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# Brain computer interface based robot wheelchair control using motor Imagery

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**Abstract**
Electroencephalography (EEG) is used in measuring the electrical activity of the brain which is generated by billions of nerve cells. In the proposed system eight electrodes were used to capture the motor imagery of EEG from the brain to build a Brain Computer Interface (BCI) based real time control for wheelchair to help the disabled persons. The input signals of Forward, left, right and backward are the four motor imagery movement of EEG signals are recorded. Using the EEG signal activate the robot wheel chair by Hamming Window Technique and Fast Fourier Transform (FFT) for feature extraction of the Beta and Mu wave frequency bands. Classification of the movement of wheel chair such as forward, left, right and backward motion occurs using statistical calculation. Degree of contribution developed using the ANOVA reveals that Forward, Right, Left, and Backward motion has 95.84%, 88.11%, 95.28 and 97.88% contribution, respectively in different subject to robot motion wheel chair. Large FAo value 1206.08 of backward motion indicates that the variation of the robot motion parameter makes a big change on the accuracy of wheel chair movement. The experiment results confirmed that this system can provide an accurate manner to control a wheelchair in real time. Based on the motor imagery the system would be allowed to the user to operate the wheelchair easily and reach the goals efficiently and accurately.

**Keywords:** Electroencephalography (EEG), Brain Computer Interface, Robot wheel Chair,

## 1. Introduction

Brain Computer Interfacing (BCI) has been one of the growing fields of research and development in recent years. An Electroencephalogram (EEG) based Brain Computer Interface (BCI) provides a new communication channel between the human and a computer. The Brain Controlled Wheelchair (BCW) was designed to provide mobility to individuals who have lost most voluntary muscle control, but who are able to use a BCI. The low signal-to-noise ratio and low spatial resolution of the data can degrade the translational performance of the BCI. The low classification signal problem and the uncertainty in commands of the BCI systems, the user have need a additional concentration and time to navigate the wheelchair to the desired location. A BCW control strategy that reduces the total time required to complete a task and the concentration effort imparted by the user. Millions of people around the world suffer from mobility impairments and hundreds of thousands of them rely upon powered wheelchairs to get on with their activities of daily living. However, many patients are not interested the powered wheelchairs because they are physically unable to control and activate the chair using the conventional interface, or because they are thinking that incapable of driving safely.
Consequently, it has been estimated between 1.4 to 2.1 million wheelchair users might benefit from a smart powered wheelchair, if this is to provide a degree of additional assistance to the driver .This work mainly targets a population who are or will become unable to use conventional interfaces, due to severe motor disabilities. To meet the challenge of affording people with the greatest level of disability the ability to control sophisticated prosthetics, BCI control schemes allow the movement of a robot to be guided by signals directly recorded from the brain. Patients with conditions ranging from spinal cord injury to Amyotrophic Lateral Sclerosis (ALS) and locked-in syndrome could potentially greatly benefit from control schemes based on BCI.

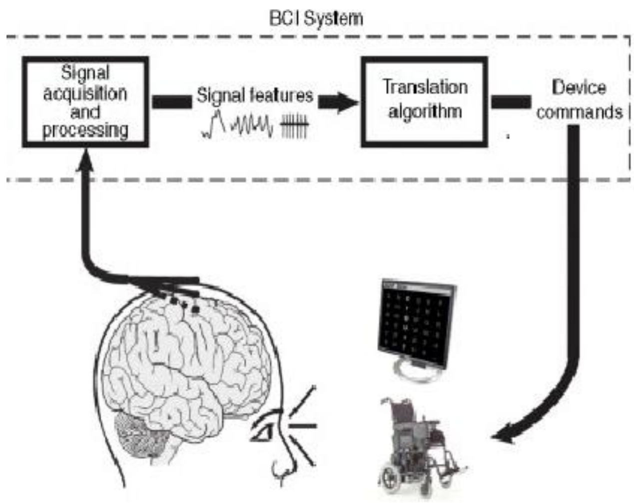


**Fig.1 Overview of the BCI system**

Even for amputees and patients capable of a significant amount of volitional motor movement, direct brain interface could be the most intuitive way to control robot wheelchair.

The overview and flow of BCI system has shown in Fig.1.Using the motor imagery the EEG based brain actuated wheelchair system. To overcome the limitations of existing work of gaze dependence and unnecessary stops four motor imagery commands was introduced (like Forward, left, right and backward) were decoded based on the motor imagery correlates with EEG signals. Motor imagery is a mental process by which an individual rehearses or simulates a given action used in sport training as mental practice of action, neurological rehabilitation process. This type of phenomenal experience implies that the subject feels himself as performing action. It corresponds to the so-called first person perspective of sport psychologists. Motor control is located in the motor cortex of the brain, and different limbs control is linked to specific areas of this cortex. The outstanding property of these signals is to behavior when someone merely imagines movements, because this causes a change with similar features, although with notably lower amplitude.

Motor Imagery (MI) defines that the imagination of physical movement produces a changes in the sensory motor cortex. In example, imagination of left and right middle finger imagination produces changes, namely (de-)synchronization on electrode positions around C3 and C4. Good features are around 10 and 20 Hz. The motor imagery features will be extracted from user's raw EEG signals. The EEG signals will be spatially filtered using Common Average Reference (CAR) and then band-pass filtered between 8-32Hz. The wheelchair system offers a convenient and efficient user interface for a motor imagery based BCI. In addition, the system could be integrated with various techniques by modularization. In previous wheelchair systems and those based on Steady State Visually Evoked Potentials (SSVEP) did not offer such convenience to user, since they had to keep watching a screen constantly in order to extract commands from EEG signals.

