite study among youngsters and activists. This field is mainly focuses on how to optimise interfaces and social interfacea as a human who are actually social agents

2.5.4 Social Interaction:

Humans are known as social agents, so with respect to this there are many applications that has been done in the field of social interaction. Through brain processes we are capable to explore self analysis ability to see or hear socially. So we can say that communication and social inter linkage are not the yielding types of processing incoming boosts. We have to follow some rules or we have to synchronise with the partners whom which are working. A method it offered that is used by EEG researchers to understand and observe whether the actions and conversational synchronization exists. In the method of hyper-scanning data is gathered or recorded from different people at a time by permitting them to make the in-depth view of their qualities and social interactions.

2.5.5 Physchology and Neuroscience:

EEG also plays a vital role in the field of psychological studies. In this field through EEG, we are capable to see the processes of the brain that take the details related to the consciousness, recollection and learning.

Through the delivery of continuous monitoring, the brain data we extricate the event related potential as they are repetitive , event related potential pointed out the event with higher details in the time scale.

Amplitude is the property, with the help of which we can identify event related potentials time and voltages can also be used for the identification of event related potentials.

2.5.6 Clinical and Physchiatric Studies:

EEG also plays a vital role in analysing the different state of the patients including thinking play state, scrap site, and also helps in the classification of sysmptoms when the processes of the brain impede we can easily say that there is abnormality somewhere in the brain.

It also plays very important role in determining or evaluating the result of psychological and medical treatment. Through continuously monitoring the brain data and with the help of improved virtual technology in form of artificial intelligence [22] we are able to predict how much time brain will it takes to improve. That's due to EEG headset we were able to diagnose Locked-In Syndrome and Amyotrophic Lateral Sclerosis Syndrome in the patients which later on reveal the truth that these syndromes can not be treated and these patient can only survive on external help which is also provided by using electroencephalography technology in form of EEG headset controlled wheelchair to provide assistance to them.

2.5.7 Brain Computer Interfaces (BCI):

When we can use the brain signals to control the devices or machines or other things this is actually brain computer interface. Which is new but an originating field in EEG through this we are able to do the detailed analysis of the active regions of the brain.

Brain computer interface play the powerful role in providing feasibility to the people who are paralysed example through BCI [15] brain signals can be used to operate the wheelchair of the paralysed person that if a person wants to move forward left right or backward when he thinks about moving forward a specific brain signal will be produced which give command to wheelchair in order to move forward or in any direction needed by the patient.

2.6 Brainlink Mindwave EEG headset:

Figure 6: Brainlink Mindwave EEG Headset

2.6.1 Applications of Brainlink Mindwave EEG headset:

Locked-In Syndrome Patients Aid:

As a patients of locked in syndrome and amyotrophic lateral sclerosis has totally dependent on external assistance and always need a person to move them from one place to another. To solve the problem first electronic wheelchairs have been invented but since to move more freely and independently they need another technology added to electronic wheelchairs so that they can move easily around. For such purposes wheelchairs with the help of EEG technology and Machine Learning have been invented to help them in mobility and provide them freedom to move around. For EEG with Jaw Clenches have to use EEG headset to detect the brain activity play using jaw movement in the form of blinking. Through this technology we are capable of recording the brain data in the real world environment otherwise without EEG headset we have to many numbers of electrodes but in

EEG headset electrodes are already built which makes the process of detecting brain signals more easier . The EEG technology allows us to record the brain signals but limitations are there since we have less number of electrodes so signals to noise ratio will also be less and sometimes detection of signals might also be hindered due to error chances increases. We can use the modulation of alpha waves nothing this way you got to know that if we correctly recorded the brain electricial signals in form of data acquiring from jaw movement. We can also produce some result but obviously seeing in the reality signal strength will be reduced in terms of signal to noise ratio.

Playing Games:

Brainlink mind wave EEG headset have an application for smartphones, Iphones or andriods named as Brain Link through which headset is directly connected to phones and different games can be played using EEG headset detecting brain capabililty. For eample: when we are playing race games and our headset is connected withour PC so we play game by simplying thinkng pf moving foward and our player in game will keep moving forward.

Meditation/Relaxation:

Our headset can be connected to many applications which provide meditation effect to brain thus relax as aresult which is best for pregnant ladies and stree taking persons.

2.6.2 Brainlink headset use:

It is a EEG device that will be used to record brain waves and using different movements of different body parts specified according to the user which could be jaw clenching, eye blinking, and etc. For instance, a language or hand disabled person wearing such a device could show his or her emotions to service robot if the device detects that he or she is in certain kind of emotional state. As we all know, an motion recognition EEG device with easy installation is popular in todays world. In order to realize this idea, in our paper, we used relatively lower number of electrodes for EEG signals collection, the EEG collection device is called Brainlink mindwave EEG headset [16], which has two non-invasive dry electrodes in the forehead position. When the user is in a different state (focused or relaxed), the Brainlink will display different colors of brain waves . And then perform emotion recognition on the collected EEG data through the system.

This EEG headset has application named brainlink for androids, IOS, Windows, and MAC IOS. Thus we uses that app for visualising signals on phone and PCs as well.

Figure 7 : Brainlink Mindwave Headset

2.6.2.1 Advantages of EEG headset:

- It is a powerful tool for tracking play brain changes during different phases of life such as sleep analysis can indicate significant aspects of the timing of brain development, including evaluating, illusion, brain maturation play.
- EEG headset is easily placed on forehead with less number of electrodes and can detect brains electrical activity.
- It allows easy human brain computer interface..
- It is tolerant of participant movement.
- It is combined with other brain imaging techniques.
- It doesn’t aggravate claustrophobia.
- It is non-invasive technology and cheaper than Positron Emission Tomography (PET) and functional magnetic resonance imaging (fMRT).
- EEG has very high temporal resolution on the order of milliseconds rather than seconds.
- It doesn't involve exposure to high intencity magnetic fields.
- Its hardware cost is significantly lower than the other techniques.
- It is silent which allows for better study of the response to auditory stimuli.
- It is low morbidity and readily repeatable.
- It is Portable and ambulatory.

2.6.2.2 Limitations of EEG headset:

- It loss partial resolution on the scalp.
- It determines neural activity that occurs below the upper layers of the brain poorly.
- It takes a long time to connect a subject to EEG.

- Its signal to noise ratio is poor.
- It may falsely localise epileptogenic zone.
- It has relatively low sensitivity and specificity.
- Sometimes its artifacts subject to both electrical and physiologic.
- It has limited time sampling for routine EEG and spatial sampling.
- Sometimes it is difficult to interpret the results and for that we have to be well trained and skilled.
- It doesn't specify where in the brain activity is coming from so for that we have to be well acknowledged.

2.6.2.3 Features of EEG Brainlink mindwave Head set:

- Brain link headset is easy to wear.
- It helps in human computer interface.
- It is compatible for iOS, Android and windows, It has easy to wear design and comfortable to use.
- It supports 15 plus apps an update constantly.
- It is an open source application.
- It has baud rate of 57600.
- It has three dry electrodes where two electrodes are on forehead and one electrode is on ear clip.
- It can detect electrical and raw brain data.
- It has Bluetooth compatibility within the range of 10M.
- It is compatible for iOS, Android, windows and Mac OS.
- It takes input of 5 VDC/500m-1000mADC.

2.6.3 Detection of Alpha waves in real time:

Alpha waves are one of the type of electrical brain waves that allow our brain to function. alpha waves are normally in between the range of 7 to 12 Hertz. When we are in relaxed state close your eyes or quietly ,resting, alpha waves naturally produced alpha waves arre also called berger’s wave after the founding father of EEG.

Detection of alpha waves in real time using brain link mindwave headset:

We detected Alpha waves by placing brainlink EEG headset on forhead where its electrodes are on forhead and when we move our jaw brain produces some electrical acticity inside it which is detected by headset abd then visualising signals on macrotellect software to see frequency range of wave we acquired from brain's electrical activity. We applied filters of zero phase band pass and notch filter to remove noise if any in signals and get the signals in normalized form where true frequency could be defined and we get the range of signals and then we defined it classifucation whether its aplha wave or not. We apply filters on other signals to get the range of the wave we needed as an aplha waves.

2.7 Related Softwares:

2.7.1 Open BCI:

It is a software which is used to record stream and visualize brain data. It also helps to observe that how brain signals behaves in frequency domain and draw conclusions based on it.

2.7.2 Open BCI Python And Jupyter:

We used open BCI Python to record our brain signals through brain link mindwave headset and observe them on the open BCI GUI. We modify the open BCI Python file user.py and make our own plugin name for real CSV to collect and integrate the Python terminal work to power charm with IDE of Python . We shifted from Python terminal window PyCharm because in terminal window each time we have to enter plugins and Mac address of the device through which we want to connect, but in PyCharm we have all plugins we simply type the plug in and operate the headset. It was very hard to shift from Python to pycharm we have to make changes in code which was in form of user.py and reproduce CSV file collect open BCI files. Normally, in CSV we collect the data is stored in CSV file but we save the data in the list and plot the data in real time.

Plotting the brain data in real time on PyCharm was not an easy task. In user.py when code runs each time we have to enter the Mac address of the device through which we want to connect for this reason we modified the file and code so that by default it'll build connections with our device and instead of asking for Mac addresses of the device each time.

2.7.3 Macrotellect BrainLink Lite Software:

This software is specifically used for brainlink mindwave EEG headset for acquiring signals as an input data and then show its visual representation beside Open BCI software. This software helped us to classify and identify waves in form of signals which we need as an input for our project.

2.8 Alpha waves Classifications:

After successful interfacing device with Python the main aim is the classification of alpha waves in real time. When capturing recording the brain data, the signal also contains the artifacts these artifacts may be arrived from the movement of subject technical issues or due to noisy environment. These unwanted signals remove through the notch filter. As in frequency domain the range of alpha waves are in between 7 to 12 Hz [17] by applying band pass filter who captured the window of 7 to 12 Hz and extract the information of alpha waves which is the foundation of our project basis on the jaw clench.

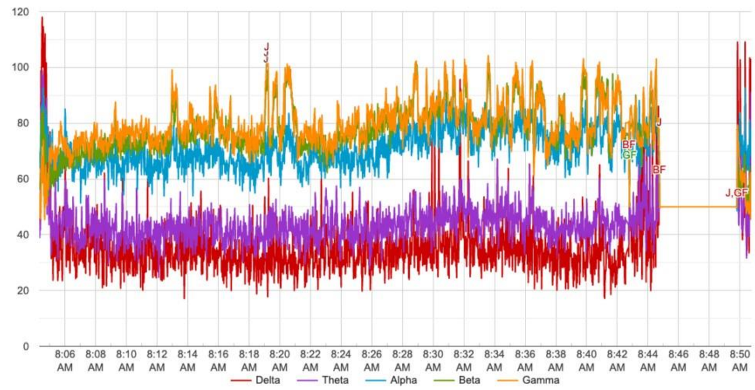


Figure 8: Mind Monitoring for absolute Brain Waves

2.9 Applications on Alpha Waves:

After the classification and identification of alpha waves we transmit the detected alpha signal by applying artificial intelligence and deep learning using maching learning techniques to through the Arduino using HC-06 module which further controls one of the functions of the wheelchair module.

- Through focused jaw movement artifact wheelchair module start to move forward.
- Through specifying the frequencies for the jaw movement, our wheelchair module was able to move right or left.
- When our patient’s jaws are relaxed, a wheelchair module goes to rest mode.

2.10 Conclusion:

The purpose of this project is to establish an automatic wheelchair which are used by the disabled brain. Learning data is done by averaging the imagery of movements with the given cases. The EEG signal data we analyze is the from jaw clench of a person also we analyzed the concentration and meditation data. From the data collecting, acquisition and processing that we did for continuously acquisation of data using EEG headset to gain the optimal results. The optimum results obtained from the data and its range of values could be used for a model of a wheelchair prototype in form of the walking left and right with left and right jaw clench movements and walking forward with both jaw clench, walking backward by little relaxation in both jaw clench together, relaxing jaw movement for stop. Thus in such way jaw movement can be used for stop,forward, backward, turn left, and turn right movements of our AI based brain controlled wheelchair prototype.

