SUPERHUMAN

Brain Controlled Wheelchair

Capstone Project Report

Mid-Semester Evaluation

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ABSTRACT

Electroencephalography (EEG) equipment are becoming available in the public domain. This implies more diverse research in the field of Brain-Computer Interface (BCI). There is a need for such frameworks that makes interpretation of EEG user-friendly and affordable. Thus, making the aforementioned technology readily available to people thereby making their everyday life easier. Brain Computer Interface (BCI) aims at providing an alternate means of communication and control to people with severe cognitive or sensory-motor disabilities or any handicapped person. Such systems are based on the single trial recognition of different mental states or tasks from the brain activity. Thus, this project is an effort to improve the life of such handicapped person. The main focus has been building a system which enables usage of the available EEG device, and making a prototype that incorporates all parts of a functioning BCI system. These parts are 1) acquiring the EEG signal 2) process and classify the EEG signal. 3) Interfacing with the Arduino with motors The solution method in the project will use the raw mindset data for part 1, the Time-Frequency Transform and an artificial neural network for classifying brain wave patterns in part 2.

DECLARATION

We hereby declare that the design principles and working prototype model of the project entitled **Superhuman** is an authentic record of our own work carried out in the Computer Science and Engineering Department, TIET, Patiala, under the guidance of Mr. Shatrughan Modi during 6th semester (2018).

Date: 30 May, 2018

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LIST OF ABBREVIATIONS

ANN	Artificial Neural Network
ARR	Automatic Artifact Removal
EEG	Electroencephalography
EMG	Electromyography
FIRDA	Frontal Intermittent Rhythmic Delta
OIRDA	Occipital Intermittent Rhythmic Delta
SVM	Support Vector Machine

INTRODUCTION

1.1 Project Overview

Our project *Superhuman - Brain Controlled Wheelchair* aims at providing an alternate means of control of wheelchair to people with severe cognitive or sensory-motor disabilities or any handicapped person. Our System is based on the single trial recognition of different mental states or tasks from the brain activity. Thus, this project is an effort to improve the life of such handicapped person.

The goal of the project:

- The goal of our project is to ease the motion of the wheelchair (or other) with some simple gesture of our body movements using EEG signals.
- This would save their precious time and vital energy for the more productive work they need to involve in.
- This would certainly make them self-sufficient and strong as a person.

People who have severe movement disorders like Amyotrophic Lateral Sclerosis (ALS) or Locked in Syndrome, is a condition where a patient is awake and aware of its surrounding but unable to communicate or perform any action due to paralysis of almost every voluntary muscles in the body (with the exception of eye movements and blinking). The people who are suffering from severe Cerebral Palsy disorder are not able to speak or not understandable enough so they could not communicate, navigate and interact with others. ALS patients, paralyzed patients, Physically Challenged and Old age .These people also have severe movement disorder .Imagine these patients having a fully functional brain trapped within a non-functioning body. This project is dedicated to them.

The project is principally based on EEG signals. EEG stands for electroencephalography. EEG is an electrophysiological non-invasive, monitoring method to record electrical activity of the brain. Brainwaves are naturally occurring electrical signals in the brain which are caused by the neurons 'firing'. These pulses can be measured on the surface of the head (scalp) using an EEG.

There are five distinct frequency ranges of brain waves that indicate different brain states. In ascending frequency order these are known as delta, theta, alpha, beta and gamma and they are correlated to different levels of awareness, focus and excitation in the brain. The description of the different brain frequencies are described as follows:

- Delta: It has a frequency of 3 Hz or below. It tends to be the highest in a mplitude and the slowest waves. It is normal as the dominant rhythm in infants up to one year and in stages 3 and 4 of sleep. It may occur focally with subcortical lesions and in general distribution with diffuse lesions, metabolic encephalopathy hydrocephalus or deep midline lesions. It is usually most prominent frontally in adults (e.g. FIRDA - Frontal Intermittent Rhythmic Delta) and posteriorly in children e.g. OIRDA - Occipital Intermittent Rhythmic Delta).
- Theta: It has a frequency of 3.5 to 7.5 Hz and is classified as "slow" activity. It is perfectly normal in children up to 13 years and in sleep but abnormal in awake adults. It can be seen as a manifestation of focal subcortical lesions; it can also be seen in generalized distribution in diffuse disorders such as metabolic encephalopathy or some instances of hydrocephalus.
- Alpha: It has a frequency between 7.5 and 13 Hz. Is usually best seen in the posterior regions of the head on each side, being higher in amplitude on the dominant side. It appears when closing the eyes and relaxing and disappears when opening the eyes or alerting by any mechanism (thinking, calculating). It is the major rhythm seen in normal relaxed adults. It is present during most of life especially after the thirteenth year.
- Beta: Beta activity is "fast" activity. It has a frequency of 14 and greater Hz. It is usually seen on both sides in symmetrical distribution and is most evident frontally. It is accentuated by sedative-hypnotic drugs especially the benzodiazepines and the barbiturates. It may be absent or reduced in areas of cortical damage. It is generally regarded as a normal rhythm. It is the dominant rhythm in patients who are alert or anxious or have their eyes open.

We can have a look at the graphical representation of these EEG waves in FIGURE 1.

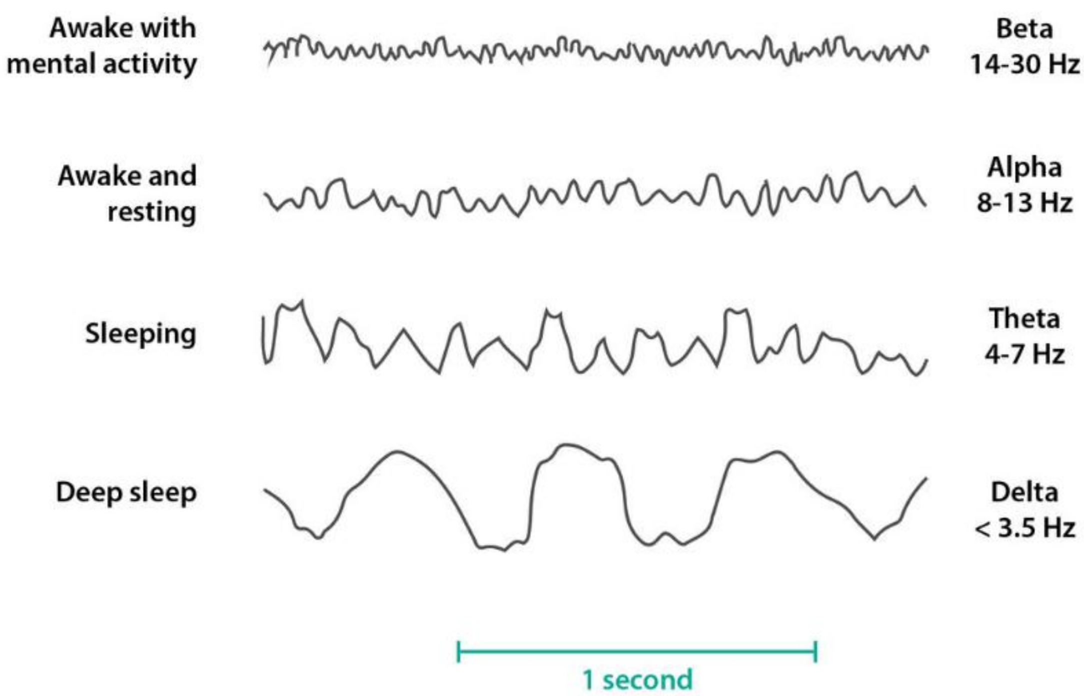

FIGURE 1: Graphical Representation of EEG waves in time domain

An EEG device records electrical signals from the brain, specifically postsynaptic potentials of neurons originating from the cerebral cortex, through electrodes that are attached to the subject's scalp as shown in FIGURE 2. The electrodes attached to the subject's scalp transmit the electrical signals produced by the brain to the EEG monitor. Since these electrical signals are very small (of the order of 10s of microvolts) the EEG acts as an amplifier, typically amplifying them by 10,000 times, as well as a device to measure them. The signals are then amplified so as to obtain a processable signal for the working of the project. The data received after conversion to csv contains 39 columns out of which only 14 columns are relevant to us. These 14 features correspond to 14 different locations of the brain. A label column is added for supervised learning. The model is then trained on these 15 features. The signal is preprocessed and then passed into the machine learning trained model to get the defined classified actions of locomotion. The classified actions would be implemented using motors with the help of Arduino.