### 1.1 Literature Review

A survey has carried out on research papers based on brain computer interface, electroencephalogram, automated navigation and signal processing to gain knowledge and to implement this study on to wheelchair. Abdul et al.,[1] exposed about the extraction of the brain signals using the feature extraction techniques like time analysis, frequency analysis, time-frequency analysis and time-frequency-space analysis. Extracted features are classified using artificial neural network trained with the back propagation algorithm. The EEG signal are collected and some special filters used for preprocessing. Back propagation algorithm is adaptive for complicated nonlinear systems because of little input variables, simple configuration and high precision and strong learning ability. The future to build a hardware model for the EEG feature-extraction and classification system using the Gate Array program field. Al-Haddad et al.,[2] has proposed a EOG signals eye gazing and blinking are used to control the motorized wheelchair to automatically navigates in the desired goal point. Blinks and gaze angle are measured and taken as inputs for the controlling method. Tangent Bug algorithm is build to navigate the wheelchair in Auto controlling method. The new auto navigation method was done by microcontroller which knows the goal point direction and distance by calculating the gaze angle that the user is gazing. Future work to integrate Human Computer Interface (HCI), wheelchair and EOG system together.

Barea et al., [3] has proposed a Electrooculography (EOG) based wheelchair system for disable peoples which is control by the ocular position (eye displacement into its orbit).sensors and graphics user interface are used as a feedback system. Carlson et al., [4] has evaluated a shared control system, placing particular emphasis on the human factor analysis. A suite of tools, including joystick signal analysis, secondary tasks, and eye tracking, which enabled people to drive the wheelchair safely, at a slight cost in time, while concurrently reducing the demands on visual attention, cognitive workload, and manual dexterity. Francisco et al., [5] has proposed a BCI based wheelchair system was controlled without a graphical interface and audio-cued paradigm with several navigation commands to reduce the misclassification probability. This system works in particular environment only, in future want to work in any environment. Galan et al.,[6] has studied about to assess the feasibility and robustness of an asynchronous and non-invasive EEG-based Brain–Computer Interface (BCI) for continuous mental control of a wheelchair. The system can be autonomously operated by the user without the need for adaptive algorithms externally tuned by a human operator to minimize the impact of EEG non-stationarities.

Jan et al., [7] has valuated about the Brain-computer interface (BCI) technology is a potentially powerful communication and control option in the interaction between users and systems. At present, most BCI applications focus on assistive care, providing an alternative communication medium for those who cannot use a keyboard or mouse, but applications have the potential to include any task that would benefit from interaction beyond the keyboard. Jose et al., [8] has proposed a mobile robot with the combination of Asynchronous EEG analysis and machine learning techniques for controlling rapid and complex sequence of moments. The mental high-level commands executes the robot autonomously using its on-board sensors, the sensors commands are guarantee obstacle avoidance and smooth turns. The feedback system will give the result and movement. This experiment was held in a house with different rooms without any collision and safety. Mental control was more good comparable to manual control. Future work was to improve the machine learning and to convert it to online commands. Kam et al., [9] has studied about non-homogeneous spatial filters on the time-frequency domain for EEG based multi-class motor imagery classification. We certified that considering different sets of basis signals at different time-frequency segments leads increase of classification accuracies. While the proposed method enhanced the performance, it used a filter 28 bank with a fixed bandwidth dissecting a wide band of interest into smaller ones across subjects without considering spectral variation in task relevant brain responses.

Keun et al.,[10] has proposed a EEG based brain-actuated wheelchair system using motor imagery to overcome some of the problems facing by the user like gaze dependence and unnecessary stops. The system was modularized into BCI, control, and network, by this conclusion the user can control the Brain –actuated wheelchair in multi-directional (left, left-diagonal, right, right-diagonal, and forward). Robotics and computer vision techniques are used to increase the safety. Millan et al., [11] has studied about the novel idea of controlling robots by mapping asynchronously high-level mental commands into a finite state automaton. This automaton is a key feature for the efficient control of the mobile robot. Such an efficient control could not been achieved with a naive, direct mapping of mental commands into robot motor actions. The possibility of physically disabled People to use a portable EEG-based brain-machine interface for controlling wheelchairs and prosthetic limbs. Muller et al.,[12] has studied about how a viable brain-actuated wheelchair can be constructed by combining a brain–computer interface with a commercial wheelchair, via a shared control layer. The shared controller couples the intelligence and desires of the user with the precision of the machine. It found that this enabled both experienced and inexperienced users to safely complete a driving task that involved docking to two separate tables along the way. Onose et al.,[13] has proposed a EEG-BCI robotic arm for the chronic tetraplegic person using the motor imagery. Cluster analysis, Statistics entailed multiple linear regressions and decoding methods are used for the cerebral motor commands. The camera is used to record the eye movement of the user and the visual feedback system us used. Future wants to increase the reliability of the robot arm and the motor imagery commands.