CHAPTER 3

METHODOLOGY

3.1 Methodology:

Our project is divided in four main modules and then implemented it one by one. Those four modules are shown below in block diagram of project:

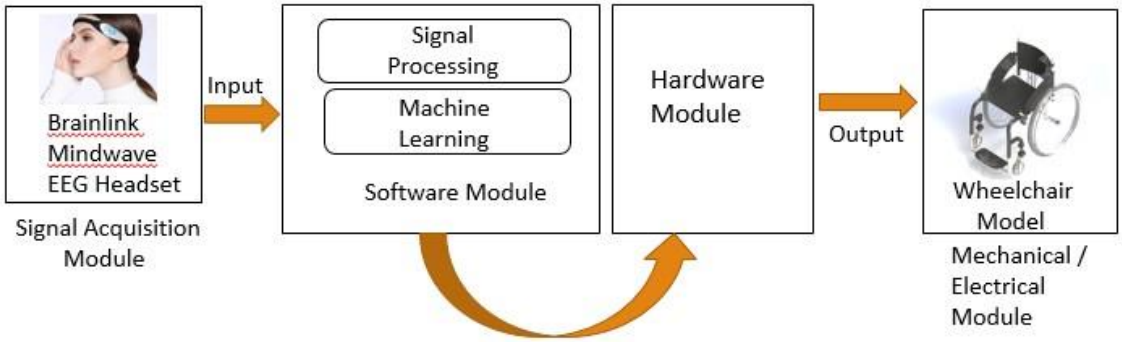


Figure 9: Block Diagram Of Brain Controlled Wheelchair

Above shown modules are implemented one by one in a sequence. Firstly, signal acquisition module is implemented using Brainlink mindwave EEG headset. Brainlink Mindwave EEG headset is used to detect and record brain waves caused by jaw movement of a person. For software module, in first part signal processing is performed on brain waves obtained from EEG headset using different filters to acquire Alpha waves. Alpha waves (8-13Hz) are the core component of our project. For machine learning part, different offline raw datasets are used for training a model and checking validity of the data acquired from brain waves in form of Alpha waves. Different Artificial Intelligence based Models are used to train model in Jupyter. In jupyter, MacroML library performed the main part of converting trained model on Python script in to C code which was further combined with c-code on Arduino IDE according to requirement of running wheelchair in four output movement : left, right, forward and rest. This code is then burnt on Arduino Uno to run designed wheelchair in Hardware Module. For Hardware Module, Arduino Uno, l298n motor driver, battery, servo motor, and Bluetooth HC-06 module are combined together on a chases according to the requirements of working wheelchair. Thus, following the above described procedure, we were able to design a AI based brain controlled wheelchair prototype model.

3.2 Signal Acquisition Module:

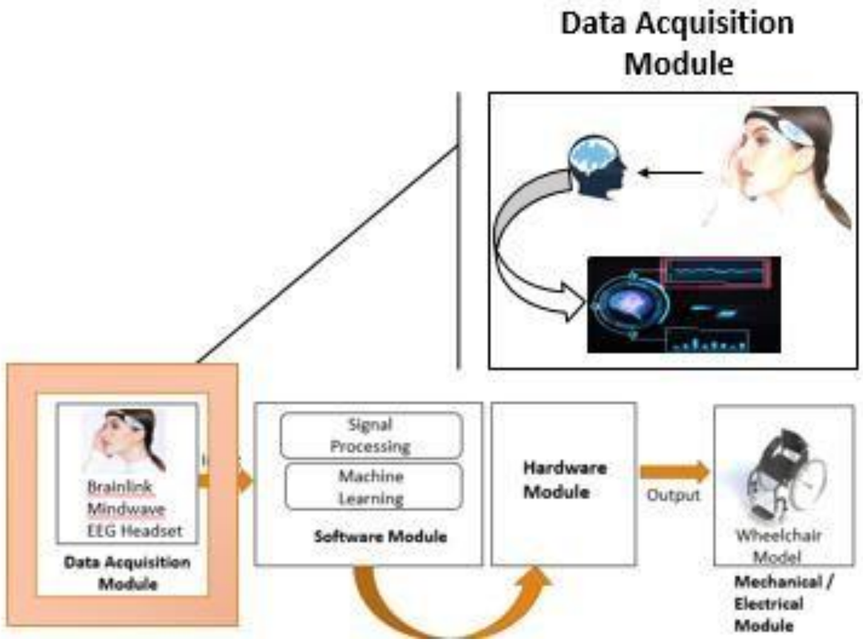


Figure 10: Block Diagram of Signal Acquisition from Brainlink EEG Headset

Brain signals that exist due to electrical activity of neuron can be acquired in the term of voltages, amplitudes or frequencies. The signal acquisition device used in project is open BCI brain link mindwave EEG headset that requires to detect signal through electrodes built-in and placing headset on forehead we can detect brain electrical activity where as in EEG where we have to place electrodes on scalp connected to wires using conductive paste or gel which may result in loss of important data if connections are loose and the require large number of electrodes.

In this case we have placed a headset on brain and electrode are placed in a way that they are on forehead from where they detect the brain electrical activity which are produced due to the jaws movement in form of clenching.

Data acquired from the Brainlink Mindwave EEG headset can be seen on Macrotelllect software which is specifically designed for Brainlink EEG headset.

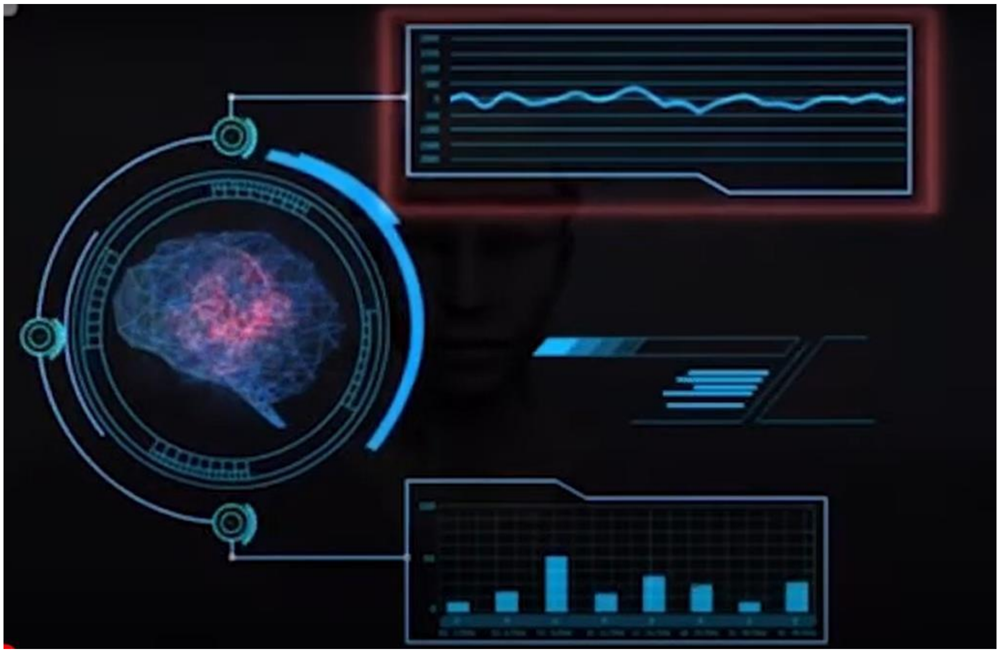


Figure 11: Signal Acquisition On Macrotellect

3.2.1 Brainlink Mindwave Headset Bluetooth Interface with HC-06 Bluetooth Module:

Direct interfacing of Brainlink mindwave headset with PC was not possible so we established the serial communication between headset and PC using an external blutooth module i.e. HC-06. We made master and slave Bluetooth module in a connection. As master was Brainlink mindwave EEG headset builin Bluetooth and External HC-06 bluetooth module was slave and then serial communication was established between PC and headset for data acquisition and data processing.

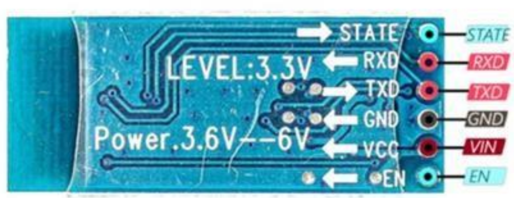


Figure : Bluetooth HC-06 Pins configuration

3.2.2 Establishing Connection with HC-06:

Bluetooth is a wireless connection for sharing of data between two devices. In our case brain link mindwave headset is communicating with the computer as it is recording the brain signals in real time in transmitting it to the computer through Bluetooth low energy and we are also using the brain link app in our phone and in our computer for signals visualization.

After classification and identification of the brain signals on computer by using the app and the Bluetooth module HC-06 with the help of machine learning we will able to establish a connection. We have to use a Bluetooth module that has to provide signals to Arduino to drive functions in a wheelchair which will be able to perform specific actions. To connect our brain link mindwave headset to the computer we have to use the Bluetooth module as it do not connect directly because our headset seem to be connect to the Apple Mac book only which wasn't available to us at the time of working so we use the method of master and slave Bluetooth by using serial communication and did signal acquisition and analyzing through this method for acquiring signal.

We use Bluetooth module to connect with our hardware too that's is the wheelchair prototype model.

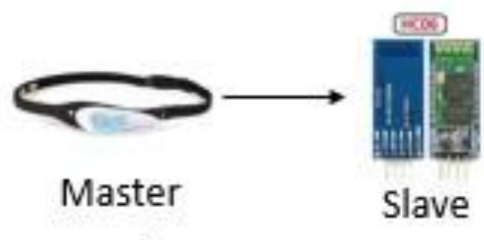


Figure : Bluetooth Serial Communication

3.2.3 HC-06 Functionality:

The Bluetooth module is called as a slave Bluetooth module which is designed for wireless serial communication. It is a slave module which means it can receive serial data one serial data is sent out from a master Bluetooth device (it will be able to send serial data through the air that would be smart phones, PC). When the module receives wireless data, it is sent out through the serial interface exactly as it is received.

As we just tried to code an Arduino in order to perform certain functionality but in HC-06 module, no source code is needed because it is a chip which has a built in code and it just connects with external devices serially with arduino. After connection of Arduino to the HC-06 module, command is sent to the Arduino which usually comes from the external device to HC-06 and external device can be any device depending upon the work we want to perform. In our case when we are moving wheelchair based on brain signals so we connect Python with HC-06 add the library used in Python is Pi Blues which connects Python with HC-06[18].

Now after sending commands from Python to HC-06 , then HC-06 sends that command to Arduino and after that Arduino and actuators in return response accordingly as specified in the source code. When the module is not in a paired state the LED on the module blinks rapidly whereas when paired with external device LED on the module is a steady red.

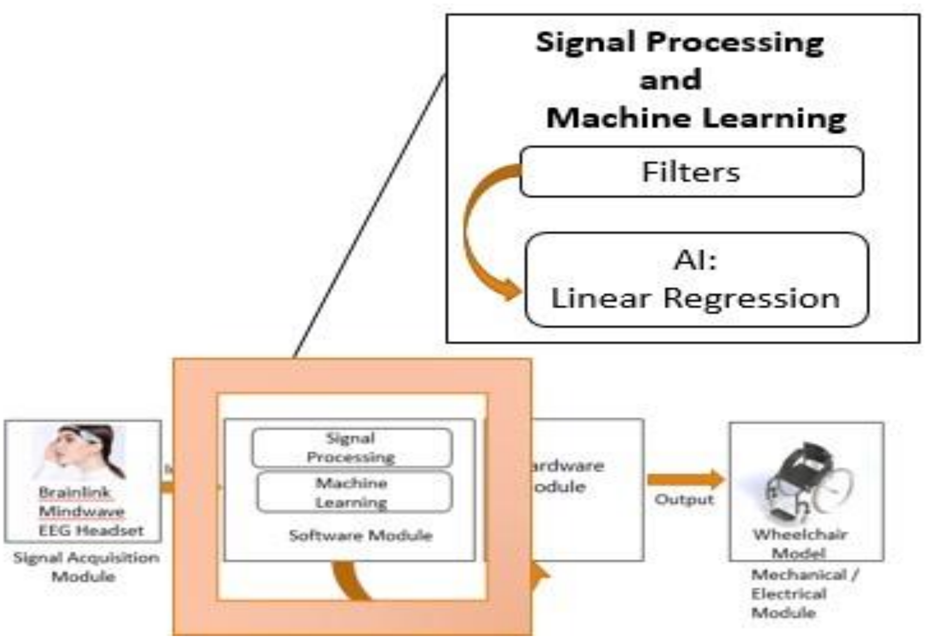
3.2.4 HC-06 Module Pins:

The module generally has 4 pins known as VCC, GND, TX and RX future required in order to make a connection with Arduino Uno.

