Wheelchair Control Using Brain Computer Interface

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Abstract

The objective of this paper is to aid the patients to achieve a command based movement of wheelchair using Electroencephalogram (EEG) signals. A wheelchair is developed with a BCI system to help the below neck paralyzed. In such patients, brain fails to interact with the external environment.. A Brain Controlled Wheelchair provides mobility to locked-in patients with the help of BCI in a safe and efficient way. In this proposed work, the EEG signals are detected from the brain through the connected headset. The patient makes the decision for movement and blinks his/her eyes accordingly. Once the decision is made for the movement, the eye blinks are detected and a signal corresponding to that particular direction is sent to the controller via bluetooth. The received signals are analyzed and moves the wheelchair accordingly. Wheelchair prototype is constructed using DC motors fitted onto a platform using L brackets, screws and nuts. The microcontroller, bluetooth module and ultrasonic sensors are mounted on this platform.

Keywords : *Brain Computer Interface (BCI), wheel chair, Electroencephalography(EEG)*

I. INTRODUCTION

The Brain Computer Interface (BCI) provides a direct interface between computer system and human brain which assist the locked-in patients. The brain neural activities are translated into commands to the interfaced devices through BCI. The BCI adopts the following steps: Acquire the brain signals, analyze them, translate them to commands and the output them to an external device to take desired action according to the brain signal received. Three types of BCI to acquire brain signals are :"Non-Invasive, Semi-invasive and Invasive".

Non-Invasive BCI: The electrical potentials generated by the brain are acquired by the sensors placed on the scalp Among the several non-invasive BCIs, Electroencephalogram (EEG) is the most commonly used due to low cost and hardware portability. The technique followed in Non-Invasive BCI is as shown in Fig.1.

Semi-Invasive BCI: To measure electrical activity from the cerebral cortex, Electrocorticography (ECoG) employs electrodes positioned on exposed surface of the brain as shown in Fig. 2. Semi-invasive still requires a craniotomy to implant the electrodes.

Fig 1: Non-Invasive BCI

ISSN: 2233-7857 IJFGCN

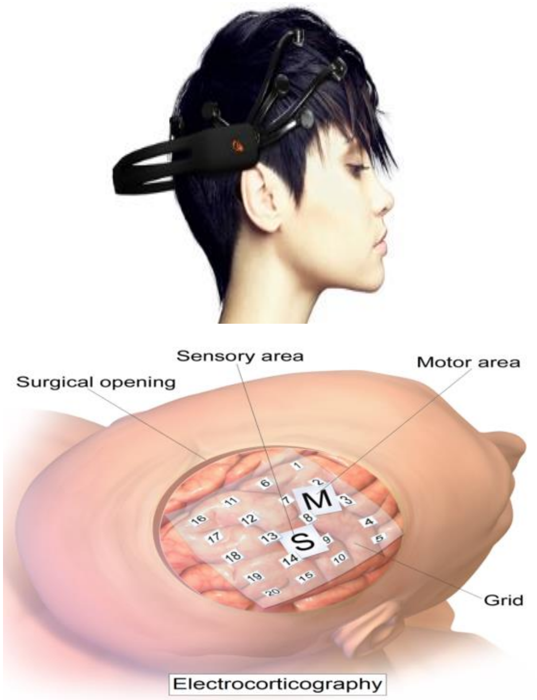

Fig 2: Semi-Invasive BCI [Source: Internet]

Invasive BCI: Invasive types of BCI (Fig. 3) are implanted directly into the brain during neurosurgery. There are Multiunit BCIs detect signals from multiple areas, whereas, single unit BCIs detect the signal from a single area of brain cells. Since neurosurgery can be a risky and expensive process, the target of invasive BCI is mainly for blind and paralyzed patients.

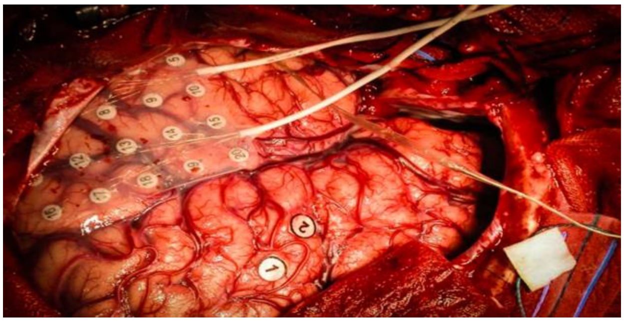

Fig 3: Invasive BCI

1.1 Electroencephalogram (EEG)

In EEG, electrical activity in the brain is detected by the electrodes. Neural oscillations of the brain activity (rhythms) are represented by power, frequency and phase. Oscillations that occur at specific frequencies include delta, theta, alpha, beta, and gamma.