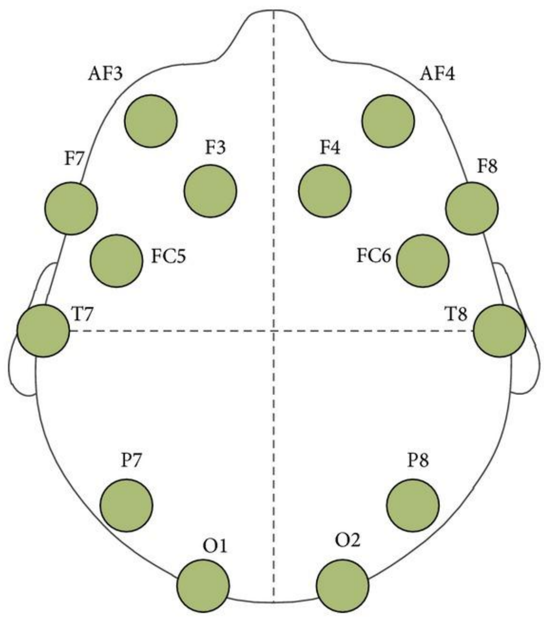

FIGURE 2: Showing 14 points in the brain corresponding to the 14 channels of EEG

1.2 Need Analysis

Today the world has become easier than our ancestors could ever think of. We have remote controls for televisions, air conditioners or for that matter, pretty much any electronic device. We have the concept of self-driving cars rising up with several companies already at the brink of launching their first models. Our homes have become smarter, for instance, the room's light can be controlled by an app or even better, it could automatically switch on detecting your presence.

Fundamentally, one can visualize it as a new technique for controlling things. Till date, one had to move his/her muscles to do anything whether it be switching on the TV, changing AC temperatures, driving cars or as simple as switching on the lights. With this, you need not move your fingers. Just think and ZAP the work's done.

The world is running faster than ever imagined. People are in a constant haste. Time is becoming as crucial an entity as money. From top businesses to a common man, everyone wants to save time. And our project aims to do exactly what they want by replacing the need to move, for things like controlling lights or fans. Secondly, since, things would be controlled by brain, it would reduce the dependence of day to day chores on limbs. So, people with physical disabilities will no longer be dependent on others for fulfilling basic requirements. So, for example, a man with no hands can switch on or off lights of his/her room without calling out for help. A person with problems in walking, would no longer need to rely on someone else for steering his wheelchair. Yet another case where it can be used is in vehicles. The device can detect when the driver is about to doze off and can warn him/her by sounding alarms or flashing lights thus preventing about 1/5th of all road accidents. Apart from improving lifestyles, this can also be used for leisure activities like gaming.

Currently, we are trying to help the handicapped person to move with just simple facial movements (or gesture) using brain waves. This work can be extended to all class of people to ease their motion from one place to other.

1.3 Problem Definition and Scope

The current scope of this project is to target the patients with disabilities. They will be able to move themselves sitting on a wheelchair just by thinking. There will be a machine learning model ready to tell which action was just performed. Electrical component including motors, wheels and other circuit would function according to brain signals. The end product of this project development would be a software which will be used to control a robotic buggy (prototype of wheelchair).

1.4 Approved Objectives

- To study research papers and other literature related to Brain Computer Interface.
- To gather data and preprocess it to remove ambiguities.
- To develop Machine Learning algorithms for classification.
- To control various devices based on what one thinks.
- Test and validate the final system.

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1.5 Methodology Used

- Enormous study of research paper associated with EEG and BCI technology.
- Acquired EEG device and learnt the working of the device with the testbench software.
- Began data collection process using EEG device.
- Preprocessed the data using flattening and removing noise.
- Built SVM model to train and to test the data.

1.6 Assumptions

- **Scope**

  The project scope won't change and will remain static till the end of this project development process. The current scope of this project is to target the patients with disabilities. They will be able to move themselves sitting on a wheelchair just by thinking. There will be a machine learning model ready to tell which action was just performed. Electrical component including motors, wheels and other circuit would function according to brain signals. The end product of this project development would be a software which will be used to control a robotic buggy (prototype of wheelchair).

- **Resources**

  All the hardware and other resources required would be readily available at the time of development of the project.

- **Schedule**

  The Capstone project schedule is fixed from January 2018 to November 2018. The deadlines would not be preponed or extended.

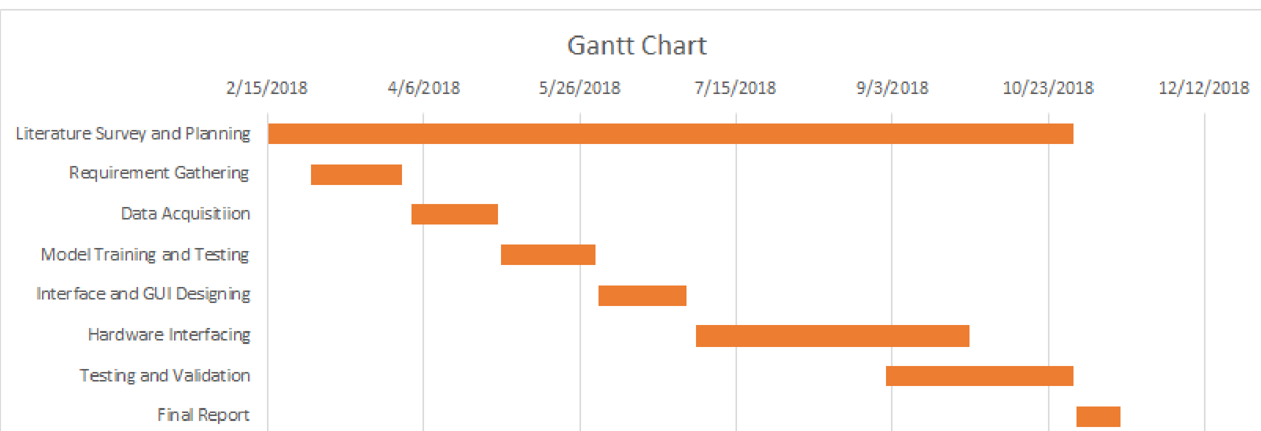
- **Financing**
  - The overall cost of day-to-day activity will not increase.
  - Cost of saline solution for EEG device will not change.
  - Cost of hardware required will not change.
  - Overall economical conditions will stay the same.

- **Expectation**
    - The end users would be specifically, the patients with disabilities (eg. paralysis) who need a wheelchair to move around. The wheelchair will be automated by the user's thoughts.
    - The EEG device is properly hydrated and has a good connection in all 14 channels before starting and using the program.

1.7 Summary of project outcomes

With just a simple gesture, a person can move from place to place. There are three actions and three kinds of motions corresponding to them. We have defined three actions as Teeth clenching, Mouth rinsing and fast Eyes blinking. First motion is forward motion and other two are clockwise rotation and anti-clockwise rotation to change the direction of the motion. The stop signal is corresponding to the neutral state(no action/gesture). Using these actions, one can quite easily become independent to move from anywhere to anywhere.

1.8 Project Schedule



	Final Report	Testing and Validation	Hardware Interfacing	Interface and GUI Designing	Model Training and Testing	Data Acquisitiion	Requirement Gathering	Literature Survey and Planning
Start Date and Time	11/1/2018	9/1/2018	7/2/2018	6/1/2018	5/1/2018	4/2/2018	3/1/2018	2/15/2018
Days	14	60	88	28	30	28	29	258

FIGURE 3: Gantt Chart of our Project schedule

2.1 Background

There is no doubt that technology has changed our life drastically. Using electroencephalography (EEG) sensors that pick up and monitor brain activity, brain wave technology has been advancing quickly in the last few years. A number of companies already sell basic brain wave reading devices, such as the Muse headband, Emotiv Epoc plus, Neurosky set. There are five distinct frequency ranges of brain waves that indicate different brain states. In ascending frequency order these are known as delta, theta, alpha, beta and gamma and they are correlated to different levels of awareness, focus and excitation in the brain.

The development of information and electronic technology to promote the convergence of various disciplines, EEG evolved from biological information, combined with information technology, extend the application of many related, that many have about the application of EEG Mature, there are many applications of EEG are related to research such as playing game, controlling lights/fans etc.

Many studies indicate that different EEG frequency bands, representing the corresponding activities of the brain, this stage are divided into the following EEG frequency bands:

- V Band (1-4 Hz) reflects sleep, relaxation and fatigue.
- T Band (4-8 Hz) reflects the excitement and shock.
- D Band (8-14 Hz) reflects the calm of the brain work.
- E Band (14-30 Hz) reflects the concentrated work of a busy brain.

In the analysis of EEG frequency bands, applications are generally divided into two types, one is the direct use of the different EEG frequency bands, in the research, such as the AR model using wavelet analysis and other methods will be able to extract the signals of different frequency bands of EEG The purpose of the signal, currently in medical applications, there are many successful cases. Such as band, physically, in the delta wave state, the physical and mental recovery was fastest. Psychologically, this is the best to eliminate the mental stress suffered during the day.

2.2 Existing System(s)/ Related Work

The pictorial representation of work in the field of EEG and BCI is shown below in FIGURE 4. It shows the research in BCI since 1875.