- The VCC pin receives its input voltage and is connected to the 5V pin on the Arduino
- The GND pin is connected to GND pin of Arduino so it is a reference point.
- The TXT and RXD are the transmit and receive pins of the HC-06.

HC-06 receive the data from the master external device through RXD and then it transfer the data or command to the Arduino through TXT pin. The GND on the module is the ground pin which connects to the ground pin on the Arduino. The Tx pin of HC-06 is connected directly to the Rx pin of Arduino and RXD pin is directly connected to the Tx pin of the Arduino using a voltage divider circuit as the RXD on HC-06 can support voltage up to 3.3 volts.

3.3 Signal Processing Module:



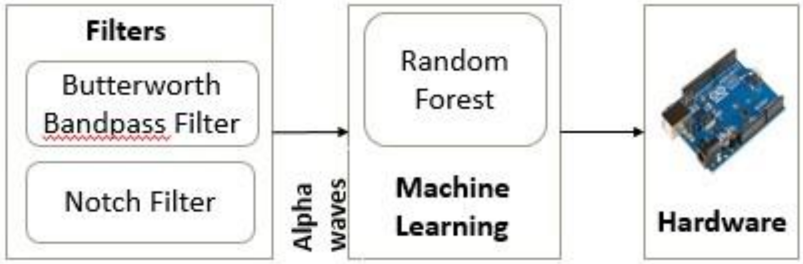


Figure 12 : Signal Processing Module

Our designated frequency range is the alpha waves (7-13 Hz) [17]when the subjects moves their jaw . To handle real-time data, we tested at 60 Hz with a frequency of two seconds. The signal was first notched-filtered at 30 Hz and 13 Hz to eliminate power-line commotion utilizing a Butterworth channel. After information pre-handling, we utilized Power Spectral Density (PSD) to remove the some extra power of the band.

3.3.1 Signals in Open BCI:

For visualization purpose of signals, signals are first visualized in Open BCI software. It is a software used to see what types of signals are present in our data. We also get information about the frequencies and amplitudes of signals.

Figure 15 : Visual Signal Representation of Jaw Clench Signals in Open BCI

3.3.2 Butterworth Filter:

A Butterworth filter is a type of signal processing filter designed to have a frequency response as flat as possible in the passband. Hence the Butterworth filter is also known as "maximally flat magnitude filter".

Butterworth band pass filter [19] is used for filter out Alpha waves where Bandpass filter the signal between 1 and 20 Hz as Alpha waves lies in range of 7-13 Hz frequency.

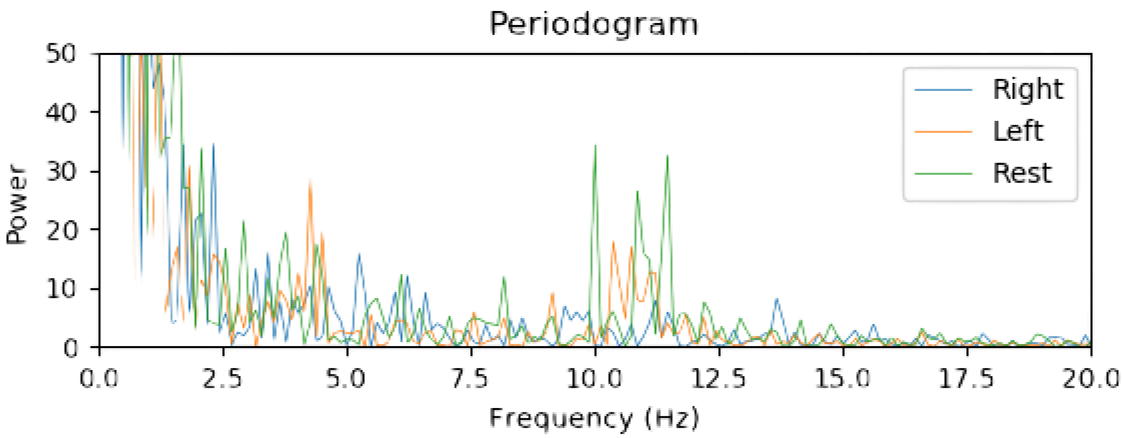
3.3.3 Notch Filter:

A notch filter [20] is a type of band-stop filter, which is a filter that attenuates frequencies within a specific range while passing all other frequencies unaltered. For a notch filter, this range of frequencies is very narrow. The range of frequencies that a band-stop filter attenuates is called the stopband. It passes all frequencies except those that fall within a relatively narrow range. Sometimes Notch filter is also called as Band-Stop Filter. Notch filter filtered the Alpha waves at 13Hz.

3.3.4 Power Spectral Density:

Spatial features consisted of isolating channels of interest. In our case, imagined right/left jaw movements are isolated at electrodes localized over the motor cortex areas of the brain. To obtain spectral features, as demonstrated in /real-time/RT.py, we computed the signal power through the power spectral density (PSD).

The spectral features therefore consisted of obtaining mean PSD values at frequencies of interests.



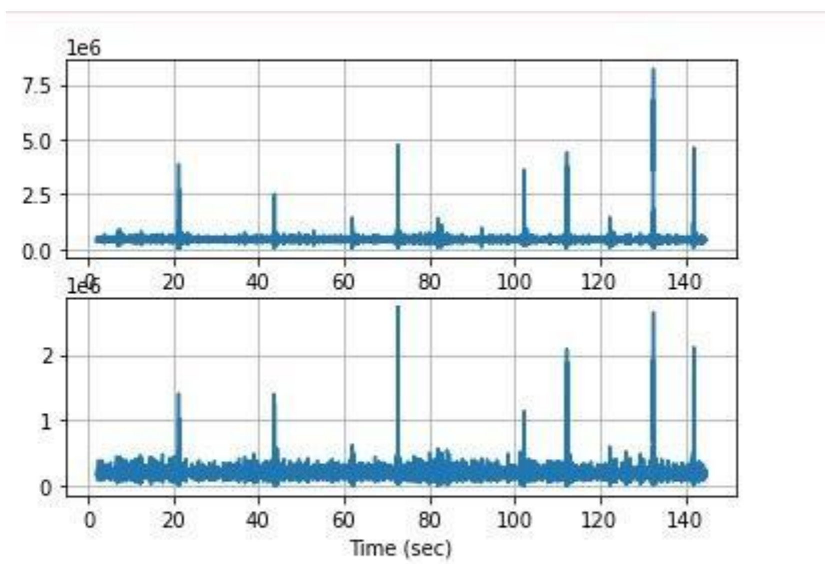


Figure 13 : Before Filters applied on Brain waves

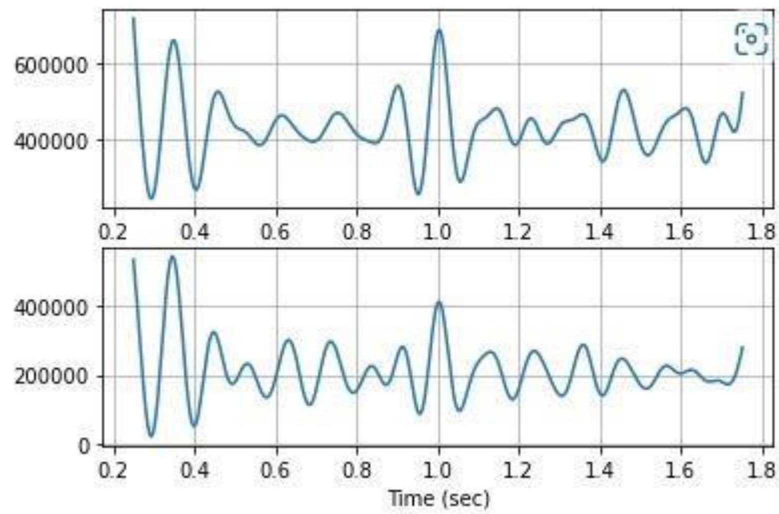


Figure 14: After Filteration on Brain Waves

```
import matplotlib.pyplot as plt
import matplotlib.mlab as mlab

from scipy.signal import butter, lfilter, iirfilter, welch


from scipy.fftpack import fft

import numpy.fft as fft1

def initial_preprocessing(raw_eeg_data,bp_lowcut =1, bp_highcut =70, bp_order=2,
                          notch_freq_Hz  = [60.0, 120.0], notch_order =2):
       """
       Filters the data by applying
       - A zero-phase Butterworth bandpass was applied from 1 – 70 Hz.
       """

       nyq = 0.5 * 250 #Nyquist frequency
       low = bp_lowcut / nyq
       high = bp_highcut / nyq

       #Bandpass filter
       b_bandpass, a_bandpass = butter(bp_order, [low, high], btype='band')
       bp_filtered_eeg_data = np.apply_along_axis(lambda l: lfilter(b_bandpass, a_bandpass ,l),
                                                   0,raw_eeg_data)
       notch_filtered_eeg_data = bp_filtered_eeg_data
       low1  = notch_freq_Hz[0]
       high1 = notch_freq_Hz[1]
       low1  = low1/nyq
       high1 = high1/nyq
       b_notch, a_notch = iirfilter(2, [low1, high1], btype='bandstop')
       notch_filtered_eeg_data = np.apply_along_axis(lambda l: lfilter(b_notch, a_notch ,l),
                                                      0,bp_filtered_eeg_data)
```

Figure 16: Butterworth and Notch Filters on Acquired Signal in Jupyter

3.4 Machine Learning Implementation in Software Module:

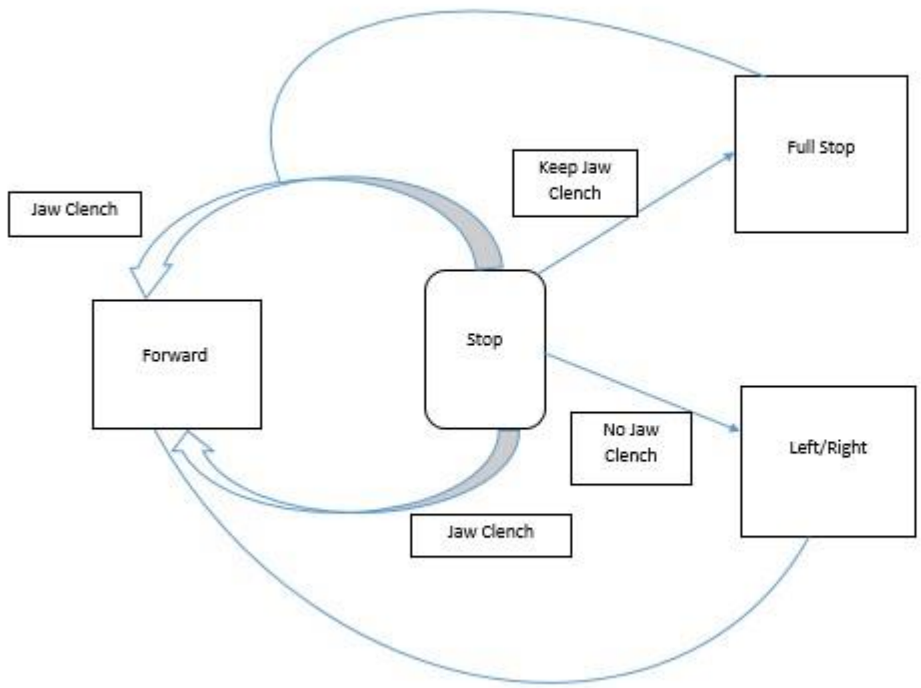


Figure 17: Block Diagram Defining Jaw Clench Signals for Wheelchair Movement

This paradigm is used to move, turn, and stop the wheelchair comprises of shifting back and forth between three states: Rest, Stop, Left and Right. Motor imagery characterization happens, which yields either a full stop, or an order to turn the wheelchair in the fitting course. To change starting with one state then onto the next, ancient rarities, for example, jaw-clenches, are utilized. A supported antique sign will order the wheelchair to move to the following state. A linear regression is utilized to classify the motor imagery state of the user in real-time. The feature utilized in the regression is the typical mu band power, given as the normal of the frequencies of interest forever focuses. The linear regression then, at that point, gives a motor imaginary state for each given time point. The course with the most event inside a 3 second time-window is an official choice result and is taken care of to the wheelchair.