It is found that there exists association between rhythms and different brain states. For example, in case of EEG-BCI, the electric potential of the brain activity is obtained from the scalp has EEG bands like alpha, beta, delta, theta and mu suppression, each corresponding to different states of brain like relaxing,(8-14 Hz); concentrating(13-30 Hz), deep sleep, (0-4 Hz); meditating (4-8 Hz), moving your hands or legs or just by imagining these motor actions respectively. With the advancements in technology, acquisition devices that acquire EEG signals are compact, handy and wireless. For real-time applications, EEG is reliable as it measures the signals for every thousandths of a second. In order to interpret Event Related

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Potential (ERP), EEG signals are acquired simultaneously from multiple electrodes. An amplifier is required as the acquired signal detected by the electrodes is weak.

1.2 Electrodes

Electrodes on scalp are positioned according to International 10/20 Electrode placement system as shown in Fig. 4. Electrodes can be either Wet or Dry. Wet electrodes use saline solution of gel. Majority is made of stainless steel, tin, gold or silver and is covered with a silver chloride coating. Dry type electrodes are directly placed on the scalp. Dry electrodes are easy to use and are more convenient.

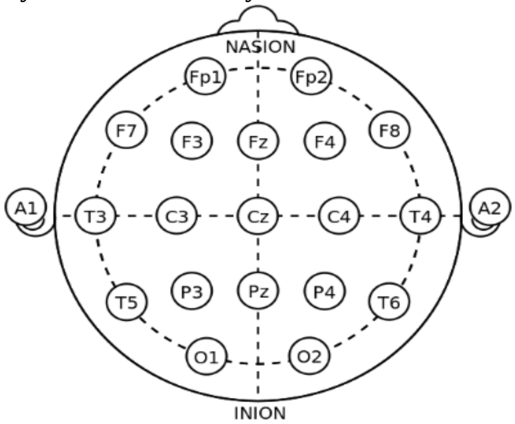

Fig. 4: 10/20 Electrode placement system

Active electrode, reference electrode and ground electrode are required for minimum configuration. When no electrical activity from the brain, it becomes difficult to get a reference. Reference electrode is placed on the ear lobes, mastoid, or tip of the nose. The differential voltage between the active and the reference points is measured by the ground electrode.

II. EXISTING PROBLEM AND SOLUTION

BCI based on wheelchair control system has headset consisting of 14 electrodes and two gyroscope sensors that assists a disabled person who is not able to operate a joystick to drive a powered wheelchair without the use of hands[1]. The said headset is worn on the user's head for the measurement of user's bio signals. These bio signals are produced during eye blinking. User's eyeblinks are translated into control commands to guide the wheelchair's movements.

An electric wheelchair equipped with BCI system focuses on the population of patients who are paralyzed below the neck [2]. Arrays of electrodes are placed on the scalp to monitor the brain activity in real time. User's eyeblinks are processed by the combination of MCU, portable EEG headset and firmware. The direction of motion is determined based on the decision of the microcontroller. This results in the creation of an add-on conversion kit for a common manual wheelchair.

A technology [3] is proposed to enable a healthy human brain to control powered wheelchair movement. Here, Emotive Software Development Kit (SDK) is used to acquire EEG data. This is aimed at improving the accuracy rate of brain controlled systems. The control action is developed by the combination of Arduino microcontroller and .NET based software.

The design of BCI controlled wheelchair involves classification of the EEG signals to control a wheelchair [4]. The classification mechanism system is derived from fuzzy neural networks (FNN). Real time control of the wheelchair is accomplished using speed and direction command given to the wheelchair. The accuracy of wheelchair control is greatly improved.

BCI convey reflections of brain activity into output. EEG activity from the scalp is collected from non-invasive BCI. An adaptive algorithm in this context can provide a solution to people with severe spinal cord injuries with multidimensional point-to-point movement control [5]. The adaptive algorithm

ISSN: 2233-7857 IJFGCN

picks up on the features of electroencephalogram that the person is able to control the best and provides improvement in that particular control area. This prevents the hassle of invasive BCIs.