Pablo et al.,[14] high-frequency SSVEP based BCI with high frequency flickering stimulation was proposed also power spectral density analysis was done to reduce the error command rate. The BCI system achieves high ITR (integrated test range) and the user reaches the goal safely. By the SSVEP visual stimuli the evade obstacles, avoid collisions. Rajesh et al., [15] has proposed a thought controlled wheelchair by the captured brain signals and process it to control the wheelchair. 2D cursor control BCI techniques were to control the wheelchair. By imagining his right hand motion and the left hand motion imagination is to move the wheelchair right and left. The horizontal motion mu beta rhythm for forward and vertical motion is based on P300 potential for backward. Atmegha microcontroller is used to control the drives system. In future want to improve the accuracy and speed of the system. Rebsamen et al., [16] has studied about to develop a brain controlled wheelchair for navigation in familiar environments, decided to use a slow but reliable interface for destination selection, and motion guidance for safe and autonomous navigation. The results obtained with healthy subjects demonstrate that the strategy enables to move the wheelchair in a building environment safely, efficiently, with limited effort and in a reasonable time. Sandesh et al., [17] has proposed a system for disable peoples to guide and control the wheelchair through the Human Computer Interaction (HCI). Using the camera the Eye movement was detected and control the devices using the Image Processing. The system has two stages eye movement detection and sending of control signals to the wheelchair. The system can be proposed to control the equipments such fans, lights, etc. The software can be modified, and along with sound synthesis can be used to generate voice commands.

Saugat et al., [18] has proposed a human controller autonomous mobile robot trough the BCI from motor imagery with control mechanism. The paper employs the usage of finger-elbow-shoulder movement and the left-right imagery. The control signals detect the error and the efficient of EEG signal encoded to the robot control system. The classified results generate a control code and transmit to Khepera robot through radio transmission after encryption using codebook. The receiver system will decode and remove the error and form an efficient code. The future is to develop the control system and improve robot motion control. Samuel et al., [19] has studied about the model relating arm movement to neuronal population activity in the motor cortex, there have been efforts to recruit this activity to control external devices directly with the brain. Brain-computer interface (BCI) prosthetic devices have the potential to aid the over 250,000 people in the US alone who suffer from debilitating motor deficits such as spinal cord injury and ALS. BCI systems can do this by bypassing motor lesions located outside of the CNS, cortical activity reflecting subject intent can instead be expressed directly by action in a machine.

Siuly et al., [20] has proposed a algorithm to extract the motor imagery (MI) data from the typical patterns of electroencephalography (EEG) signal. Cross-correlation based logistic regression (CC-LR) algorithm was introduced first for the classification of the EEG signal and later modified version of CC-LR algorithm with three diverse feature sets where the input was take to the LR classifier. This will gives the detail about how to select reference channels which are suitable for the problems. The performance of this algorithm was high compare to others. The future work to propose this algorithm to extend for the multiclass motor imagery (MI) tasks EEG signal classification. Tom et al., [21] has proposed to overcome the struggles of the powered wheelchair users by the help of collaborative control mechanism. This mechanism will control the signals and achieve the goal safely. The eye tracking has done. Multiple collisions while driving was reduced. The future work is to reduce the use of joystick movement in the Brain Computer wheelchair. Vijay et al.,[22] has proposed a BCI wheelchair to help handicapped persons to achieve the goal using only eight electrodes to get the EEG signal from the scalp. Wavelet Packet Transform (WPT) was used for feature extraction of signal and Radial Basis Function Neural Network (RBFNN) for classification. It is safe, low coast and provides optimal interaction between the wheelchair and the user. In future, planning to reduce the number of reference channel (electrodes) and to improve the classification method. Yongwook et al.,[23] has proposed an Asynchronous noninvasive BCI based navigation system for a humanoid robot, experimental procedure undertake three different session's offline learning, online feedback test and real time control of robot in an indoor maze. Laplacian filter is used to extract the EEG. The robot was serviced through the visual feedback system. The system proposed optimal feature selection and hierarchical classification to improve accuracy. By the help of Asynchronous control and the visual feedback information the subject can modify the movement quickly. The future work is to test this system for more subjects because now they test for only two subjects.

From the literature surveyed, knowledge on working of BCI system and the signals generated from the brain had been gained. A method to eliminate the noise in the obtained brain signal from the user had been learned. The interfacing of the brain signal with the wheel chair has been surveyed. Based on the signal obtained from the brain, the controlling of wheel chair system had been analyzed. Based on the study, the use of Fast Fourier Transform and various window techniques for feature extraction and classification of the signal of the robot had been decided as a better option. Using window technique, specific function can be defined for specific command. The main objective is to control a wheelchair through signals from the brain and based on that signal wheelchair is navigated in the environment.

## 2. Research Methodology

This research work is to take BCI technology beyond the demonstration stage to the real world applications, so that the quality of life for paralyzed patients is improved. Detected the changes in the EEG patterns due to mental tasks. Investigated the controlling of a power wheelchair by mental tasks (EEG signals). This was an attempt to control direction of wheelchair through brain signals.

### 2.1 Brain actuated robotic wheelchair

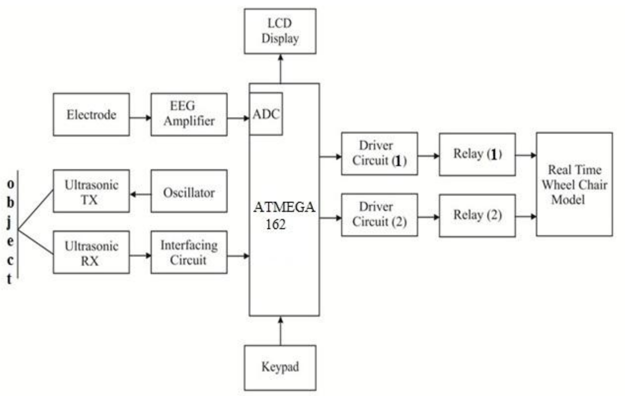


**Fig.2 Architecture of brain actuated robotic wheelchair**

This work is used three major steps to implement from planning, implementing and testing. All the methods used for finding and analyzing data regarding wheelchair motion control. Fig.2 shows the overall robotic architecture of brain actuated wheelchair. In begin discussing the brain computer interface the human is central to the design philosophy. The wheelchair hardware and modifications are described, before explain how the shared control system fuses the multiple information sources in order to decide how to execute appropriate man oeuvres in cooperation with the human operator. Finally, the present results of an experiment involving four healthy subjects and compare them with those reported on other brain–actuated wheelchairs. Find that our continuous control approach offers a very good level of performance, with experienced BCI wheelchair operators achieving a comparable performance to that of a manual benchmark condition. EEG electrode output signal connected to ADC device. ATmegha162 a microcontroller connected with ADC input signal and the Relay connected in Output device, which controls the wheel chair motor. Ultrasonic sensor used to detect the obstacle avoidance of the object.