In the event that no motor imaginary signals are identified and jaw-clenching is not maintained and jaw is relaxed, the wheelchair will go into a stop. Supporting these antiques again will carry the wheelchair to push ahead in the forward again.

```
    print_results(clf, X_test, y_test)

def get_nn_model():
    model = Sequential()
    model.add(Dense(60, input_dim=window_len, kernel_initializer='normal', activation='relu'))
    model.add(Dense(30, kernel_initializer='normal', activation='relu'))
    model.add(Dense(30, kernel_initializer='normal', activation='relu'))
    model.add(Dense(10, kernel_initializer='normal', activation='relu'))
    model.add(Dense(1, kernel_initializer='normal', activation='sigmoid'))

    model.compile(loss='binary_crossentropy', optimizer='adam', metrics=['accuracy'])
    return model

def run_nn(X_train, X_test, y_train, y_test):
    print("================================================================================")
    print("Running Neural Network classifier...")
    estimator = KerasClassifier(build_fn=get_nn_model, epochs=10, batch_size=32, verbose=0)
    estimator.fit(X_train, y_train)
    print_results(estimator, X_test, y_test)

def print_results(clf, X_test, y_test):
    y_pred = clf.predict(X_test)
    print('Accuracy: {:.4f}'.format(accuracy_score(y_test, y_pred)))
    print('\nConfusion Matrix')
    print(confusion_matrix(y_test, y_pred))
    print('\nClassification Report')
    print(classification_report(y_test, y_pred))
```

Figure 18: Training a model

```
def run_random_forest(X_train, X_test, y_train, y_test):
    print("================================================================================")
    print("Running RandomForest classifier...")
    clf = RandomForestClassifier()
    clf.fit(X_train, y_train)
    print_results(clf, X_test, y_test)

def get_nn_model():
    model = Sequential()
    model.add(Dense(60, input_dim=window_len, kernel_initializer='normal', activation='relu'))
    model.add(Dense(30, kernel_initializer='normal', activation='relu'))
    model.add(Dense(30, kernel_initializer='normal', activation='relu'))
    model.add(Dense(10, kernel_initializer='normal', activation='relu'))
    model.add(Dense(1, kernel_initializer='normal', activation='sigmoid'))

    model.compile(loss='binary_crossentropy', optimizer='adam', metrics=['accuracy'])
    return model

def run_nn(X_train, X_test, y_train, y_test):
    print("================================================================================")
    print("Running Neural Network classifier...")
    estimator = KerasClassifier(build_fn=get_nn_model, epochs=10, batch_size=32, verbose=0)
    estimator.fit(X_train, y_train)
    print_results(estimator, X_test, y_test)
```

Figure 19 : Random Forest Classificatier Algorithm on Trained Model

3.4.1 Artificial Intelligence (AI):

Artificial intelligence, or AI, [20] is one of the oldest fields of computer science and very broad, involving different aspects of mimicking cognitive functions for real-world problem solving and building computer systems that learn and think like people. Accordingly, AI is often called machine intelligence to contrast it to human intelligence.

The field of AI revolved around the intersection of computer science and cognitive science. AI can refer to anything from a computer program playing a game of chess to self-driving cars and computer vision systems. Due to the successes in machine learning (ML), AI now raises enormous interest. AI, and particularly machine learning (ML), is the machine's ability to keep improving its performance without humans having to explain exactly how to accomplish all of the tasks it's given. Within the past few years, machine learning has become far more effective and widely available.

3.4.2 Machine Learning :

Machine learning [21] is a subfield of AI. The core principle of machine learning is that a machine uses data to "learn" based on it. Hence, machine learning systems can quickly apply knowledge and training from large data sets to excel at people recognition, speech recognition, object detection, translation, and many other tasks.

Unlike developing and coding a software program with specific instructions to complete a task, ML allows a system to learn to recognize patterns on its own and make predictions.

Machine Learning is a very practical field of artificial intelligence with the aim to develop software that can automatically learn from previous data to gain knowledge from experience and to gradually improve its learning behavior to make predictions based on new data.

Machine Learning and Artificial Intelligence:

Even while Machine Learning is a subfield of AI, the terms AI and ML are often used interchangeably. Machine Learning can be seen as the "workhorse of AI" and the adoption of data-intensive machine learning methods.[22]

Machine learning takes in a set of data inputs and then learns from that inputted data. Hence, machine learning methods use data for context understanding, sense-making, and decision-making under uncertainty. As part of AI systems, machine learning algorithms are commonly used to identify trends and recognize patterns in data.

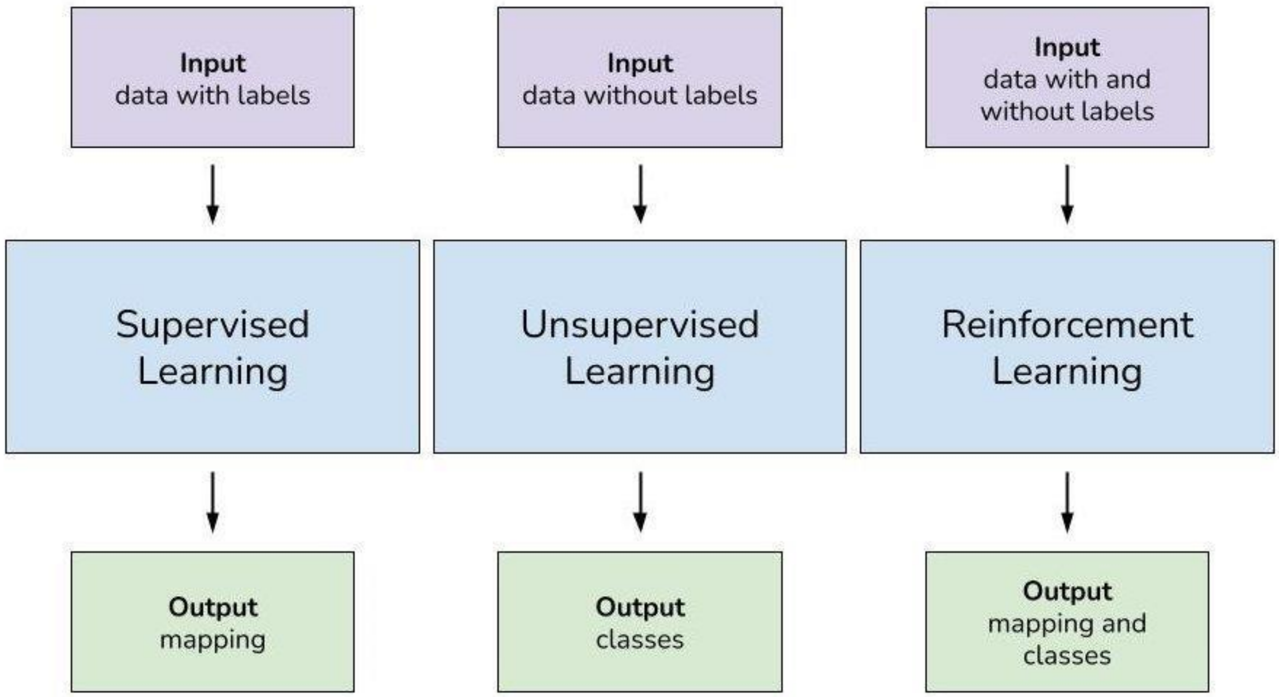


Figure 20: Different Learning Techniques in Machine Learning for training a Dataset

Machine learning applications can be found everywhere, throughout science, engineering, and business, leading to more evidence-based decision-making. Various automated AI recommendation systems are created using machine learning. An example of machine learning is the personalized movie recommendation of Netflix or the music recommendation of on-demand music streaming services. The enormous progress in machine learning has been driven by the development of novel statistical learning algorithms along with the availability of big data (large data sets) and low-cost computation.

3.4.3 Models of Artificial Intelligence:

AI or Artificial Intelligence is a subfield within computer science associated with constructing machines that can simulate human intelligence. An AI model is a program or algorithm that utilizes a set of data that enables it to recognize certain patterns. This allows it to reach a conclusion or make a prediction when provided with sufficient information. This is especially useful for solving complex problems using huge amounts of data with high accuracy and minimum costs.

Relation between AI and ML:

AI is a larger concept associated with the creation of machines that can simulate human behavior and intelligence.

On the other hand, ML is a subset within AI associated with providing machines the ability to learn from experience without the need to be programmed explicitly or in simple words, ML or machine learning is a part of AI. So while all ML models are by default AI models[23], the opposite may not always be true.

List of the Most Popular AI Models:

- Linear Regression (LR)
- Deep Neural Networks (DNN)
- Logistic Regression (LR)
- Decision Trees (DT)
- Linear Discriminant Analysis (LDA)
- Naive Bayes (NB)
- Support Vector Machines (SVM)
- Learning Vector Quantization (LVQ)
- K-nearest Neighbors (KN)
- Random Forest (RD)

Random Forest models is the main model which we have used for Implementing AI and ML in our project. The Random Forest model is described below:

a. Random Forest:

Random forest is a supervised learning method, meaning there are labels for and mappings between our input and outputs. It can be used for classification tasks like determining the species of a flower based on measurements like petal length and color, or it can used for regression tasks like predicting tomorrow’s weather forecast based on historical weather data. A random forest consists of multiple decision trees each of which outputs a prediction. When performing a classification task, each decision tree in the random forest votes for one of the classes to which the input belongs. [23]

b. Random Forest Classifier :

In the case of regression [24], instead of determining the most populous vote from conclusion the random forest will average the results of each decision tree. Because random forests utilize the results of multiple learners (decisions trees), random forests are a type of ensemble machine learning algorithm. Ensemble learning methods reduce variance and improve performance over their constituent learning models.

Random Forest Logic:

The random forest algorithm can be described as follows:

1. Say the number of observations is N. These N observations will be sampled at random with replacement.
2. Say there are M features or input variables. A number m, where m < M, will be selected at random at each node from the total number of features, M. The best split on these m variables are used to split the node and this value remains constant as the forest grows.
3. Each decision tree in the forest is grown to its largest extent.
4. The forest will output a prediction based on the aggregated predictions of the trees in the forest. (Either majority vote or average)

3.4.4 Epochs:

The number of epochs [25] is a hyper parameter that defines the number times that the learning algorithm will work through the entire training dataset. One epoch means that each sample in the training dataset has had an opportunity to update the internal model parameters. An epoch is comprised of one or more batches. The number of epochs is traditionally large, often hundreds or thousands, allowing the learning algorithm to run until the error from the model has been sufficiently minimized.[26]

We used 10 epochs and 32 batch size to train our model.