A Brain Controlled Wheelchair is aimed at providing mobility to locked-in patients with the help of BCI in a safe and efficient way. A destination is chosen among a list of predefined familiar locations using a slow but reliable P300 based BCI [6]. This helped to reduce the effort on part of the user of the BCI Interface in terms of concentration and control.

A strategy [7] is introduced with the aim of reducing the total time taken to complete the task successfully and the concentration effort imparted by the user of the BCI. Low signal-to-noise ratio and classification accuracy is experienced in BCI controlled system which could contribute to degrading the translational performance of the BCI. Approaches in this direction include synchronous and self-paced brain-controlled wheelchair. These involve a shared method of control and the "automated assistive control (AAC)" component. This results in elimination of false activations and misclassifications.

Operating a powered wheelchair comes as a challenge to paralyzed patients. Independent mobility is of utmost importance to carry out daily life activities. One of the designs incorporates a safety controller with peripheral safety sensors that assist when an obstacle is detected by overriding the user command and stopping the wheelchair on its path [8].

To identify the need among people suffering from spinal cord injuries or the like for a BCI with specific priorities for applications and design features along with time investment and risk acceptable [9]. This involves descriptive statistics of independence of functionality, movement support structures, importance of varied tasks and features of design, along with acceptable levels of performance.

A prototype [10] with both software-hardware integration is developed that controls left, right, forward, and backward motion, as well as stopping with eyeblinks. The user interface (UI) and interface controls are imparted in a sample of ALS patients with a moderate level of disability.

This paper [11] explains the design of smart wheelchair built with headset aid the blind and paralyzed patients having no control over their body. This employs deep learning to identify four different movements from the recorded EEG signal, to move left, right, forward, and stop.

The paper [12] develops a brain controlled wheelchair prototype which incorporates control interfaces consisting of joystick and a remote control with android phone. Control mechanisms are integrated so that it allows the user to change the mode of control by simply changing the state of the slide switch.

III. METHODOLOGY

The EEG signals are detected from the brain through the connected headset. These signals get detected when there are eye blinks from the patient. Thus obtained signals are sent to laptop/PC via Bluetooth. The laptop/PC provides a Graphical User Interface (GUI) to help the patient in selecting the appropriate direction. Once the decision is made and the patient blinks his/her eyes, the blinks are detected and a signal corresponding to that particular direction is sent to the controller via Bluetooth which analyses the received signal and moves the wheelchair accordingly. Figure 10 shows the block diagram of the Wheelchair Control using BCI and the components used is described below.

a) Brainsense Headband

Our brain is made up of billions of nerve cells called neurons. The neurons interact through chemical reactions and emit a measurable electrical impulse. These impulses are generated throughout the brain every moment. The observation process of brainwaves through these pulses is called Electroencephalography or EEG. The active electrode in the headband detects these impulses that are

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generated during eye blinks and translates it into meaningful data. Brainsense measures Stress levels, Attention, Meditation, Focus, and Eyeblink. Fig. 5 shows the BrainSense Headband.

Fig. 5: BrainSense Headband

Technical specifications:
Uses Dry Electrode, Ear clip electrode and ThinkGear ASIC Module -TGAM1 module. It provides automatic wireless pairing. Uses three AAA batteries to provide up to 6-hours battery run time. Supports iOS, Android and PC (MATLAB , LabVIEW ,Java ,.Net, C, C#). Bluetooth v2.1 Class 2 (10 meters range). It can measure Raw-Brainwaves Output of EEG power spectrums (Alpha, Beta, etc.), EEG/ECG signal quality analysis.

b) Thinkgear Chip
ThinkGear ASIC Module (TGAM) processes raw EEG signals obtained by the headset. ThinkGear chip enables the interface between users' brainwaves and device. Both raw EEG signals as well as attention and meditation values are calculated on the ThinkGear chip. These values are outputed by the ThinkGear chip to PC through headset. The TGAM processes and outputs EEG frequency spectrums, EEG signal quality, raw EEG, and three NeuroSky eSense meters attention; meditation; and eyeblinks.

Technical Specifications:
512 bits per second sampling frequency.
3-100Hz frequency range.
Max Power Consumption: 15mA at 3.3V.
Operating voltage: 2.97 to 3.63V.
Noise immunity of ThinkGear chip is achieved by advanced filtering technology. It consumes less power and applicable for portable battery-driven applications.

c) Bluetooth (HC-05)
A Bluetooth module provides full-duplex wireless functionalities to transfer data. With the help of USART it communicates at 9600 baud rate and is compatible to any microcontroller that supports USART. Refer Fig.6.