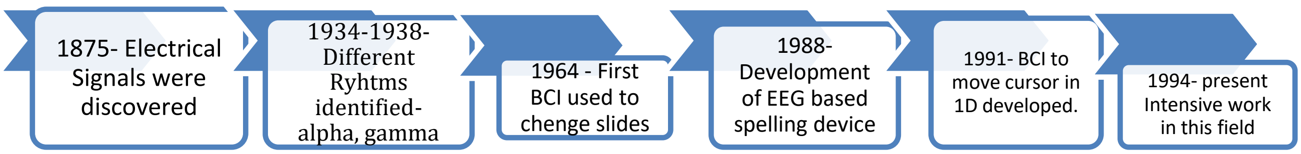


FIGURE 4: Pictorial representation of work in the field of EEG and BCI

Recently, some BCI studies started to introduce SSVEP-based mental spelling systems [4]. Since 2010, BCI researchers have developed increased numbers of applications related to navigation using a wheel chair or virtual reality, as well as robot arm controls.

The BCI applications that are classified as "others" also considerably increased in 2010 and 2011, indicating that BCI technology has increasingly been applied to new applications. These included a brain switch for turning on/off a BCI system [7], a mobile phone application (Y. T. Wang, Wang, & Jung, 2011), a real-time drowsiness detection system (C. T. Lin et al., 2008), a brain-controlled smart home system (C. T. Lin, Lin, et al., 2010), and a cognitive ability assessment system (Perego et al., 2011).

Finally, BCI applications for controlling a mouse cursor and playing a computer game have been steadily developed each year. Converting Your Thoughts to Texts: Enabling Brain Typing via Deep Feature Learning of EEG Signals by Xiang Zhang, Lina Yao, Quan Z. Sheng, Salil S. Kanhere, Tao Gu, Dalin Zhang[17]. The state-of-the-art approaches can achieve an accuracy of at most 70-85%. In this paper, they present a hybrid deep learning model to decode the raw EEG signals for the aim of converting the user's thoughts to texts. The model employs the RNN and CNN to learn the temporal and spatial dependency features from the input EEG raw data and then stack them together. The proposed approach adopts an Autoencoder to recognize the stacked feature and to eliminate the artifacts and employs the XGBoost classifier for the intent recognition.

They evaluate our approach on a public MI-EEG dataset and also a real world dataset collected by ourselves. Both results (95.53% and 94.27%) outperform the state-of-the-art methods.

- There are attempts made by few researchers to automate the wheelchair but they have achieved limited accuracy using brain waves and can only detect a few different commands. Maintaining these mental exercises when trying to maneuver a wheelchair around a cluttered environment can also be very tiring. We are trying to improve the system to assist the intended audience.

2.3 Problem Identified

For the handicapped person, there is always dependence on someone for the menial activity. We have identified that if motion can be automated using command by brain itself using EEG signals.This can ease their life and can make them independent and self-sufficient.

2.4 Methods and Tools Used

Using EEG, with some auxiliary equipment, can directly signal the brain thinking activities to comunicate with the outside world, to achieve "heart to heart" communication, even to the control of the surrounding environment, which is the brain-computer interface system. The so-called brain-computer interface, is a not rely on peripheral nerve and muscle tissues such as the brain is usually output channel communication system.

For EEG feature extraction and classification methods, in order to improve the accuracy of the algorithm used in many algorithms used are not generally divided into two stages, first feature extraction stage, the main algorithm in the following areas:

1.Artifacts Removal Techniques:

- Independent component analysis
- Automatic artifact removal (ARR) in MATLAB

2. Dimension Reduction
    - Principal Component Analysis (85.6%)
    - Feature Extraction
    - Wavelet Transformation (91.1%)
3. DWT (Discrete Wavelet Transmission)
    - Fast Fourier Transformation (86.7%)
    - LDA (Linear Discriminant Analysis)

Classifiers used for the application of BCI (Brain computer interface)

TABLE 1: Classifiers applied for BCIs

S.No.	Methodology	Reference	Description
1.	Improved Support Vector Machine(ISVM)	Han-Jeong Hwang , Soyoun Kim , Soobeom Choi & Chang-Hwan Im (2013)[9]	A new method for rolling was presented. The method focused to emphasis on LMD, IMFE and ISVM-BT. The preprocessed and quantified vibrational signal is fed into multi-fault classifier to fill those recognitions automatically. The outcomes are the prove to be very optimistic
2.	(IACO-SVM) Improved Ant Colony Optimization SVM	Ang, K. K., Chin, Z. Y. [3]	Here, the focus was to maximize the methods and ways which affects how the classifier responds and performs. Both best and worst solutions determined using the ants are made to update the table of arranged pheromone trails and adjust the range of optimized parameters. Thus, the proposed algorithm can give higher recognition accuracy

3.	Multi Kernel SVM(MSVM)	Erik Andreas Larsen (2011) [7]	MSVM is a very robust tool when it comes to diagnosis of small samples with high dimensions. Using it with chaotic particle swarm optimization (CPSO) and empirical mode decomposition (EMD) are used for high accuracy of optimal parameters and preprocessing respectively. Results indicate that the approach is a productive and achieves higher accuracy and strong realization ability
4.	SVM	2015,XiaLi Zhang, XueFeng Chen[17]	The discussed method is well known to detect the defects of rolling machine and bearings. Salient features need to be found to distinguish that what are the reasons for fault and how to maximize the optimizing parameters, thus an ant algorithm is made for SVM in intelligent fault diagnosis of the rotating machines is proving it as a better option.
5.	Least Squares SVM (LSSVM)	Rajesh Singla, Brijil Chambayil , Arun Khosla, Jayashree Santosh (2011)[13]	There is a need to improvise performance of conventional Empirical Mode Decomposition (EMD). The signal is already processed and weighted to subdue the result of components intermitting components of large frequency and some other unrecognizable noises. LS-SVM rolling forecast signal is attached to denoised signal. LS-SVM is used to obtain local mean curve after designing both envelopes of data and

			smoothing. The information is demodulated to get faulty characteristics. By using stimulations and applications to bearing fault diagnosis the effectiveness is verified.
2.	Artificial Neural Networks	Rajesh Singla, Brijil Chambayil, Arun Khosla, Jayashree Santosh (2011) [13]	This focused on a process based on how and what are the patterns and do we recognize them. We use this technique to solve the faults of induction motor bearings. Three cases, the defects of all three cases were investigated. Use of time domain methods obtained from direct processing of signals are used as an alternative to frequency. The ANNs are trained and efficiency of proposed method is evaluated. WE analyze and infer that using the time domain features is advantageous to us to identify and rectify the limitations of motor

On observing and studying the research papers of last few years, the classifiers had a very big role to play in fault diagnosis of ball bearing. The focus was on diagnosis using Artificial Neural Network (ANN) and Support Vector Machine (SVM). The specific defects consider as inner race with spall, outer race with spall, and ball with spall. Statistical techniques are applied to calculate the features from the vibration data and comparative experimental study is carried using ANN and SVM.

In geometry a hyper plane is a subspace of one dimension less than its ambient space. A SVM is a discriminative classifier usually mentioned by a hyper plane which is separating. In other supervised learning, one confined hyper plane which categorizes new examples is outputted by an algorithm. SVM combined with various other techniques gives different results, each having one or the other advantage. But the biggest limitation of using a SVM is the choice of kernel. Also speed and size in testing and training serves as a big drawback. An ANN is a computational model based on how a pattern is configured to recognize patterns and how data is classified through a learning process. They surely serve as a very highly accurate time series analysis but they are hard to tune. They might attract the best signals but they are not helpful in determining the path of reaching the conclusion. A third type of classifier is Random Forest (RF). Random forests or random decision forests are algorithms using multiple learning algorithm to obtain better performance for classification and regression. These work on outputting the class which is the mean of predicting individual trees (Classification and regression), from constructing or developing many decision trees at training time.

3.1 Software Requirement Specifications

3.1.1 Functional Requirements

Software functional requirements

1. It should provide the user the authorization to start/stop the EEG detection.
2. It should be able to receive the brain signals that are captured by EEG device and convert it to tabular form.
3. Software should be able to preprocess the received data to make it compatible with pre-trained classifier.
4. Accurately predict the user's action using a pre-trained classifier
5. It should send the classified action on Arduino ports.
6. It is required to control the wheel chair motor with the help of Arduino.

External Interface Requirement

1. Software Interfaces: This embedded system should have Bluetooth drivers installed and other communication port must be enable for the proper functioning of the system.
2. User Interfaces: The interface should be just a start/stop button which helps the user to enable/disable the system.
3. Hardware Interfaces: This application should begin responding as soon as it is worn on head by user and is in enable mode.

3.1.2 Non-functional Requirements

1. **Safety**: The system should be shock-proof. It should not cause any kind of injury to the patient.

2. **Security:** The connection between the Emotiv (eeg device) should be secure and it should only communicate with the intended device.
3. **Usability:** It should be easy enough to be used by a complete layman since it is not to be used by professionals but by patients.
4. **Testability:** Every system is required to be tested for any flaws or bugs before handing it to the customers. It should be easy for the testers to validate the device's performance.
5. **Maintainability:** The sensors in the EEG device are available separately and can be easily replaced once they wear off.
6. **Extensibility:** The technology can be extended to use in large number of applications like gaming and virtual reality.
7. **Scalability:** It can be configured to link as many thoughts as one desires to control numerous things, like lights or fans.