3.4.5 Optimizer:

Optimizers are algorithms or methods used to change the attributes of the neural network such as weights and learning rate to reduce the losses. Optimizers are used to solve optimization problems by minimizing the function. Optimization algorithms are responsible for reducing the losses and to provide the most accurate results possible. The weight is initialized using some initialization strategies and is updated with each epoch according to the update equation. There are many optimizers have been discovered in recent years due to researches and the most advanced level optimizer is ADAM optimizer which is combination AdaGrad and RMSprop where AdaGrad optimization algorithm keeps track of the sum of the squared gradients that decay the learning rate for parameters in propagation to their update history and RMSprop optimization algorithms fix the issue of AdaGrad by multiplying decaying rate to the cumulative sum and enable to forget the history of cumulative sum after a certain point that depends on the decaying term that helps to convergence to global minima. Thus Adam is a replacement optimization algorithm for stochastic gradient descent for training deep learning models. Adam combines the best properties of the AdaGrad and RMSProp algorithms to provide an optimization algorithm that can handle sparse gradients on noisy problems.Adam is relatively easy to configure where the default configuration parameters do well on most problems**.** Due to advanced optimization of ADAM and noise removal at maximum level, it is used in our python code to find the most accurate answer possible and precise and accurate results for the output. Following ADAM optimizer is discussed generally. [27]

ADAM:

Adam was presented by Diederik Kingma from OpenAI and Jimmy Ba from the University of Toronto in their 2015 ICLR paper (poster) titled “Adam: A Method for Stochastic Optimization”.[28]

WORKING:

Adam is designed to accelerate the optimization process, e.g. decrease the number of function evaluations required to reach the optima, or to improve the capability of the optimization algorithm, e.g. result in a better final result.

This is achieved by calculating a step size for each input parameter that is being optimized. Importantly, each step size is automatically adapted throughput the search process based on the gradients (partial derivatives) encountered for each variable.

$$\delta_{M_i} = \beta_1 * \delta_{M_i} + (1 - \beta_1) * \nabla\theta_i \tag{3.1}$$

$$\delta_{V_i} = \beta_2 * \delta_{V_i} + (1 - \beta_2) * \nabla^2\theta_i \tag{3.2}$$

$$\widetilde{\delta_{M_\iota}} = \frac{\delta_{M_i}}{1-\beta_1} \tag{3.3}$$

$$\widetilde{\delta_{V_\iota}} = \frac{\delta_{V_i}}{1-\beta_2} \tag{3.4}$$

$$\theta_i := \theta_{i-1} - \frac{\eta}{\sqrt{\widetilde{\delta_{V_\iota}} + \varepsilon}} * \widetilde{\delta_{M_\iota}} \tag{3.5}$$

Adam optimization algorithm is the developed version of the RMSprop by taking the first and second momentum of the gradient separately. Therefore, Adam also fixes the slow convergence issue in closing the global minima. In this version of the adaptive algorithm, the mathematical expression is given by:

where δMi is the first-moment decaying cumulative sum of gradients in eq 3.1,
δVi is the second-moment decaying cumulative sum of gradients in eq 3.2, the hat notation δM, and δV are bias-corrected values of δM and δVi in eqs 3.3 and 3.4 respectively and ŋ is the learning rate in eq 3.5. [29]

BENEFITS OF ADAM OPTIMIZER OVER OTHER OPTMIZERS:

The Benefits of using Adam as follows:

- Straightforward to implement.
- Computationally efficient.
- Little memory requirements.
- Invariant to diagonal rescale of the gradients.
- Well suited for problems that are large in terms of data and/or parameters.
- Appropriate for non-stationary objectives.
- Appropriate for problems with very noisy/or sparse gradients.
- Hyper-parameters have intuitive interpretation and typically require little tuning.

3.4.6 MicroML Library for C-code Conversion:

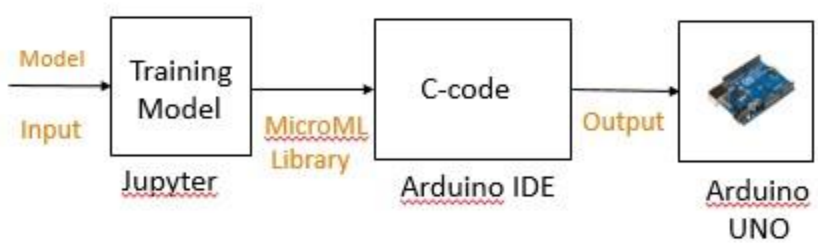


Figure : ML to C-code Implementation

Main work after training a model is done here. This library is used in python code to convert to c-code which will be help us to run our trained model on Arduino IDE Sofware and later burning it on Arduino UNO. [30][31]

3.4.7 C-Code in Arduino IDE software:

For running wheelchair using Arduino Uno, we burnt c-code on Arduino IDE software. C-code script is written in a way that it integrates the c-code converted from Python using MicroML library with c-code written that has to be used for movement of wheelchair in left, right, backward and forward directions or rest/stop mode. [32]

3.5 Hardware Implementation Module:

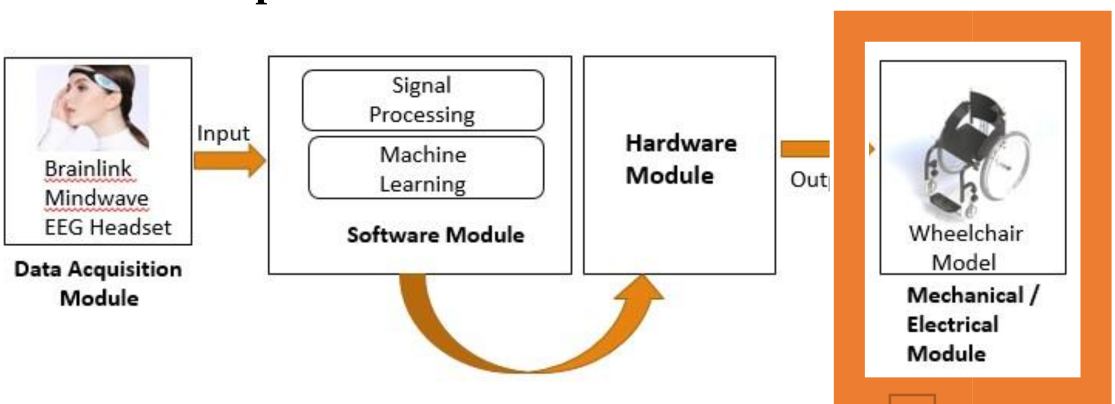


Figure 21: WheelChair Prototype Module

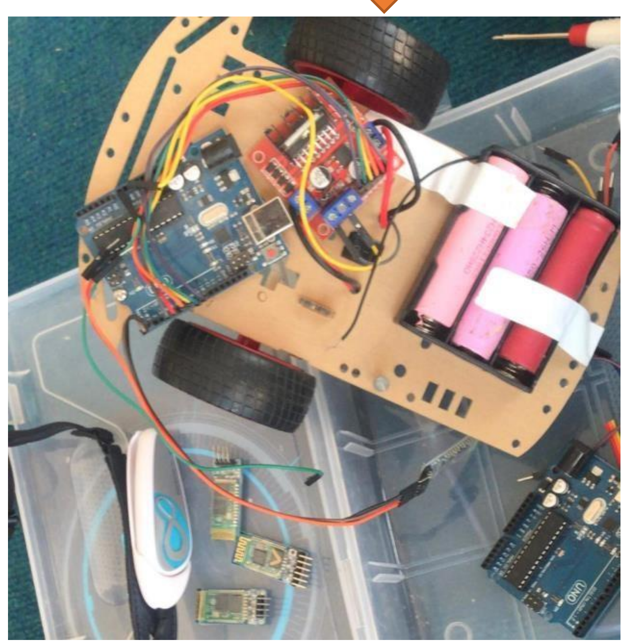


Figure 22: Wheelchair module in making process

Figure 23 : BrainLink Mindwave EEG Headset with External Bluetooth HC-06 Module And Battery