Brain-Controlled electric wheelchair could be shown that how to make a person become mobile without moving their body. Paralyzed people could be useful to physically activate the joystick of an electric wheelchair. Use the BCI technology to gain some independence, and to take a break from needing an attendant to push their wheelchair so that they can get some fresh air. Robot system includes an electric wheelchair, interface circuit, EEG headset, and the data collection using ready-made and custom software. The electrical nature of the human nervous system has been recognized for more than a century. It is well known that the variation of the surface potential distribution on the scalp reflects functional activities emerging from the underlying brain. This surface potential variation can be recorded by affixing an array of electrodes to the scalp, and measuring the voltage between the pairs of these electrodes, which are then filtered, amplified and recorded. The resulting data is called the EEG. Fig.3 has explains the waveform of an 8 second EEG segment containing 20 recording channel pairs when the subject was asked to close his eyes first and then open his eyes, thus we have two spikes and these waveforms can be processed and used in switching applications like switching the lights OFF and ON.

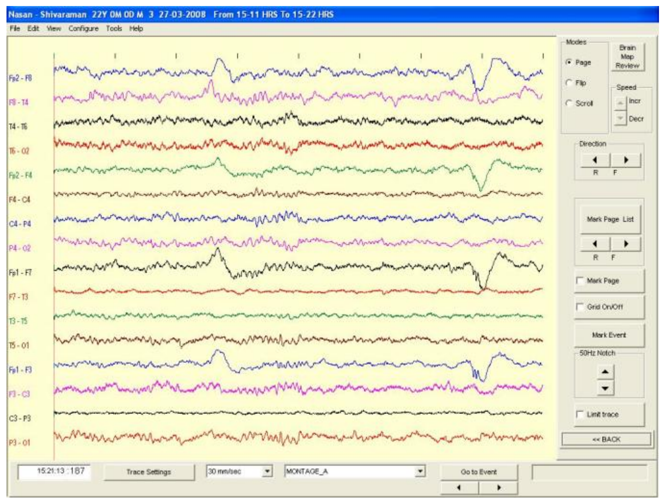

**Fig.3 A segment of a multichannel EEG of a subject performing a task.**

### 2.2 10-20 System of electrode placement

The electrode locations and names are specified by the International 10-20 system as shown in Fig.4 for most clinical and research applications.

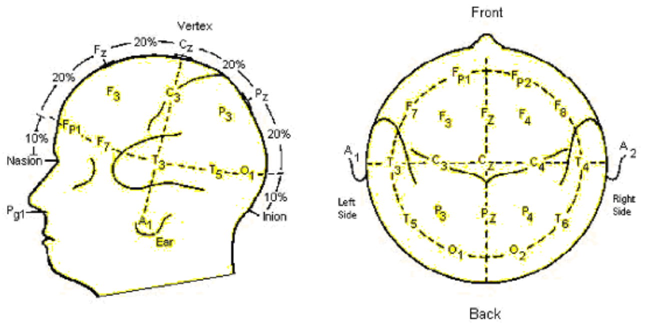


**Fig.4 International 10-20 Electrode Placements**

The 10-20 system is widely used to describe the location of scalp electrodes in the context of an EEG experiment. The system is based on the relationship between the location of an electrode and cerebral cortex. The 10 and 20 refer to the fact that the actual distances between adjacent electrodes are either 10 % or 20 % of the total front-back or right-left distance of the skull. Each site has a letter to identify the lobe and a number to identify the hemisphere location. The letters F, T, C, P and O stand for Frontal, Temporal, Central, Parietal and Occipital respectively [6]. Note that there exists no central lobe; the C letter is only used for identification purposes only. Z refers to an electrode placed on the midline. Even numbers (2, 4, 6, 8) refer to right hemisphere electrode positions, and odd numbers (1, 3, 5, 7) refer to those on the left hemisphere electrode position.

Two anatomical landmarks are used for the essential positioning of the EEG electrodes:

- **Nasion** which is the point between the forehead and the nose.
- **Inion** which is the lowest point of the skull from the back of the head and is normally indicated by a prominent bump.

The successful working of the robot requires the synchronized working of mechanical structure, the electronics setup and the user cooperation. Fig.5 shows the block diagram of the setup.

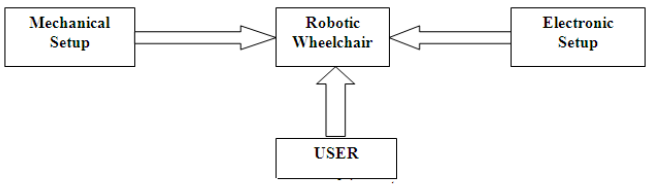


**Fig.5 Block Diagram of the prototype**

### 2.3 Mechanical Structure

The mechanical structure of the Robotic wheelchair consists of two wiper motors are fixed at left and right side of the wheelchair. To the end of each wiper motor a round shaft was welded which is help to rotate the wheel of the wheelchair. When the motor start to rotate the shaft present at the end of the motor also start to rotate, then it will help to move the wheelchair. Fig.6 shows the mechanical assembly of the Robotic wheelchair.