3.1.3 Use case diagram

Below in FIGURE 5 is the use case diagram for our project which describes all the features of the project and describes user who are going to use it.
There are three actors in our use case: Patient, EEG Headset and Arduino which are explained below:
1. PATIENT: The patient would think certain movements of the limbs which helps the Emotive EEG headset to capture the brain waves corresponding to the thought.

2. EMOTIV EEG HEADSET: The Emotiv EEG Headset would capture the brain waves (alpha, beta, gamma and delta waves) from the patient.

3. ARDUINO: The Arduino would receive the classified signal from the System and send the relevant programmed voltage signal to the motors in order to produce the desired locomotion.

The various use cases are alassify signal, signal as input to arduino, control motors, transmit signal to interface, and capture the brainwaves of person's thoughts.

USE CASE

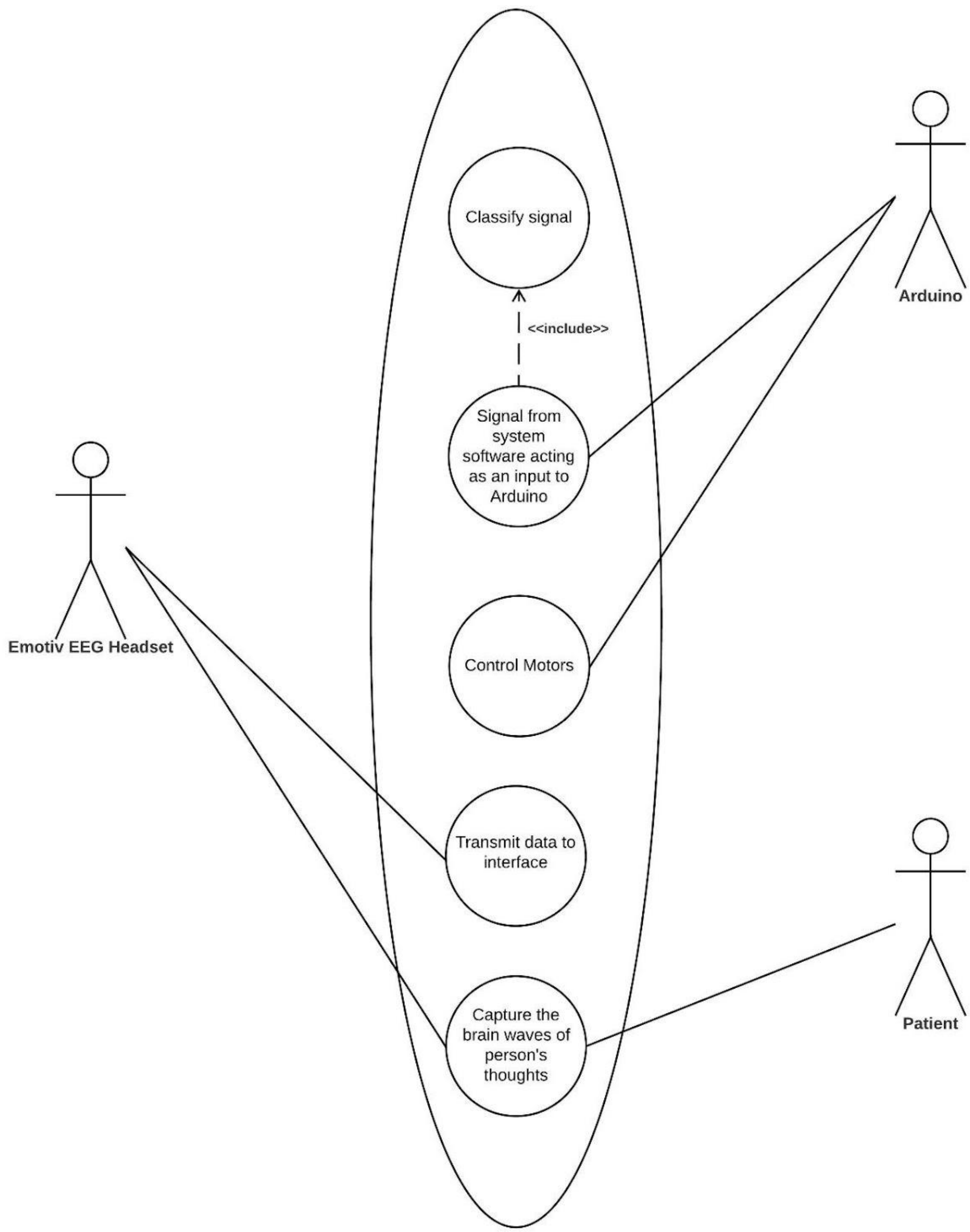


FIGURE 5: Use case diagram

3.1.3 Use case template

Use Case description – Capture the brainwaves of person's thoughts

TABLE 2: Use Case description – Capture the brainwaves of person's thoughts

Name	Capture the brainwaves of person's thoughts
ID	UC_001
Description	Emotiv EEG device is mounted on the head of the patient and this headset, consisting of 16 electrodes, records the brain waves of the patient (characterized by different amplitudes and frequencies) by means of Electro Encephalography.
Actors	Emotiv EEG Headset, Patient
Frequency of use	The brainwaves will be captured repeatedly in fixed timeframes, once the device has been turned on and start detection option is selected.
Triggers	The user selects the option to start detection.
Preconditions	1. Patient should be wearing the EEG headset properly, such that, all the electrodes are touching the scalp of patient's head. 2. The headset should be connected to software on the computer.
Postcondition	The patient thinks about the action to be performed.
Main Course	1. User clicks the start detection option on software. 2. EEG headset captures the brain signals of patient on 14 channels. 3. EEG headset amplifies the brain signals.
Exceptions	1. EEG Headset fails to capture brain waves, if device is not properly worn by the patient or the electrodes are not moist enough. 2. The software prompts the message that weak/no signals received.

Use Case description – Transmit data to interface

TABLE 3: Use Case description – Transmit data to interface

Name	Transmit data to interface
ID	UC_002
Description	The signals captured by EEG Headset are amplified. Then, it sends the

	recorded data to the software via Bluetooth or USB.
Actors	Emotiv EEG Headset
Frequency of use	This use case will be used repeatedly after fixed intervals of time, whenever the data is ready to be transmitted.
Triggers	EEG headset is ready to transmit the data and the software has acknowledged to begin receiving the data.
Preconditions	1. The start detection option is selected. 2. The headset should be connected to software on the computer through Bluetooth or USB.
Postconditions	The data is received by the software and converted to readable format.
Main Course	1. EEG Headset transmits the data via Bluetooth to the software. 2. The software receives the data.
Alternate Course	1. EEG Headset transmits the data via USB cable to the software. 2. The software receives the data.
Exceptions	1. If the Bluetooth is not connected or the USB cable is damaged, software fails to receive any data. 2. The software prompts the message that weak/no signals received.

Use Case description – Classify signals

TABLE 4: Use Case description – Classify signals

Name	Classify signals
ID	UC_003
Description	The data received by the software is converted into compatible format and is used to predict the action class using a trained classification model. The classification model is also re-trained using new data.
Actors	Software
Frequency of use	Every time a new signal reading is received from the Emotiv EEG headset, this use case will be used.
Triggers	The software receives a new reading and calls the prediction function.

Precondition	The input data for classification should be in a compatible format.
Postconditions	1. The predicted action is displayed at user interface. 2. Screen to select if predicted action is correct or incorrect is displayed for the user, so that, the training data could be updated and classifier could be re-trained.
Main Course	1. Input data is used by classifier to predict output action. 2. The output is displayed on the graphical user interface. 3. Option to re-train the model is also given on the GUI. 4. User can select the option to mark the action as correct/incorrect based on which the training data can be updated and the classifier can be improved.
Exceptions	1. If the predicted action is wrong, user can manually stop the software.

Use Case description – Signal from system software acting as an input to Arduino

TABLE 5: Use Case description – Signal from system software acting as an input to Arduino

Name	Signal from software acting as an input to Arduino
ID	UC_004
Description	Arduino microcontroller receives the output predicted by classification model in the software, for performing further actions on wheelchair.
Actors	Arduino
Frequency of use	For each brainwave reading of patient, an output action is predicted. Every time the output is predicted, Arduino receives an input.
Triggers	Signal corresponding to predicted action is ready to be transmitted by system software.
Precondition	1. System software ready with the predicted output. 2. Arduino connected to the computer system via Bluetooth.
Postconditions	Arduino receives input to execute its program.
Main Course	1. Software transmits the predicted action signal using Bluetooth/Xbee. 2. Arduino receives the signal on input port.

Use Case description – Control Motors

TABLE 6: Use Case description – Control Motors

Name	Control Motors
ID	UC_005
Description	Arduino executes its program using the input received from system software and sends signal to the motors
Actors	Arduino
Frequency of use	At fixed intervals, whenever new brain waves are detected and new output action is predicted, this use case will be run.
Triggers	Particular function is called during Arduino program execution using input received from use case UC_004.
Precondition	Arduino has received input signals.
Postconditions	Motors run or stop based on the function called during program execution in arduino.
Main Course	1. Input received by arduino is used in program. 2. Function based on input received is called. 3. Arduino controls the speed and direction of motors of wheelchair according to the function called by its program.