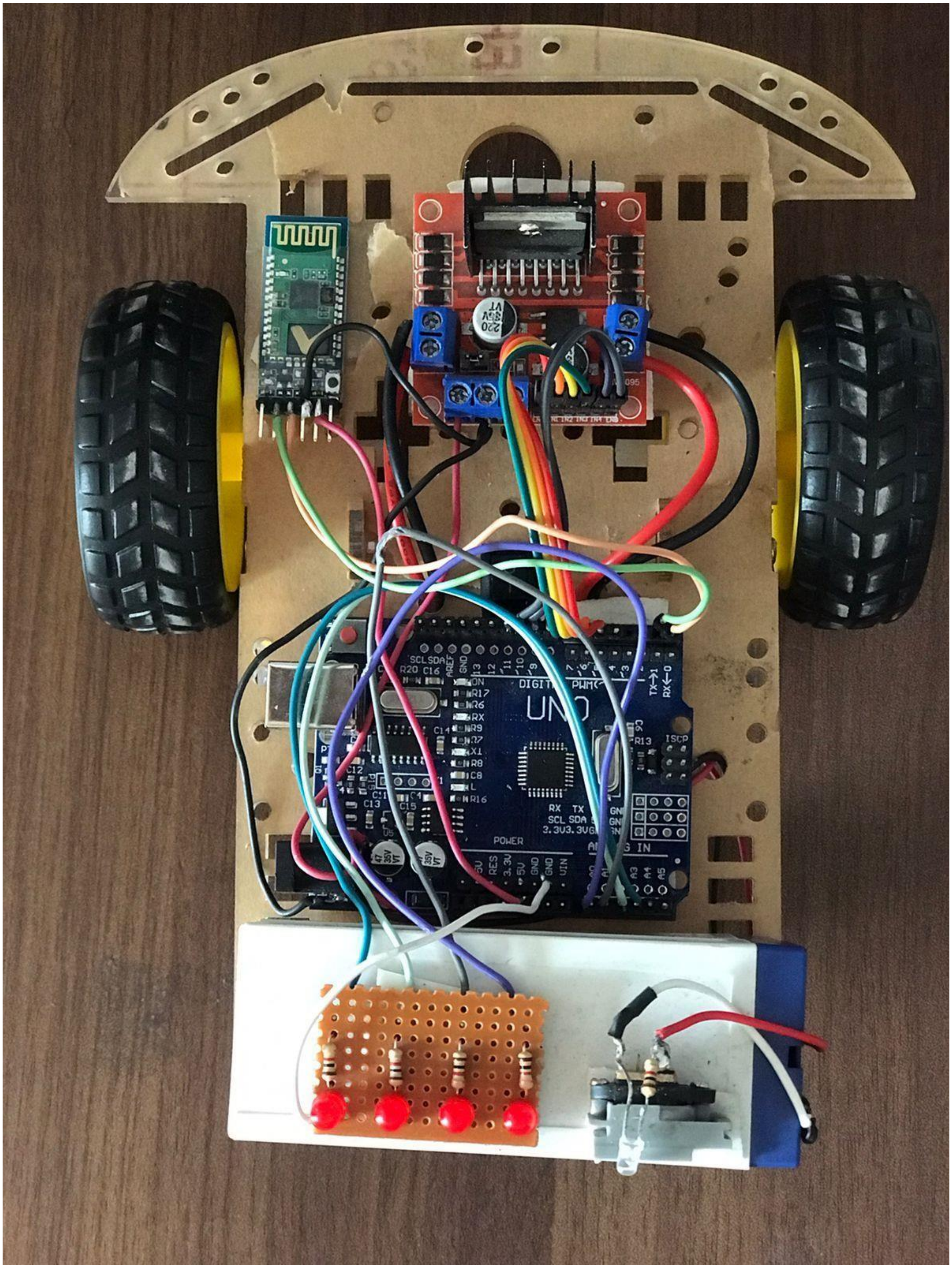


Figure 24: Wheelchair Prototype Model

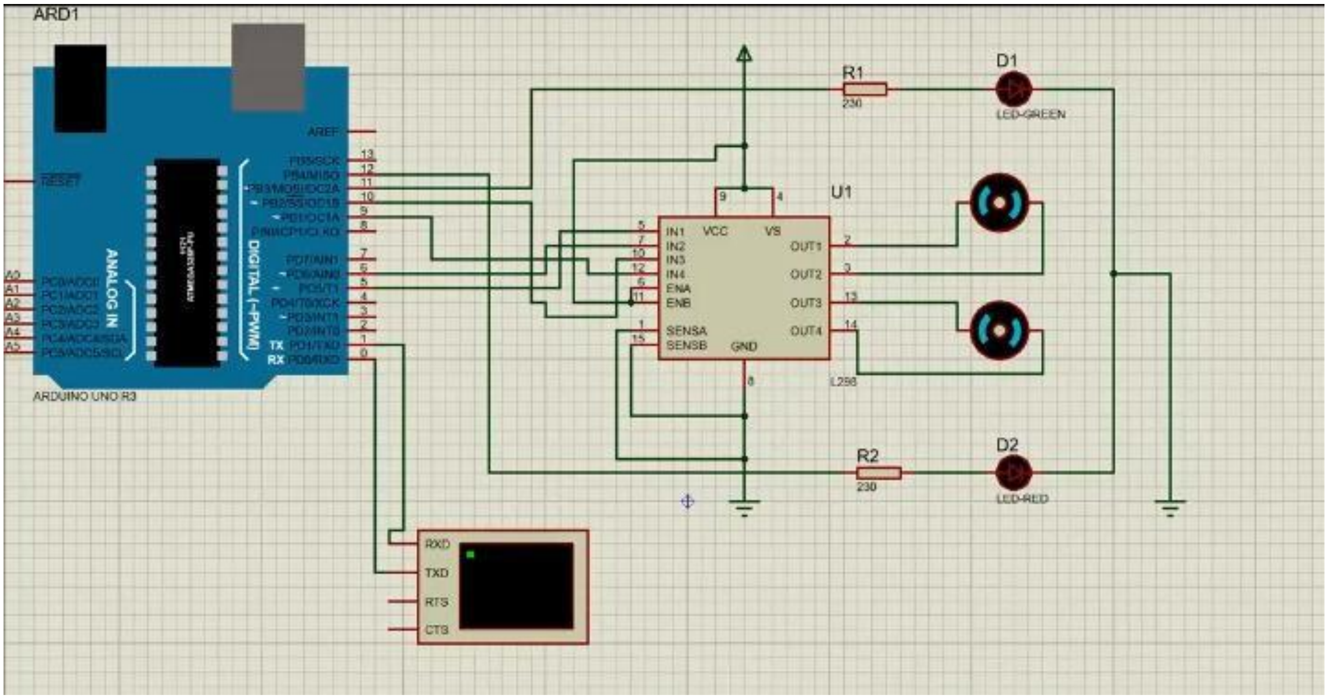


Figure 25 : Hardware Working Diagram of Project

3.5.1 Explanation Experiment Setup of Hardware Implementation:

To determine the wheelchair movement using headset, the easiest way is by processing brain electrical signal which is result of jaw clench. The processed data were classified into 5 types of movement signal consist of moving forward, moving backward, turning left, turning left, and default. In the classification of wheelchair moving data, we used imagery motor method and jaw motion, for imagery motor we used features in Brainlink mindwave headset , and for the jaws motion we processed high alpha signal recorded by the headset. We took data for imagery motor, thus the data results could be references for controlling. Brainlink mindwave headset feature has scale range from 1 to 30Hz. At a normal condition the scale is between 8 to 30Hz, and the scale can be increased up to 40 by jaw clenching and focusing the attention and meditation concentration [33]. The classification that we have done is summarized as follows:

a. Moving forward : Both Jaw Clench
b. Turning left : Left Jaw Clench
c. Turning right : Right Jaw Clench
d. Stop : Relax

Subjects for data exercise were taken from normal people since getting the post-stroke patient or LIS patients was quite challenging. The criteria for a good subject were not under pressure, not in pain (especially headache and under stress). This is because the concentration of the subject using jaw clench becomes the basic determinant so that the wheelchair can be used by everyone. In addition, for data exercise we used 3 minutes exercise duration for each classification class, and break was carried out for 5 minutes, because we did not want to impose pressure on the subject's brain to keep the jaw clench or concentrate.

1.5.2 Hardware Components:

We used following components for making module for wheelchair :

- Arduino UNO
- Motor Driver L298
- DC motors
- Battery of 12V
- CHASIS
- BRAINLINK MINDWAVE EEG HEADSET
- Bluetooth Module HC-06

Arduino Uno:

Arduino UNO [33] is a low-cost, flexible, and easy-to-use programmable open-source microcontroller board that can be integrated into a variety of electronic projects.

This board can be interfaced with other Arduino boards, Arduino shields, Raspberry Pi boards and can control relays, LEDs, servos, and motors as an output.

Arduino UNO features AVR microcontroller Atmega328, 6 analogue input pins, and 14 digital I/O pins out of which 6 are used as PWM output.

Figure 26: Image of an Arduino UNO

This board contains a USB interface i.e. USB cable is used to connect the board with the computer and Arduino IDE (Integrated Development Environment) software is used to program the board. The unit comes with 32KB flash memory that is used to store the number of instructions while the SRAM is 2KB and EEPROM is 1KB.

The operating voltage of the unit is 5V which projects the microcontroller on the board and its associated circuitry operates at 5V while the input voltage ranges between 6V to 20V and the recommended input voltage ranges from 7V to 12V.

Arduino UNO Components:

The Arduino UNO [35] board contains the following components and specifications:

ATmega328: This is the brain of the board in which the program is stored.

Ground Pin: There are several ground pins incorporated on the board

PWM: the board contains 6 PWM pins. PWM stands for Pulse Width Modulation, using this process we can control the speed of the servo motor, DC motor, and brightness of the LED.

Digital I/O Pins: There are 14 digital (0-13) I/O pins available on the board that can be connected with external electronic components.

Analogue Pins: There are 6 analogue pins integrated on the board. These pins can read the analogue sensor and can convert it into a digital signal.

AREF: It is an Analog Reference Pin used to set an external reference voltage.

Reset Button: This button will reset the code loaded into the board. This button is useful when the board hangs up, pressing this button will take the entire board into an initial state.

USB Interface: This interface is used to connect the board with the computer and to upload the Arduino sketches (Arduino Program is called a Sketch)

DC Power Jack: This is used to power up the board with a power supply.

Power LED: This is a power LED that lights up when the board is connected with the power source.

Micro SD Card: The UNO board supports a micro SD card that allows the board to store more information.

3.3V: This pin is used to supply 3.3V power to your projects.

5V: This pin is used to supply 5V power to your projects.

VIN: It is the input voltage applied to the UNO board.

Voltage Regulator: The voltage regulator controls the voltage that goes into the board.

SPI: The SPI stands for Serial Peripheral Interface. Four Pins 10(SS), 11(MOSI), 12(MISO), 13(SCK) are used for this communication.

TX/RX: Pins TX and RX are used for serial communication. The TX is a transmit pin used to transmit the serial data while RX is a receive pin used to receive serial data.

Arduino UNO Pinout:

There is a range of Arduino boards available in the market but the Arduino UNO is the most common board used in the electronic industry. The following figure shows the Arduino UNO Pinout for better understanding:

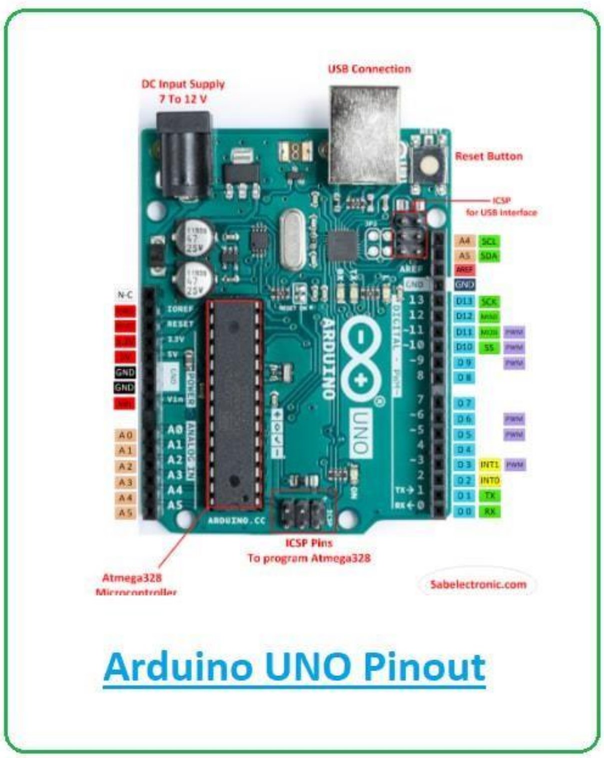


Figure 27: Image showing the pinout of an Arduino UNO board

How to Program Arduino UNO:

Arduino UNO is easy to program and a person with little or no technical knowledge can get hands-on experience with this board. The Arduino UNO board is programmed using Arduino IDE software which is an official software introduced by Arduino.cc to program the board. The Arduino program is called a sketch which you need to unload into the board. The sketch is nothing but a set of instructions that allow the board to perform certain functions as per your requirements.

Each Arduino sketch comes with two main parts:

- void setup() – this sets up the things that need to be done once and they don't happen again in the running program.
- void loop() – this part comes with the instructions that get repeated again and again until the board is turned off.

Arduino UNO Applications:

The Arduino boards can work as a stand-alone project and can be interfaced with other Arduino boards or Raspberry Pi boards. Arduino UNO board is used in the following applications:

○ Weighing Machines ○ Traffic
Light Count Down Timer ○ Parking
Lot Counter ○ Embedded systems ○
Home Automation ○ Industrial
Automation ○ Medical Instrument ○
Emergency Light for Railways

What is DC Motor?

DC motors [36] are motors that operate on Direct Current (DC). DC motors are available in several different configurations from tiny little motors to absolute huge ones. DC motors can be used in robot basics, quadcopters, model planes and boats.

How does a DC motor work?

An operating Brushed DC motor is shown below:

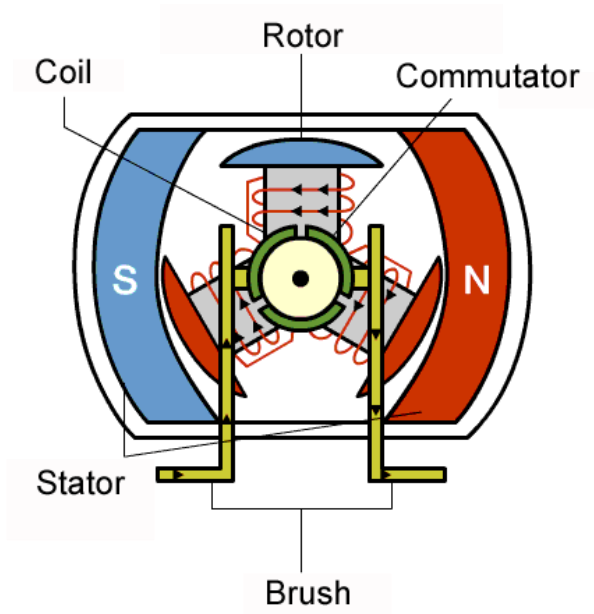


Figure 29: DC Motor ○ DC motors consist of coils of wire ○ Coils connected to the commutator ○ Coils are surrounded by a pair of magnets or a stator ○ DC current applied to the Commutator ○ The magnetic field is formed in coils ○ Coil magnetic interact with magnets(“stator”) ○ The direction of rotation can be reversed by reversing the polarity on the motor’s contacts

What is L298 Dual H-Bridge Driver?

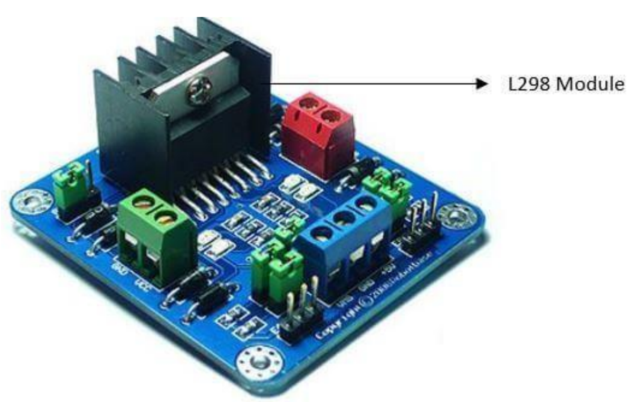


Figure 30: L298 Dual H-Bridge Motor Driver

- L298 is a high voltage and high current motor drive chip which receives TTL logic signals.
- They are mostly used when

- It is needed to operate different loads like motors and solenoid etc where an H-Bridge is required.
- High power motor driver is required. ○ Control unit can only provide TTL outputs. ○ Current control and PWM operable single-chip device are needed.
- It has two enable inputs to enable or disable the particular device attached at its output independently.
- Thus, H-Bridge is basically used to control the rotating direction in DC motors.