**Fig.6 Wiper motor with Shaft**

### 2.4 Electronic Setup

The classification of four mental tasks (motor imagery) Left, Right, Forward and backward has been carried out with the output of the classifier was interfaced with the motor using parallel port. Each direction (left, right, forward and backward) of the wheelchair corresponded to four mental tasks. Using parallel port, Motor driver IC was interfaced with microcontroller as shown in Circuit Diagram for the wheelchair controller. In the circuit, P1 acts to enable the chip and combination of P2 and P3 were used to control direction of wheelchair. All four direction of wheelchair movement were properly controlled by this designed circuit. An electric wheelchair was controlled by two permanent magnet DC wiper motors shown in Fig.1. Signals from the user were taken as the input and micro controller convert the analog signal into digital signal. They were changed to electronic signals by Pulse Width Modulation (PWM) control of a micro controller unit (MCV, Atmega152). The electrical signal was amplified using the two batteries in the control circuit that operate the two motors corresponding to the main drive wheels of the chair. Then, the travelling direction of the wheelchair was operated by the PWM control. For example, in left-diagonal command, the right wheel was rotated at twice the velocity of the left wheel, by changing the pulse width modulation.

For Left imagery task, the output of parallel port would be [0 1 0 1]. Due to opposite polarities, M2 motor would move forward and M1 motor backward which would be lead to Right movement of the wheelchair. For Forward task, the output of parallel port would be [0 1 1 0] both motors M1and M2 move forward resulting forward movement of the wheelchair. For Right task, the output of parallel port would be [1 0 1 0]. Due to opposite polarities, M1 motor moves forward and M2 motor backward resulting Left movement of the wheelchair. For Backward, the output of parallel port would be [1 0 0 1]. Due to same polarities, both motors M1and M2 move backward resulting backward movement of the wheelchair. Similarly, for stop tasks output of parallel port would be [0 0 0 0] and the wheelchair would be control by different polarities at the motors.

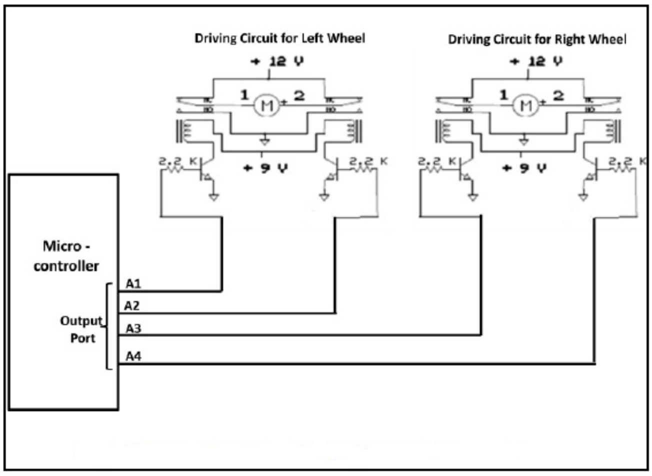


**Fig.7 Interfacing of Micro-controller and Driving circuit**

The micro-controller sends of the signals to the wheelchair controller so as to get following results. The micro-controller is interfaced with the wheelchair controller as shown in Fig.7.

## 3. Result and Discussions

The programming language used to write program for the robotic wheelchair was the Embedded C. Embedded C is a set of language extensions for the C Programming language by the C Standards committee to address commonality issues that exist between C extensions for different embedded systems. MPLAB IDE is a software which was used to run the robotic wheelchair program to compile, debug and used to find the error if any. This MPLAB give the correct output after compiling. MPLAB IDE is a software program that runs on a PC (Windows, Mac OS, and Linux) to develop applications for Microchip microcontrollers and digital signal controllers. It is called an Integrated Development Environment (IDE), because it provides a single integrated environment to develop code for embedded microcontrollers. Design of the Robotic wheelchair model done using solid work design software. The model of Robotic wheelchair design has been shown below Fig.8.

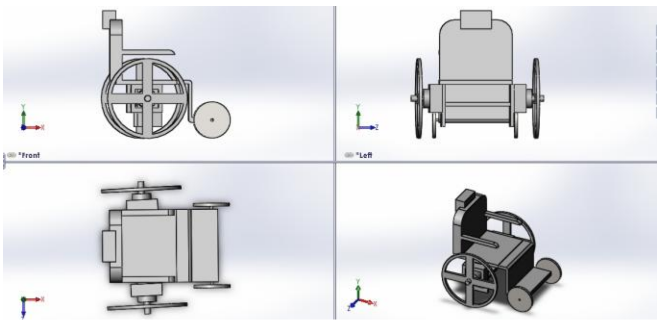

**Fig.8 Design of the wheelchair**

The plan view of a person using a wheelchair shows the following: width of the wheelchair measured to the outside of the rear wheels is 660 mm. Length of the wheelchair is 1065 mm measured from the back of the rear wheels to the front of the footrests. An additional 150 mm is shown in front of the footrest for toe/foot space because the footrest only supports the heel and not the entire foot. The width between the footrests is shown as 455 mm. The NeuroSpy system records and enables review of electro-encephalogram along with the subject's video, diagnosing their nervous system. The distinctive feature of this software is the full frequency response of 0.1Hz to 70Hz and it is a windows based digital EEG machine. It has facility to save 24Hrs of EEG data and video images. EEG Data used was recorded on a Grass Telefactor EEG Twin3 Machine as shown in Fig.9 used at Department of Neurology, SRM Hospital, Kattankulathur, Chennai. EEG recording for five healthy male subjects having no sign of any motor- neuron diseases was selected for the study. A pro-forma was filled in with detail of their age and education level. The participants were student volunteers for their availability and interest in the study. EEG data was collected after taking written consent for participation. Full explanation of the experiment was provided to each of the participants.