3.1.5 Activity Diagram

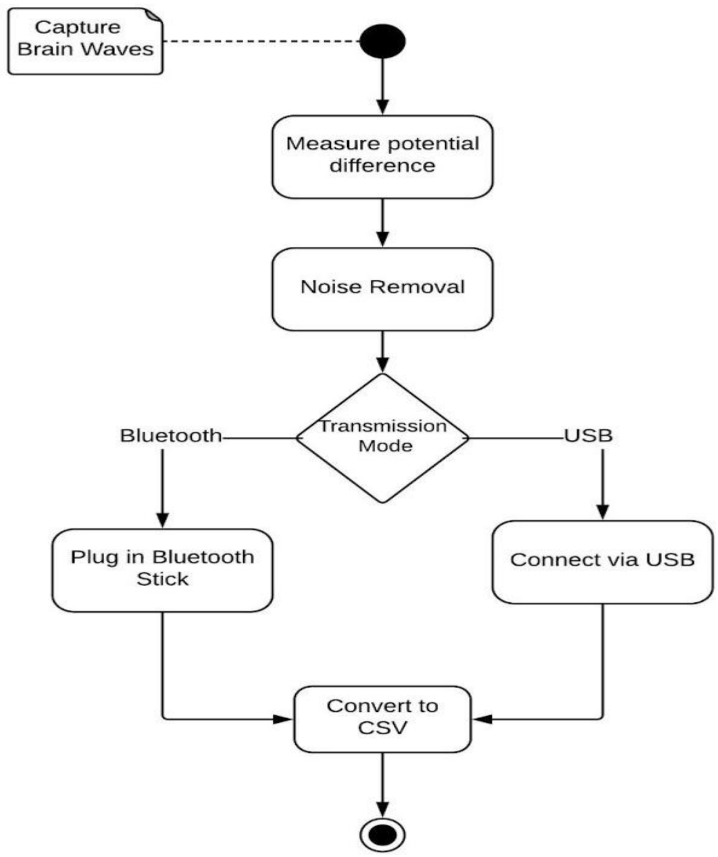


FIGURE 6: Capture brain waves

This is an activity diagram which demonstrates how brain signals are captured and converted to tabular form.

1. The neurons generate a certain amount of potential difference among themselves.
2. This difference is measured by the EEG device.
3. The measured is very noisy. Thus noise is removed by the device itself.
4. The measured voltages can now be transferred to interface using two modes. The data is then converted to an excel file.

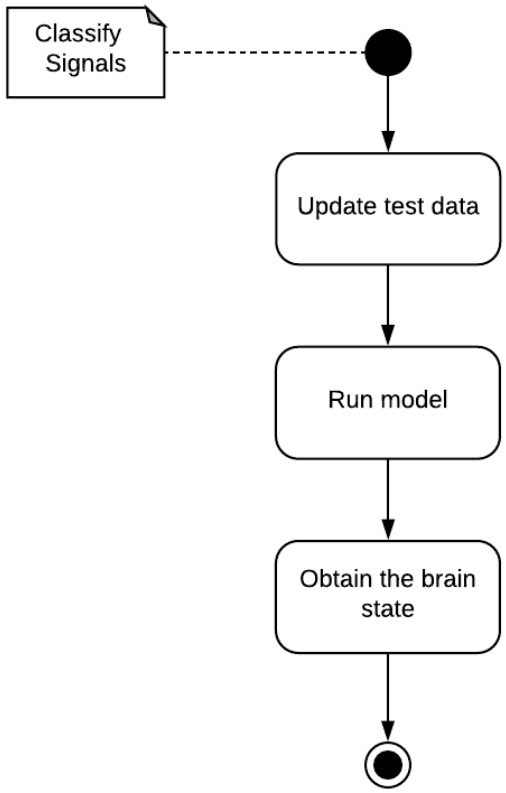


FIGURE 7: Classify Signals

This activity diagram illustrates the process of classifying signals.

1. The input data from user is added to test dataset. Thus, test dataset is updated.

2. The ML model is then run for the updated test dataset.

3. The classified signal or the brain state is obtained as output.

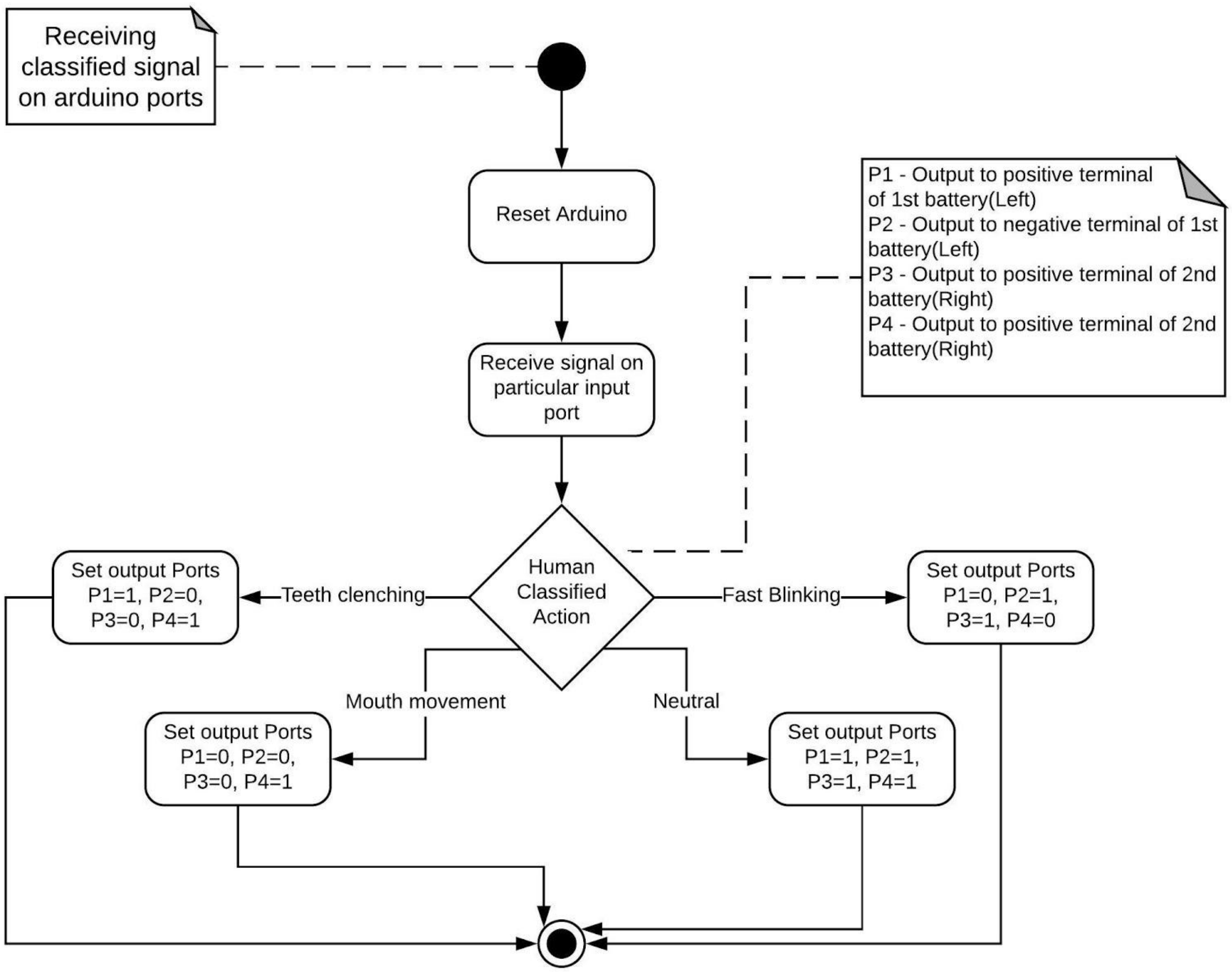


FIGURE 8: Receiving classified signals on arduino ports

This activity diagram aims at listing the steps required to receive classified action on arduino ports.