Characteristics of L298:

The main features of the L298n Module are:

- High working voltage – can reach up to 46v.
- Large output current. ○ Instantaneous peak current can reach 3A. ○ Continuous working current can reach 2A.
- 25W Rated Power.
- High-Voltage and Current full-bridge driver with 2 H-bridges used to drive inductive loads like DC and Stepper Motors.
- Controlled with standard logic level signals. ○ enable control terminals to enable or device without inputting signals.
- Able to drive a two-phase stepper motor, four-phase stepper motor or two DC motors.
- Has a high-capacity filter capacitor and freewheeling diode to protect devices from the reverse current of an inductive load.
- Built-in stabilivolt tube 78M05 can be used to obtain 5v from the power supply. (Must be used with an external 5v logic supply when the drive voltage is greater than 12v to protect the chip) **L298**

Pin-out:

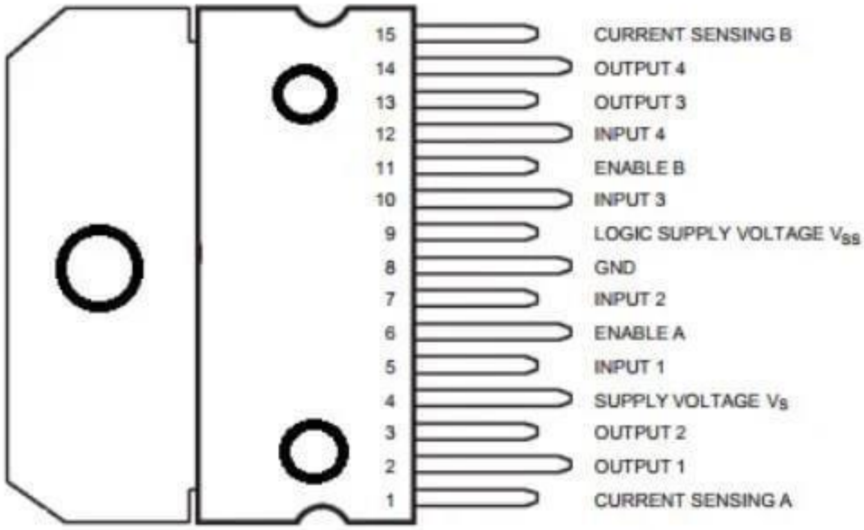


Figure 31: Pins Configuration of L298 Motor Driver L298n

Motor Driver:

The L298 module is mostly used to design motor drivers.

L298 Dual H-Bridge Motor Driver:

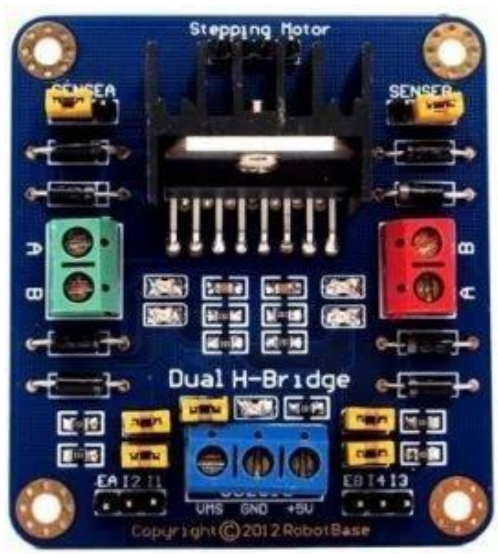


Figure 32 : L298 Dual H-Bridge Motor Driver:

- Double H driver module uses ST L298N dual full-bridge driver, an integrated monolithic circuit in a 15- lead Multiwatt and PowerSO20 packages.
- It is a high voltage, high current dual full-bridge driver designed to accept standard TTL logic levels and drive inductive loads such as relays, solenoids, DC and stepping motors.

Motor Driver L298 Module – .NET Gadgeteer Compatible:

Figure 33: L298 Module – .NET Gadgeteer Compatible:

- This motor driver module controls the speed and direction on 2 DC motors, up to 40V 3A.
- The module itself is powered and controlled from a gadgeteer mainboard but the motors are powered from a separate power source.

Grove – I2C Motor Driver:

Figure 34: Grove – I2C Motor Driver

- It directly controls Stepper Motor or DC Motor. Its heart is a dual channel Hbridge driver chip（L298N）that can handle current up to 2A per channel, controlled by an Atmel ATmega8L which handles the I2C communication with platforms such as Arduino.

- Both motors can be driven simultaneously while set to a different speed and direction. It can power two brushed DC motors or one 4-wire two-phase stepper motor.

How does l298n motor driver work?

The schematic diagram below shows L298n Motor Driver internal structure and working flow:

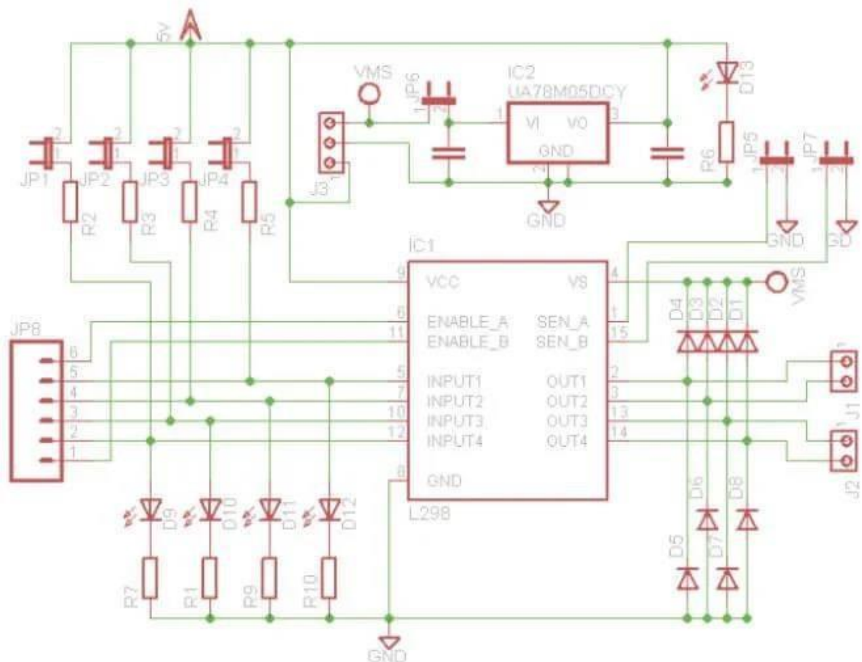


Figure 35: Schematic Diagram of L298 The control mode and state of motor A is shown in the table below:

Motor 1 (IN1), Motor 2 (IN3)	Motor 1(IN2), Motor 2 (IN4)	Motor Rotation
0	0	Stop Rotation
0	1	Clockwise
1	0	Anticlockwise
1	1	Stop Rotation

As seen from the table, the rotation direction is controlled by the control pin IN1 and IN2 for motor 1 while control pin IN3 and IN4 for motor 2. When enabled signal = 1: ○ IN1 and IN2 are 00 or 11 it means the motor is in brake state.

○ IN1 is 0 and IN2 is 1 it means motor A will rotate clockwise. ○ IN1 is 1 and IN2 is 0 it means motor A will rotate anticlockwise. ○ Motor B control method is the same as motor A.

- Motor speed can also be controlled by the module PWM control pin (ENA for Motor 1, ENB for motor 2).
- When regulating speed, IN1 and IN2 rotational direction must be first confirmed and output PWM pulses for enabled terminals.

How does l298n motor driver work with DC motor?

We will working of the l298n H-bridge motor driver works with DC motor.

In order to simplify things, I have drawn one set of the H-bridge driver with 4 switches.

It is called H-bridge because as we can see there is a letter H in the configuration with the motor sitting in the bridge part of the letter H.

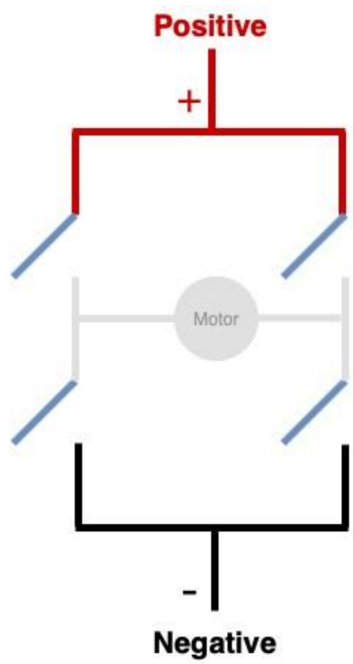


Figure 36: Working of an H-Bridge

Applying a positive voltage to the top of the H-bridge and apply a negative voltage to the bottom. To see effect on H-bridge see fig:

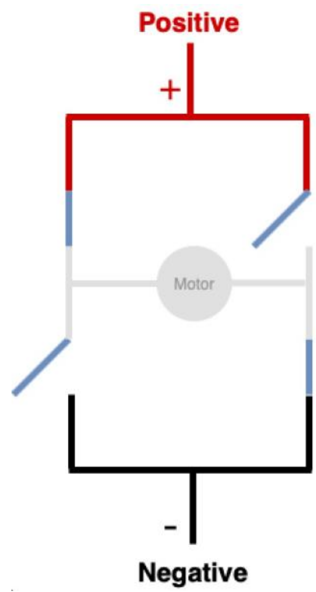


Figure 37: Positive Voltage on H-Bridge and clockwise movement of motor

The positive is applied to the left side of the motor and the negative is applied to the right side. In this case, the motor will rotate **clockwise.**

Vice versa, if we close the other two switches and leave these two open.

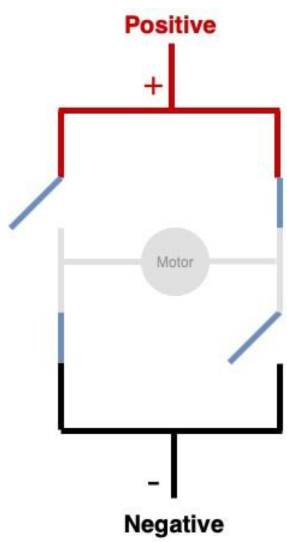


Figure 38: Anti-clockwise movement of motor

Now, the positive is applied to the right side of the motor and the negative is applied to the other side. In this case, the motor will rotate anti-clockwise.

Pulse Width Modulation (PWM):

The speed of the motor is determined by the width of the PWM pulse sent to the “Enable” input of the L298N motor driver. The wider the pulses, the faster the motor will spin. Thus, PWM allows to control the speed.

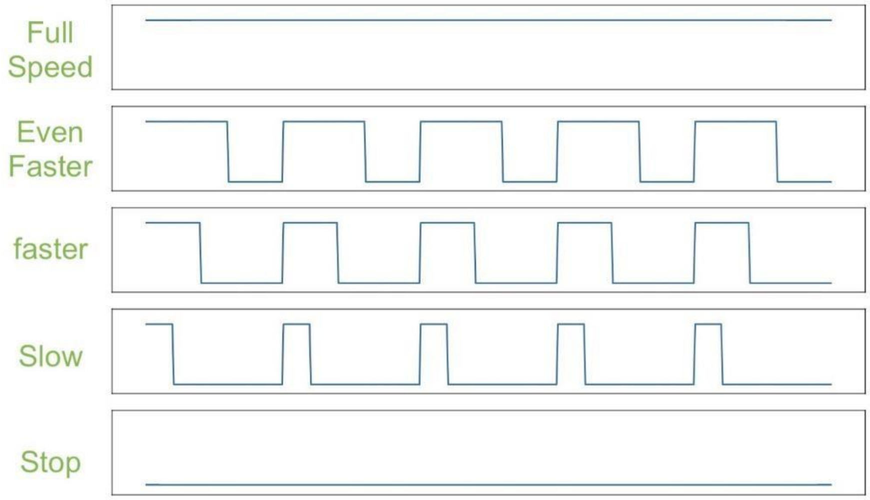


Figure 39: PWM Pulses Classification through visualization

Application of L298N:

L298n Motor Drivers are used everywhere in our everyday life ranging from vending machines to robots. We can also play around with the L298n to control DC motors right .