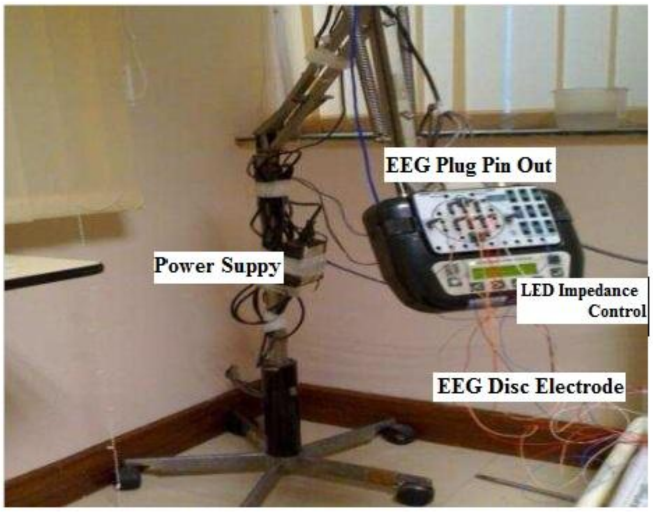


**Fig.9 Grass Telefactor EEG Twin3 Machine**

Data was recorded for 10 sec during each task and each task was repeated five times per session per day. EEG was recorded using eight standard positions C3, C4, P3, P4, O1, O2, and F3, F4 by placing Ag-Agcl silver electrodes on scalp, as per the international standard 10-20 system of electrode placement as shown in Fig.9. The reference electrodes were placed on ear lobes and ground electrode on forehead. EEG signals are filtered in the 1-35 Hz frequency band, i.e. the effective EEG frequency support. Fig.10 has shows the user after fixing the Electrodes in scalp.

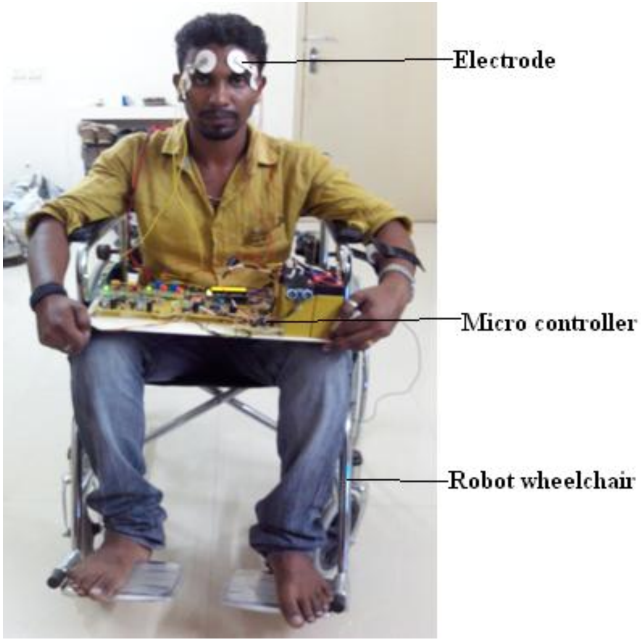


**Fig.10 Subject with electrodes on scalp**

The data collection setting are low pass filter 1Hz, high pass filter 50 Hz, sensitivity 150 micro volts/mm, sampling frequency fixed at 500 Hz and sweep seep fixed at 30mm/s. As power line and other electromagnetic noise sources have frequency supports beyond 35 Hz such filtering removes most of this noise. Eye blink artifacts are very common in EEG data they produce low-frequency high-amplitude signals that can be quite greater than EEG signals of interest. Indeed, while regular EEG amplitudes are in the range of -50 to 50 micro volts eye blink artifacts have amplitudes up to 100 micro volts.

### 3.1 System Testing

The user was sit in the robotic wheelchair after that fix the four electrodes C3, C4, F3,and F4 in forehead and the ground electrode is fixed in hand shows in Fig.10. The subject was asked to plan movement by the mental task. If the user motor imagery was right means the signals will take from the brain and send it to the microcontroller Atmegha. The signal was converted into digital signal and compiler present in the micro controller will compile the program and compare with the present signal value and already stored offline data. If the digital signal value is match in between 30 to 45 means the robotic wheelchair will move towards right. If the offline value is in between 46 to 49 means the robotics wheelchair will moves towards forward and if it is 50 to 60 it moves to left. For backward movement the range is 63 to 69.

**Table.1 Offline Data of BCI Signal for wheel chair motion**

| SUBJECT | FORWARD | RIGHT | LEFT | BACKWARD |
|---|---|---|---|---|
| 1 | 45.46 | 30.26 | 55.29 | 56.95 |
| 2 | 46.95 | 44.46 | 50.62 | 62.83 |
| 3 | 47.24 | 36.79 | 50.45 | 68.90 |
| 4 | 50.89 | 38.49 | 56.09 | 64.89 |
| 5 | 42.56 | 53.76 | 59.45 | 66.89 |
| 6 | 45.88 | 45.68 | 49.56 | 61.86 |
| 7 | 46.45 | 34.89 | 60.13 | 52.89 |
| 8 | 59.56 | 38.52 | 52.45 | 61.98 |
| 9 | 48.23 | 50.90 | 54.89 | 59.23 |
| 10 | 47.42 | 33.52 | 58.98 | 63.12 |
| 11 | 44.89 | 37.98 | 44.66 | 59.34 |
| 12 | 49.90 | 36.23 | 59.89 | 61.45 |
| 13 | 48.12 | 55.90 | 39.45 | 58.90 |
| 14 | 57.68 | 34.89 | 48.98 | 63.19 |

Table.1 is the final resultant table which was obtains by using the manual calculation method and various window technique for signal recorded for the subjects.