1. The arduino is reset to avoid any previously stored data interfere in current execution.

2. The signal is received on arduino ports based on the human classified action as shown above.

3. The arduino sets the corresponding values on the four output ports to move motors accordingly.

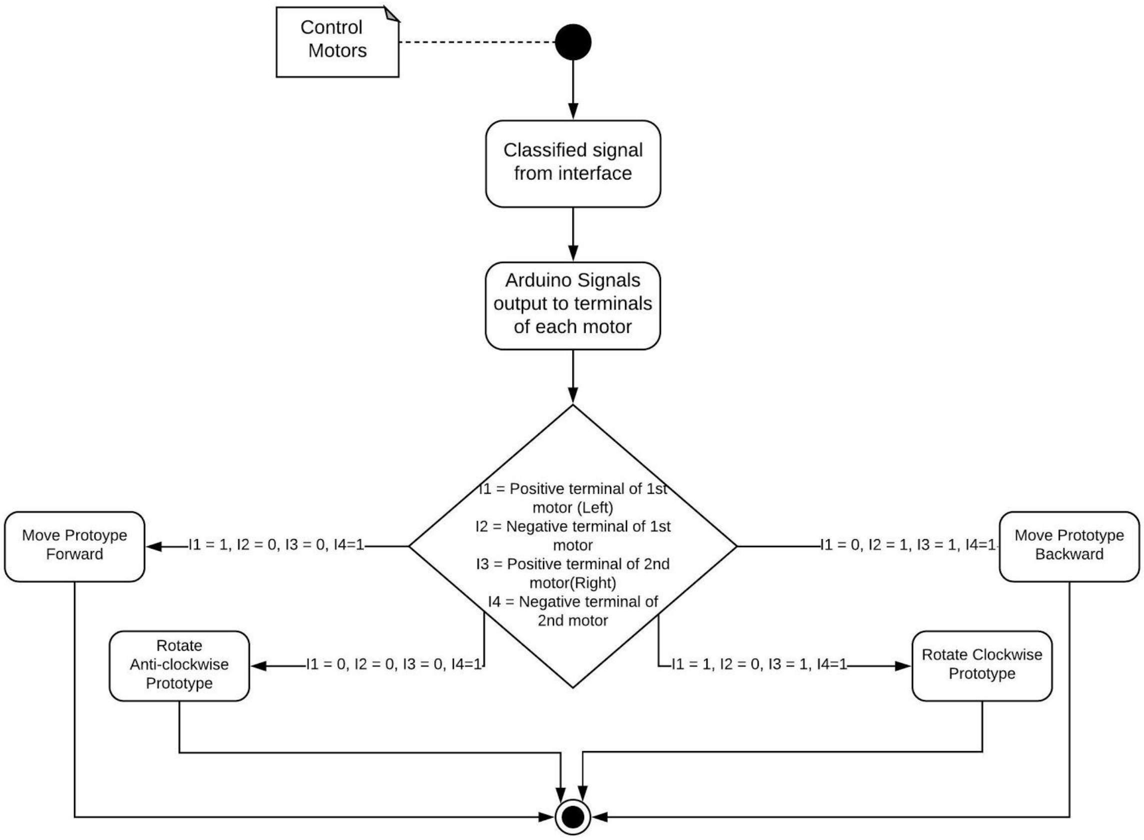


FIGURE 9: Control Motors

This activity diagram depicts how the motors are controlled.

1. The classified signal from is fed to arduino.
2. The arduino sets particular output ports with some values.
3. Based on the set output values, the motors rotate in particular direction with particular speed.
4. The buggy moves in desired direction.

3.1.6 Class Diagram

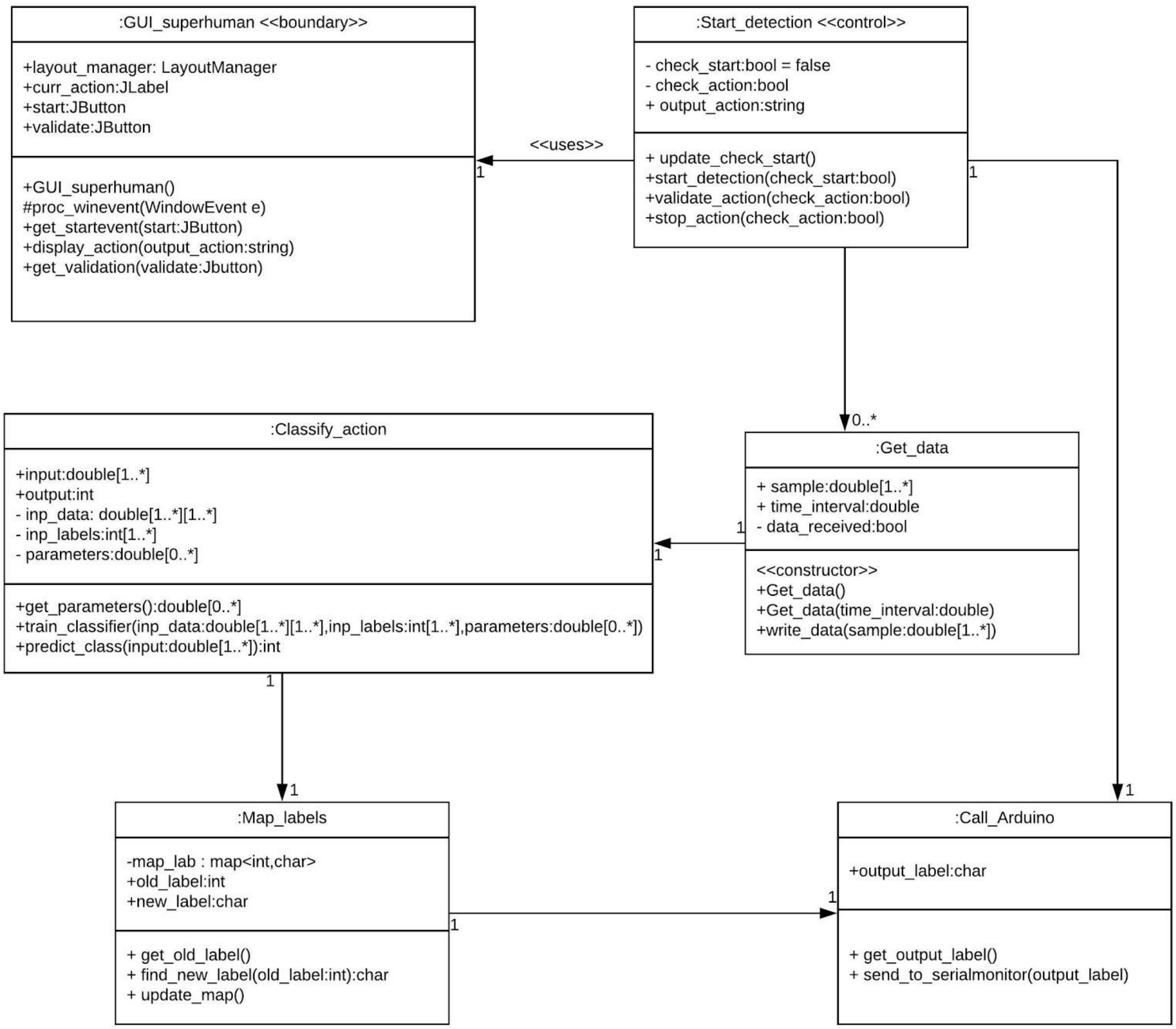


FIGURE 10: Class diagram

This is the class diagram of our project. There are in total six major classes. A brief description of all of them is given as follows:

1. GUI_superhuman: This is a boundary class which enables the user to interact with the software. Start/stop EEG detecion and validating the final predicted action by the user are the main functionalities.

2. Start_detection: This is the controller class. Once detection is started by the user. This class initializes the object of Get_data class. This class is also used to directly stop the app (using Call_Arduino class)from performing an action, once the user has claimed the predicted output to be wrong.
3. Get_data: This class is used to record data for data collection. It also has operations to detect the data for testing purpose.
4. Classify_action: This class has functionalities to train the classifier, or, predicting class based on detected data with the help of pre-trained clasifier.
5. Map_labels: This class contains a hashmap or dictionary to map numbered classes to their specific characters.
6. Call_Arduino: This class is used to send output character to serial monitor from where arduino performs that particular task.

3.2 Cost Analysis

TABLE 7: Cost Structure of all needed product

Product Name	Quantity	Price / Piece	Total Price
EMOTIV EPOC+ - 14 Channel Wireless EEG Headset	1 (Already acquired)	Rs. 20,000	Re. 0
Arduino Uno R3 with USB Cable	1	Rs. 500	Rs. 500
Jumper Wires	40	Re. 0.5	Rs. 20
DC Motors	4	Rs. 30	Rs. 120
Bluetooth Transceiver Module	1	Rs. 400	Rs. 400
4 Wheels Chassis		Rs. 800-Rs. 1200	Rs. 1200
Bio true Solution	1	Rs. 550	Rs. 550
Extension Board	1	Rs. 200	Rs. 200
Miscellaneous		Rs. 1500	Rs. 1500
Total			Rs. 4510