Controlling DC Motors with Arduino UNO:

With the L298n dual H-bridge, it allows we to switch the direction of the current which means with a motor, we can make it spin in both directions. In addition, with PWM input, we can use an Arduino to make it spin at any speed.

Brainlink Mindwave Headset Bluetooth Interface with HC-06 Bluetooth Module:

Direct interfacing of Brainlink mindwave headset with PC was not possible so we established the serial communication between headset and PC using an external blutooth module i.e. HC-06. We made master and slave Bluetooth module in a connection. As master was Brainlink mindwave EEG headset builin Bluetooth and External HC-06 bluetooth module was slave and then serial communication was established between PC and headset for data acquisition and data processing.

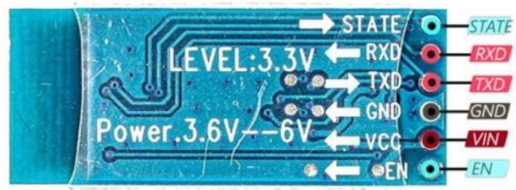


Figure 40: Bluetooth HC-06 Pins configuration

Establishing Connection with HC-06:

Bluetooth is a wireless connection for sharing of data between two devices. In our case brain link mindwave headset is communicating with the computer as it is recording the brain signals in real time in transmitting it to the computer through Bluetooth low energy and we are also using the brain link app in our phone and in our computer for signals visualization.

After classification and identification of the brain signals on computer by using the app and the Bluetooth module HC-06 with the help of machine learning we will able to establish a connection. We have to use a Bluetooth module that has to provide signals to Arduino to drive functions in a wheelchair which will be able to perform specific actions. To connect our brain link mindwave headset to the computer we have to use the Bluetooth module as it do not connect directly because our headset seem to be connect to the Apple Mac book only which wasn't available to us at the time of working so we use the method of master and slave Bluetooth by using serial communication and did signal acquisition and analyzing through this method for acquiring signal.

We use Bluetooth module to connect with our hardware too that's is the wheelchair prototype model.

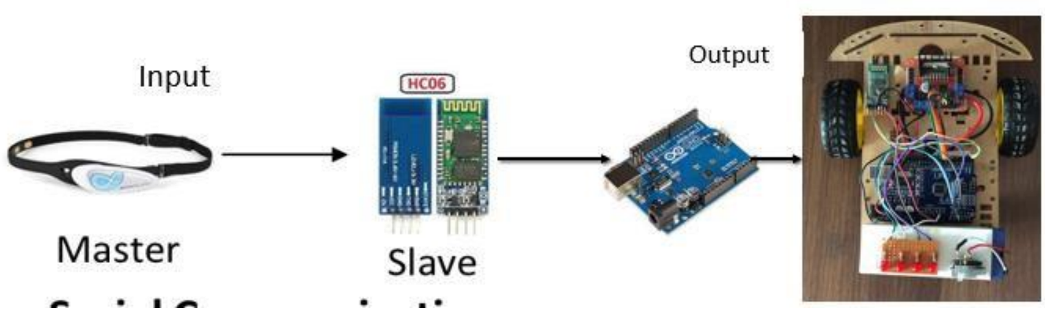


Figure 41: Serial Communication

HC-06 Functionality:

The Bluetooth module is called as a slave Bluetooth module which is designed for wireless serial communication. It is a slave module which means it can receive serial data one serial data is sent out from a master Bluetooth device (it will be able to send serial data through the air that would be smart phones, PC). When the module receives wireless data, it is sent out through the serial interface exactly as it is received.

As we just tried to code an Arduino UNO in order to perform certain functionality but in HC-06 module [37] , no source code is needed because it is a chip which has a built in code and it just connects with external devices serially with Arduino. After connection of Arduino to the HC-06 module, command is sent to the Arduino which usually comes from the external device to HC-06 and external device can be any device depending upon the work we want to perform. In our case when we are moving wheelchair based on brain signals so we connect Python with HC-06 add the library used in Python is Pi Blues which connects Python with HC-06.

Now after sending commands from Python to HC-06, then HC-06 sends that command to Arduino and after that Arduino and actuators in return response accordingly as specified in the source code. When the module is not in a paired state the LED on the module blinks rapidly whereas when paired with external device LED on the module is a steady red.

HC-06 Module Pins:

The module generally has 4 pins known as VCC, GND, TX and RX future required in order to make a connection with Arduino Uno.

- The VCC pin receives its input voltage and is connected to the 5V pin on the Arduino The GND pin is connected to GND pin of Arduino so it is a reference point.
- The TXT and RXD are the transmitter and receiver pins of the HC-06.

HC-06 receive the data from the master external device through RXD and then it transfer the data or command to the Arduino through TXT pin. The GND on the module is the ground pin which connects to the ground pin on the Arduino. The Tx pin of HC-06 is connected directly to the Rx pin of Arduino and RXD pin is directly connected to the Tx pin of the Arduino using a voltage divider circuit as the RXD on HC-06 can support voltage up to 3.3 volts.

1.6 Summary:

We implemented data acquired from Brainlink Mindwave EEG headset but the main issue we faced was interfacing the brainlink mindwave headset with Windows PC as this headset tend to be compatible with only IOS devices, we tried to connect to PC directly using Bluetooth HC-06 module but it was not possible and not working so we used master- slave serial communication between EEG headset, our designed AI based brain controlled prototype and Windows PC to acquire signal but due to poor connectivity we faced severe issues in data acquisition. We used raw datasets for jaw movement to run our prototype wheelchair. This wheelchair was made by using Arduino Uno, DC motors, L298N motor driver, 12V Battery and chases. We did data acquisition at real time for shorter interval when the connectivity was possible, using that acquired signals, we did the signal processing using filters and then detected alpha waves which were required to run the wheelchair model. We did perform Artificial Intelligence model of random forest for classification and regression. RF also known as supervised ML algorithm. This method is the machine learning algorithms or AI models that was further used to trained our model on Jupyter Notebook software. After training the model, MicroML library was used to convert model into C-code which was then used as a header file in Ccode written to run the wheelchair. The c-code written on Arduino IDE was then compiled and the burnt on Arduino Uno which as a result used to drive the wheelchair prototype in left, right, forward, backward directions and for rest.

CHAPTER 4 RESULTS and ANALYSIS:

4.1 EEG Alpha Wave Detection:

Test No	False Positive(Alpha Detected)	False Negative (Alpha Not Detected)	True Positive(Relax Alpha Detected)	True Negative (Relax Alpha Not Detected)
(20k Samples)	30s	15s	15s	30s
1	No	N(detected)	Y	Y
2	No	No	Yes	Yes
3	No	Yes	Yes	No
4	No	No	Yes	Yes
5	No	No	No	Yes
6	No	No	Yes	Yes
7	No	No	Yes	Yes
8	No	No	Yes	Yes
9	No	No	Yes	Yes
10	No	No	Yes	Yes
11	No	No	Yes	Yes
12	No	No	Yes	Yes
13	No	No	Yes	Yes
14	No	Yes	Yes	No
15	No	Yes	Yes	No
16	Yes	Yes	No	No
17	No	No	Yes	Yes
18	No	No	Yes	Yes
19	No	No	Yes	Yes
20	No	No	Yes	Yes
21	No	No	Yes	Yes
22	No	Yes	Yes	No
23	No	No	Yes	Yes
24	No	No	Yes	Yes
25	No	No	Yes	Yes
Result	2\25	5\25	20\25	23\25
Percentage	8%	20%	92%	8%

In Cooperating: 2 Channels Time =20s				
1	No	No	Yes	Yes
2	No	No	Yes	Yes
3	No	No	Yes	Yes
4	No	No	Yes	Yes
5	No	No	Yes	Yes
6	No	No	Yes	Yes
7	No	No	Yes	Yes
8	No	No	Yes	Yes
9	No	No	Yes	Yes
10	No	No	Yes	Yes
11	No	No	Yes	Yes
12	No	No	Yes	Yes
13	No	No	Yes	Yes
14	No	Yes	No	Yes
15	Yes	Yes	No	No
16	No	No	Yes	Yes
17	No	Yes	No	Yes
18	No	No	Yes	Yes
19	No	No	Yes	Yes
20	No	No	Yes	Yes
21	No	No	Yes	Yes
22	No	No	Yes	Yes
23	No	No	Yes	Yes
24	No	No	Yes	Yes
25	No	No	Yes	Yes
Result	2\25	5\25	20\25	23\25
Percentage	4%	12%	88%	96%

We used the raw datasets for the validation of alpha waves which we acquired from Brainlink Mindwave EEG headset while signal acquisition of our project implementation.

In table 1: Alpha waves detection has been done using four parameters of false positive, false negative, true positive and true negative for alpha waves detected, alpha waves not detected, relax alpha waves detected and relax alpha waves not detected respectively. Time of 15s and 30s has been set.

Whereas in table 2 : alpha waves detection done using 2 channels of EEG headset for the same parameters as in table 1. Time of 2s is set here.

4.2 Datasets Accuracy:

```
==================================================================================
Running RandomForest classifier...
Accuracy: 0.8441

Confusion Matrix
[[114  25]
 [ 16 108]]

Classification Report
              precision    recall  f1-score   support

       False       0.88      0.82      0.85       139
        True       0.81      0.87      0.84       124

    accuracy                           0.84       263
   macro avg       0.84      0.85      0.84       263
weighted avg       0.85      0.84      0.84       263

==================================================================================
```

Figure 42: Datasets Accuracy

At first, reason of poor result was invalidity of signals due to a lot of noise presence in signals as we were acquiring signals using serial communication of Bluetooth having slave and master relationship with EEG headset. Anyhow, acquired signals from EEG headset on IPhone and PC were then processed and filtered to meet the required output. The offline datasets was trained using random forest classifier. The accuracy at end of all dataset we get was 84% as a result. Model was trained using machine learning AI Model and supervised ML algorithm i.e. Random Forest Classifier which was further implemented with c-code to be burnt on Arduino UNO. C-code was used to perform motor functions of wheelchair prototype model.

4.3 Recommendations and Future Work:

1. Our hardware is made up of cheap module like low cost brain wave Brainlink Mindwave EEG headset which will make it accessible to everyone within reasonable cost as well as

portable.

2. Our project can be implemented with advanced technology in future to give more advanced results having more accuracy and good sensitivity.
3. The current algorithm we used was improved version of thresholding linear regression i.e. Random Forest in Artificial Intelligence Models and also known as supervised Machine Learning Algorithm. It is resultant of converging different machine learning algorithms.
4. It was a little achievement to detect alpha waves using jaw movement and applying machine learning algorithms on it to run a model prototype of wheelchair. Whereas we were succeeded in our goal at the level of proficiency but not with 100% results we want but we did our best to get an output where we detected brain's electrical activity using low cost EEG headset and then interfaced it with Arduino UNO using different AI and ML techniques in contrast of C-code. Using different machine learning algorithms, we were able to run the wheelchair prototype model. Whereas in future more work can be merged with more advanced techniques in AI and ML so that our work can provide advanced results with more precise and accurate details.
5. Our work can also be combined with other features for the enhancement of working of wheelchair like location tracker and heartbeat tracker.
6. After converging AI and ML techniques with our work and introducing more features, wheelchair can be introduced at market level and can also be introduced in to medical field at reasonable costs.

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