#### 3.1.1. ANOVA Analysis

The purpose of analysis of variance is to find the significant factors affecting the robot to improve the motion characteristics of brain computer interfaced based robot. ANOVA gives clearly how the motion parameters affect the response and the level of significance of the factor considered. The ANOVA table for right, left, forward and backward motion parameters of robot is calculated. In the ANOVA Table.2-5, the effects of forward motion of wheel chair robot analysis with control parameters are statistically significant at 95% confidence level. Value of $R^2$ is 0.9789 of backward motion, which signifies that the model can reasonably explain 97.89% of the variability in robot motion. The adjusted R squared ($R^2$ adj) for the model is 0.9781, which is very close to the value of ordinary R squared ($R^2$), i.e. 0.9789. Thus, it can be stated that no non-significant terms are included during empirical model building for robot motion analysis. Degree of contribution developed by using ANOVA reveals that Forward, Right, Left, and Backward motion has 95.84%, 88.11%, 95.28 and 97.88% contribution, respectively in different subject to robot motion wheel chair. Larger FAo value 1206.08 of backward motion indicates that the variation of the robot motion parameter makes a big change on the accuracy of wheel chair movement.

**Table.2 ANOVA analysis for Forward motion signal of Wheel chair**

| Parameters | Degree of Freedom (f) | Sum of Squares (SSA) | Variance (VA) | FAo | P | Contribution (%) |
|---|---|---|---|---|---|---|
| Forward motion signal | 1 | 11858.6 | 11858.6 | 598.21 | 0.000* | 95.84 |
| Error | 26 | 515.4 | 19.8 | | | 4.16 |
| Total | 27 | 12374.0 | | | | 100 |

**Significant S = 4.452 R-Sq = 95.83% R-Sq(adj) = 95.67%*

**Table.3 ANOVA analysis for Right motion signal of Wheel chair**

| Parameters | Degree of Freedom (f) | Sum of Squares (SSA) | Variance (VA) | FAo | P | Contribution (%) |
|---|---|---|---|---|---|---|
| Right motion signal | 1 | 7797.9 | 7797.9 | 192.72 | 0.000* | 88.11 |
| Error | 26 | 1052.0 | | | | 11.88 |
| Total | 27 | 8849.9 | | | | 100 |

**Significant S = 6.361 R-Sq = 88.11% R-Sq(adj) = 87.66%*

**Table.4 ANOVA analysis for Left motion signal of Wheel chair**

| Parameters | Degree of Freedom (f) | Sum of Squares (SSA) | Variance (VA) | FAo | P | Contribution (%) |
|---|---|---|---|---|---|---|
| Right motion signal | 1 | 14441.3 | 14441.3 | 525.09 | 0.000* | 95.28 |
| Error | 26 | 715.1 | 27.5 | | | 4.72 |
| Total | 27 | 15156.4 | | | | 100 |

**Significant S = 5.244 R-Sq = 95.28% R-Sq(adj) = 95.10% Table.5 ANOVA analysis for Backward motion signal of Wheel chair*

| Parameters | Degree of Freedom (f) | Sum of Squares (SSA) | Variance (VA) | FAo | P | Contribution (%) |
|---|---|---|---|---|---|---|
| Right motion signal | 1 | 20488.8 | 20488.8 | 1206.08 | 0.000* | 97.88 |
| Error | 26 | 441.7 | 17.0 | | | 2.12 |
| Total | 27 | 20930.4 | | | | 100 |

**Significant S = 4.122 R-Sq = 97.89% R-Sq(adj) = 97.81%*

Additionally, the developed response motion models for wheel chair have been checked by using residual analysis. The residual plots for the response parameters of Front, Right, Left and Backward motion with wheel chair robot is shown in Fig. 11 (a–d). In normal probability plots, the data are spread approximately in a straight line, which indicates that a good correlation between experimental and predicted values. The responses as shown in Fig. 11(a). Fig. 11(b) indicate the residual versus predicted values, which shows only a minimal variation between observed and fitted values. The statistics about the residuals are shown in histogram plots in Fig. 11(c). As a whole analysis of residual plots for both responses, the models do not reveal inadequacy of robot wheel chair motion.