3.3 Word Breakdown structure

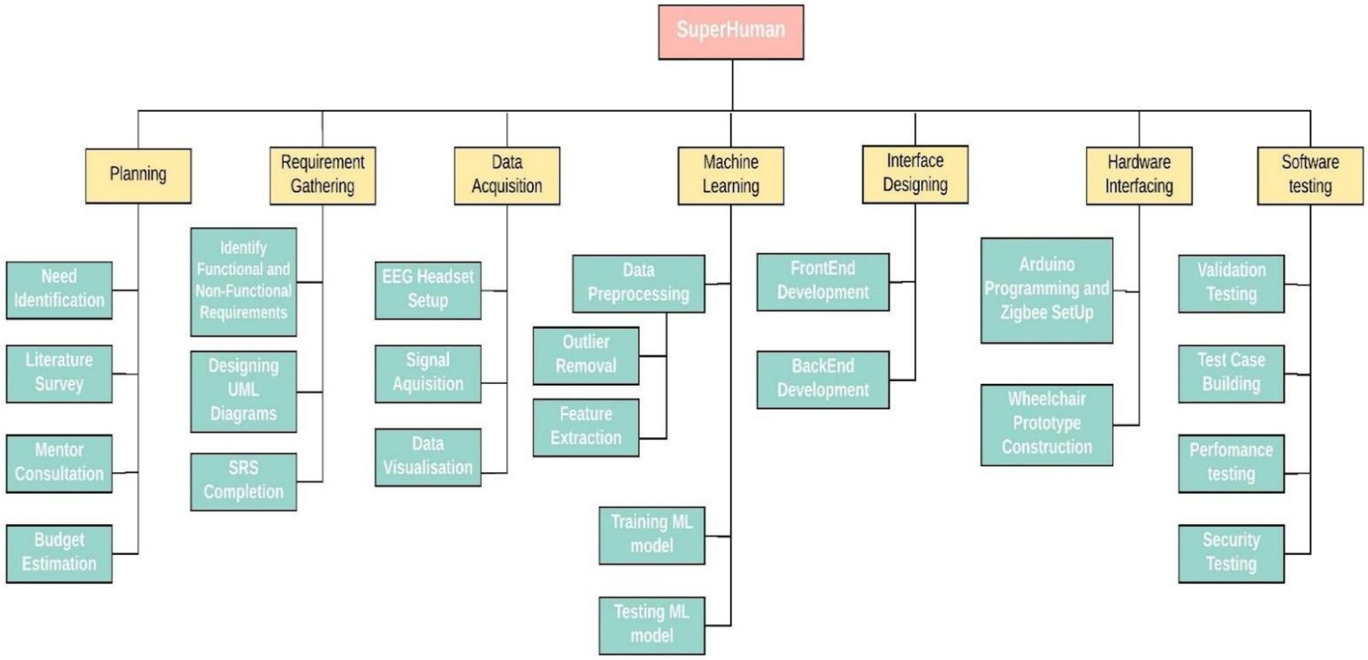


FIGURE 11: Word breakdown structure

4.1 Flowchart of the proposed system

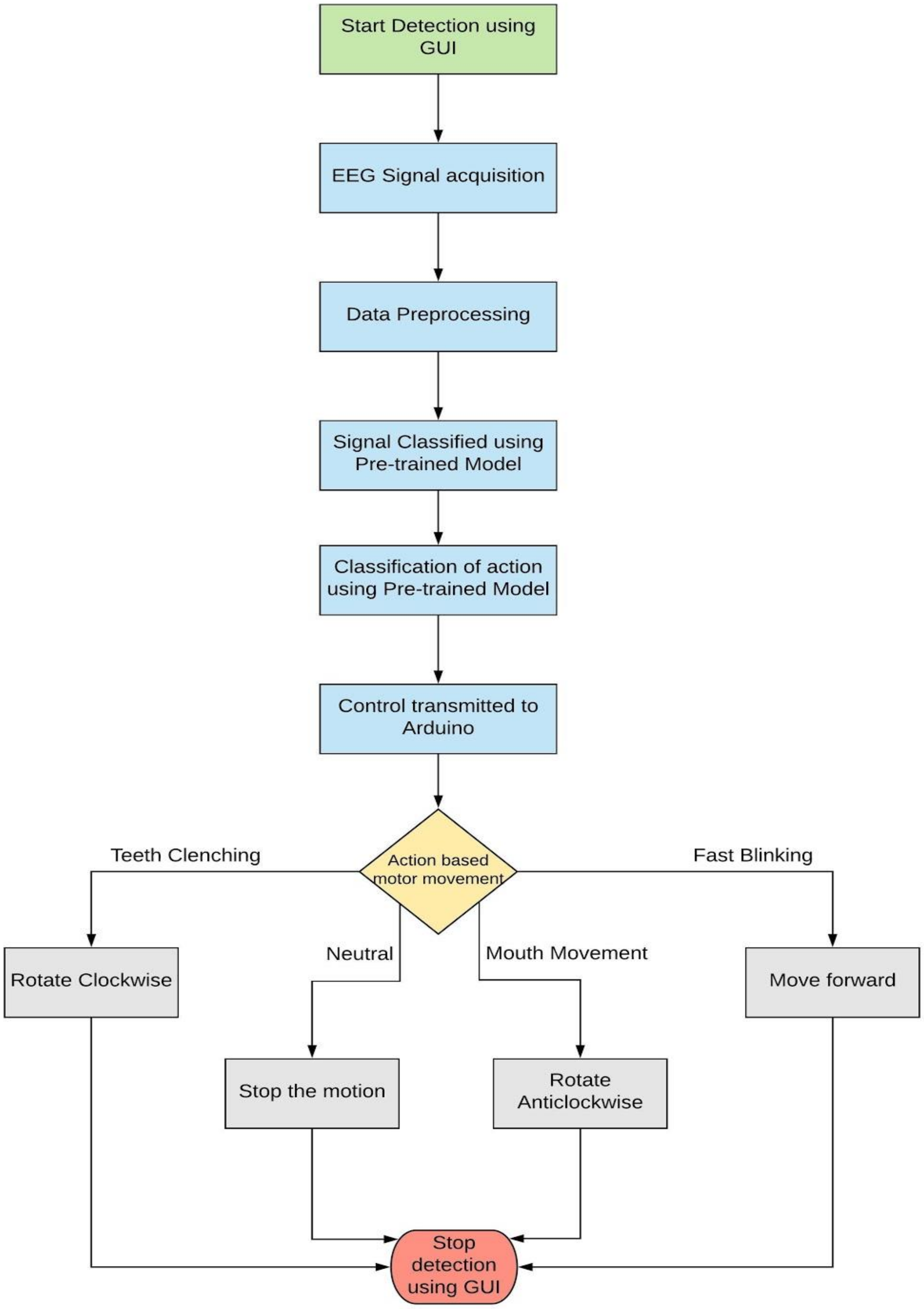


FIGURE 12: Flow chart of proposed system

In flow diagram in FIGURE 12, the input data from user is added to test dataset. Thus, test dataset is updated. The ML model is then run for the updated test dataset. The classified signal or the brain state is obtained as output. The arduino is reset to avoid any previously stored data interfere in current execution. The signal is received on arduino ports based on the human classified action as shown above. The arduino sets the corresponding values on the four output ports to move motors accordingly. The classified signal from is fed to arduino. The arduino sets particular output ports with some values. Based on the set output values, the motors rotate in particular direction with particular speed. The buggy moves in desired direction.

4.2 User Interface Diagrams

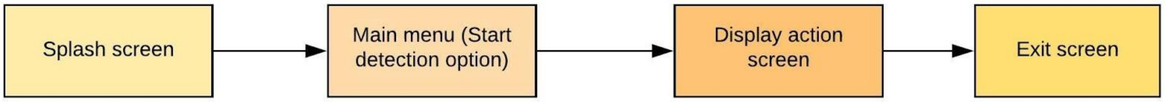


FIGURE 13: User Interface Flow Diagram

We are planning to start our application with a splash screen displaying our logo. Next will be a main menu with Start/stop detection buttons. Another screen to display the user's predicted action will be there along with a validation button. Last, there will be a dramatic exit screen.

4.3 System Components

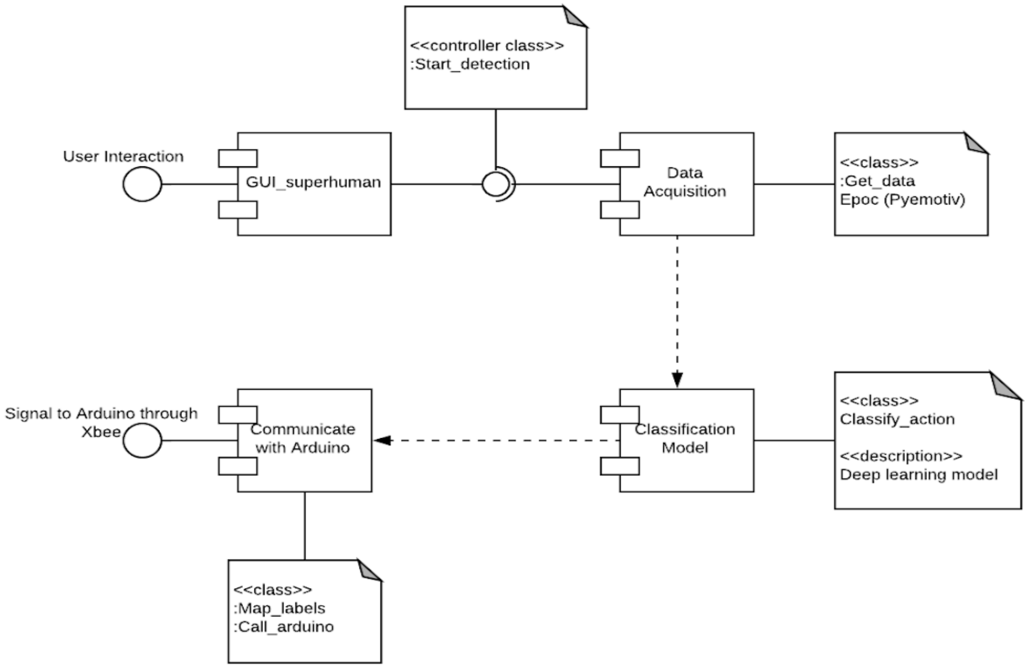


FIGURE 14: Component Diagram

This the component diagram of our project. The components have been explained below:

- GUI_Superhuman: This module contains the Graphical user interface of our software.
- Data Acquisition: This component is responsible for capturing EEG signals from the user's brain and preprocessing them.
- Classification Model: This component includes the pretrained model which will classify the brain states.
- Communicate with Arduino: This component includes all the programming of arduino and how arduino will get the signal to move the motors.