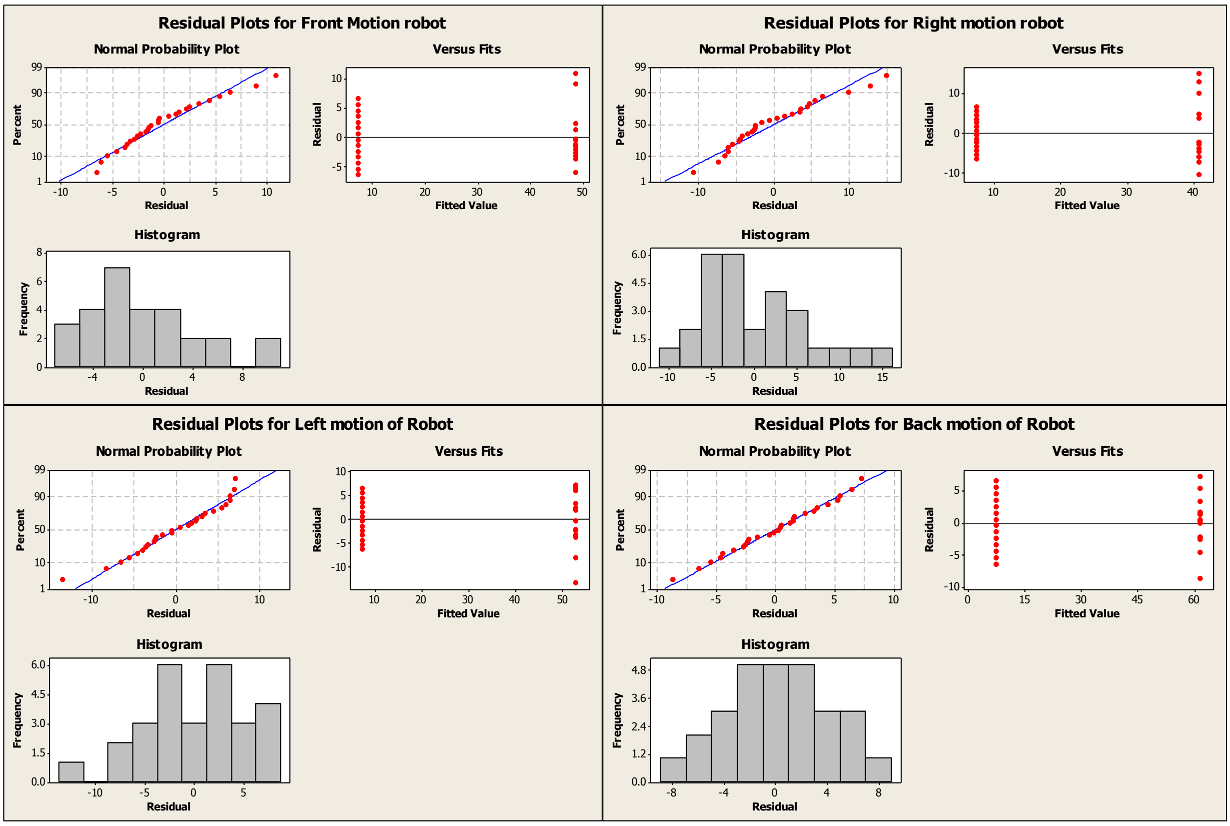


**Fig.11. Plot of residuals for different motion response (Front, Right, Left and Backward motion with wheel chair robot (a. Normal probability plot of the residuals, b. Residuals versus the fitted values, c. Histogram of the residuals).**

### 3.2 Filtering

Filtering of EEG signal is very important because noisy EEG signal can mask some important features of the Electroencephalogram (EEG). Hence it is desirable to reduce this noise for proper analysis of the EEG signal. In this FIR filter window techniques were using for EEG signal Processing. The parameters are Power Spectral Density (PSD), average power and signal to noise ratio (SNR) are calculated of EEG signal and compare the performance of different window methods used for FIR filter. Figure.11 shows the Normal EEG signal.

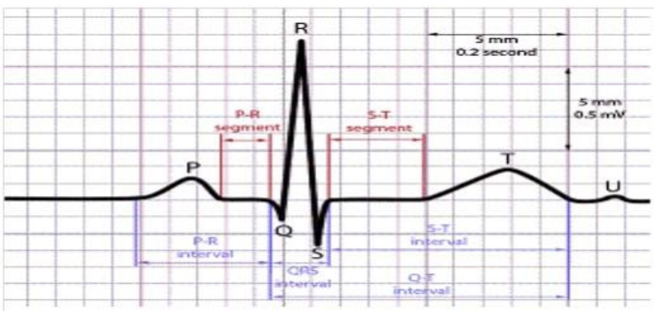


**Fig.12 Normal EEG signal**

Mechanical noises such as 50/50Hz power line interference (50 Hz noise the frequency coming from the power supply), baseline drift, electrode movement and motion artifact, white noise, etc. Hence, removal of artifacts in EEG signal is as a pre-processing operation in most analysis of disease diagnosis and clinical applications as shown in Fig.12. In the effort to remove these noises, there has been little success when employing traditional methods such as linear filers, signal averaging, and their combination. Noise removal from EEG signal is a major problem and a lot of research work has been done for this by different method and algorithms. Noise reduction is the first step in all electrocardiography signal processing.

### 4.Conclusions

The study of various theories behind the Brain Computer Interface (BCI) system, the robotic wheelchair and its working environment has been analyzed. The analytical results are summarized as follows:

1. The design and fabrication of robotic wheelchair through brain-computer interface system was developed. The robotic wheelchair can be used in unknown environment (new place) by the user without the help of other human beings.
2. The solid works model for wheelchair platform was modeled. In the proposed system simple electrode was used to capture the EEG signal from the forehead and transmitted to wheelchair control system. The proposed system was low cost, portable and easy to control the EEG signals.

3. The EEG signals were acquired from the acquisition system to composite raw package. The input signals were calculated using the microcontroller unit and transformed the control signals to control the DC motor in robotic wheelchair. The hardware along with the software proved that the effective wheelchair system makes the life of the paraplegic patients independent.
4. ANOVA gives clearly how the motion parameters affect the response and the level of significance of the factor considered. Analysis of residual plots for motion responses, the models do not reveal inadequacy of robot wheel chair.
5. To drive a brain-controlled robot, the subjects do not need to have a rather good BCI performance, but they also need to be fast in delivering the appropriate mental command at the correct time. For the safety travel of human beings the obstacle avoidance was done with the help of sensor.

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