4.4 Snapshots of Working Prototype Model

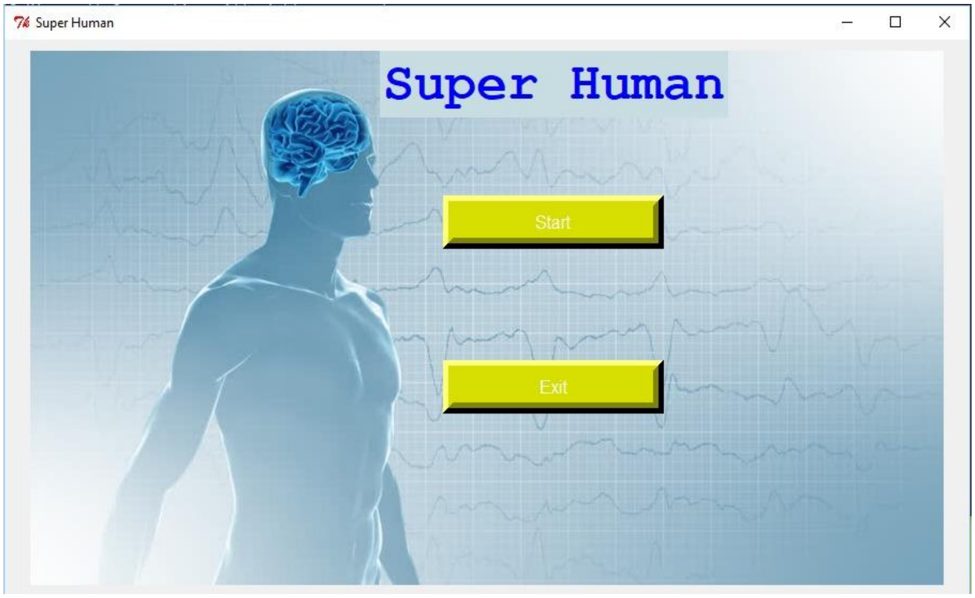


FIGURE 15(a): Snapshot of GUI of prototype

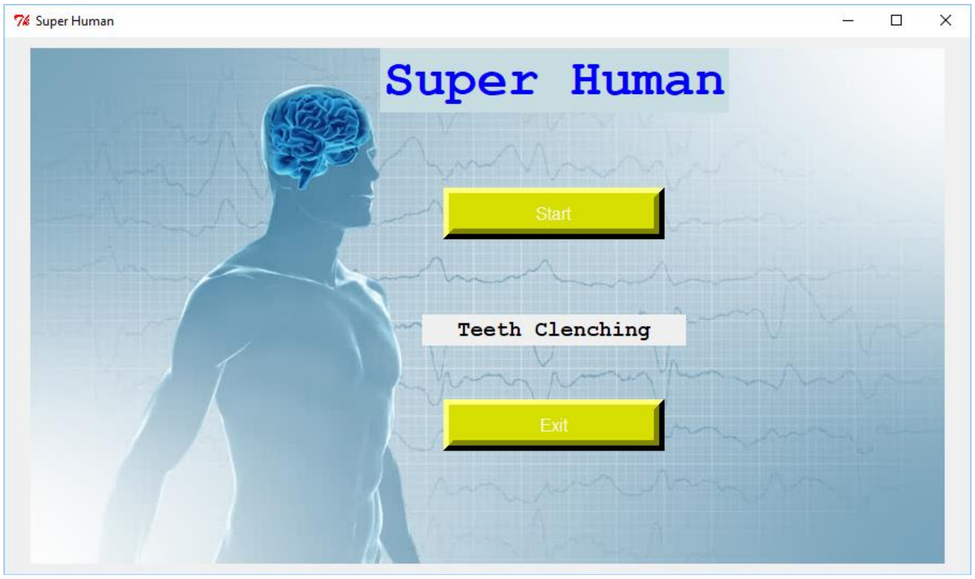


FIGURE 15(b): Snapshot of GUI predicting user's action

CONCLUSIONS AND FUTURE DIRECTIONS

5.1 Work Accomplished

The following three approved objectives have been completed (partially) as there is always space for some improvement.

- **To study research papers and other literature related to Brain Computer Interface.**

Extensive study of research papers related to the history of Brain computer interfaces have been done. We have also achieved a higher knowledge of different data acquisition techniques and the preprocessing techniques for the acquired EEG data. We have also read survey papers about comparisons between multiple machine learning algorithms and their combinations to achieve greater accuracy in terms of the predicted user thoughts.

- **To gather data and preprocess it to remove ambiguities.**

Data of 12 subjects have been collected. Each subject was asked to perform three actions:

1. Fast blinking
2. Mouth movement
3. Teeth clenching

Total of 14 x 50 attributes were extracted for each data tuple, labeled according to these 3 action states along with a neutral state.

- **To implement Machine Learning algorithms for classification of the data into various actions.**

We have done extensive research related to best machine learning algorithms for BCI. According to the literature, SVM gives greatest accuracy. We have implemented and compared the performance of 4 machine learning models on our data, which are:

1. Naive Bayes Classifier
2. Random Forest Classifier
3. Support Vector Machine (SVM)
4. Logistic Regression

cm_log - NumPy array

	0	1	2	3
0	61	1	2	0
1	2	4	10	6
2	1	0	23	2
3	0	1	17	9

FIGURE 16(a) Confusion Matrix of Logistic regression

cm_svm - NumPy array

	0	1	2	3
0	60	1	3	0
1	2	6	9	5
2	2	1	22	1
3	3	2	14	8

FIGURE 16(b) Confusion Matrix of SVM

cm_nb - NumPy array

	0	1	2	3
0	62	0	2	0
1	0	10	2	10
2	0	1	24	1
3	0	6	13	8

FIGURE 16(c) Confusion Matrix of Naïve Bayes

cm_ran - NumPy array

	0	1	2	3
0	62	0	2	0
1	0	16	1	5
2	0	1	25	0
3	0	14	9	4

FIGURE 16(d) Confusion Matrix of Random forest

5.2 Conclusions

We were able to figure out the usage of EEG softwares and APIs. We also successfully collected enough data to build the models. We were able to draw various UML diagrams/Analysis models. WE also prepared Software Requirement Specification and Project Report. Finally, we built SVM, Naïve Bayes, Logistic Regression and Random Forest on the data.

5.3 Environmental/ Economic/ Social Benefits

One of our biggest fears is being trapped in small, enclosed spaces. Now imagine being trapped inside of your own body. Completely conscious, you hear everything that people say around you and you can see perfectly fine. You have completely functional cognitive ability; the only problem is that you cannot move or speak. You strain to lift your legs so that you can find somebody, but they won't budge. You want to scream for help but your mouth does not open because your facial muscles are impaired. You are a prisoner of your own body and there is no way to communicate with the outside world. There is no way to escape until now. The medical term for being trapped in your own body is Locked-in Syndrome. This is where the patient has full awareness but is not able to communicate or move due to the paralysis of voluntary muscles. This fully paralyzing condition may not be common, but partial paralysis is a very real problem. Our project “Brain controlled wheelchair” may finally allow patients suffering from some form of paralysis to live more independent lives. This technology may be the light at the end of a long tunnel for those trapped in the prisons of their bodies.

The main social benefit with the accomplishment of our project is that it would help especially the dependent handicapped person to be an independent person in terms of maneuver and all kinds of motions.

5.4 Reflections or self learning

- We, initially, explored about brain waves capturing techniques. We found there are broadly two categories, i.e. invasive and non-invasive.
- Invasive technique may harm our brain as an electrode is inserted into the brain but EEG, being non-invasive technique helps to catch neural signals easily.
- We learnt about essential regions and their corresponding functions of brain namely Occipital lobe, Temporal lobe, Parietal lobe, Frontal lobe. Cerebral cortex, Cerebellum.
- We came across different mathematical techniques used in real time signal processing like fourier transformation, Principal Component Analysis, Linear discriminant analysis.
- We learnt about various machine learning models and the impact of different parameters on the accuracy of the models.

5.5 Future Work Plan

- Collection of even more data.
- Improving the accuracy of the model.
- Interfacing Arduino and motors.
- Improvements in the Graphical user interface

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