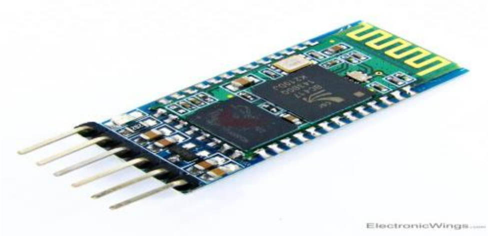

Fig. 6: Bluetooth module

HC-05 operates in two modes: In data mode , the data can be sent and can receive data from other Bluetooth devices. In AT Command mode, default device settings can be modified. By default the Bluetooth module is set to data mode. A HIGH signal on the enable pin allows the Bluetooth to operate in command mode. The Bluetooth module can operate either as master or as a slave.

Technical Specifications:
Range: <100m Operating Current: 30mA.

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Operating Voltage: 4V to 6V (Typically +5V).

d) Arduino- UNO

Arduino UNO (Fig. 7) is a microcontroller board based on 8-bit ATmega328P microcontroller. Along with ATmega328P, it consists of voltage regulator, crystal oscillator, serial communication, 14 digital input/output, 6 analog input pins, a USB connection, A Power barrel jack, an ICSP header and a reset button. The 14 digital input/output pins can be used as input or output pins of which 6 provide PWM outputs and 6 analog I/O pins.

Fig. 7: Arduino UNO

Technical Specifications:
Microcontroller -ATmega328P.
DC current on I/O pins: 40mA.
Recommended input voltage: 7-12V.
Clock frequency: 16MHz.
Operating Voltage: 5V
Flash memory: 32kB (0.5 kB is used for bootloader).

e) Ultrasonic Sensor (HC-SR04)

An Ultrasonic(HC-SR04) (Fig.8) sensor measure the distance to an object by using sound waves It is a 4 pin module, whose pin names are Vcc, Trigger, Echo and Ground respectively. The module has two eyes like projections named as Transmitter and Receiver. The working of a sensor is described as,
Distance = Speed × Time

Fig. 8: Ultrasonic Sensor

The universal speed of Ultrasonic wave is 330m/s. The built in circuitry calculate the time taken for the US wave to come back and turns on the echo pin high for that same particular amount of time.

Technical Specifications:
Practical Measuring Distance: 2cm to 80cm
Theoretical Measuring Distance: 2cm to 450cm
Operating voltage: +5V
Operating Current: <15mA

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Accuracy: 3mm
Operating Frequency: 40Hz
Measuring angle covered: <15°
The I/O pins (Trigger and the Echo pins)of US can be connected to I/O pins of the microcontroller.

f) Motor Driver L293D

Arduino microcontroller cannot provide sufficient power to drive the motors of wheelchair. Hence a motor driver IC is used which provides sufficient current to run the motors. L293D is a 16-Pin Motor Driver IC is shown in Fig.9(a). A single IC is capable of running Two DC motors can be operated simultaneously by using single L293 and also speed and directions are controlled at the same time.

Technical Specifications:

Operating voltage: 5V
Maximum Peak motor current: 1.2A
Bi-directional drive current: 600mA

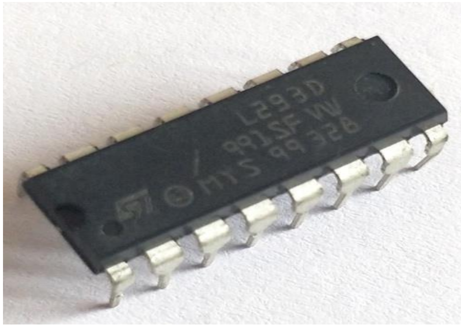

Fig. 9(a): L293D IC

Based on the principle of Half H-Bridge L293D motor driver IC is operated. H-bridge as shown Fig. 9(b) run the motors both in clock wise and anti-clockwise direction. It is capable of running two motors in any direction at the same time.

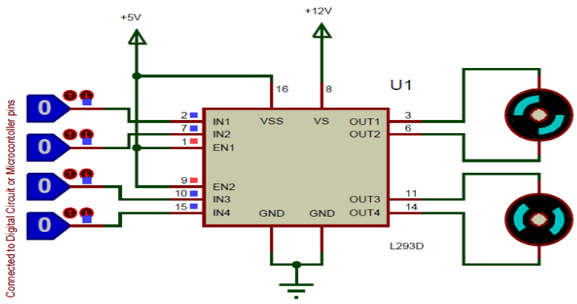

Fig. 9 (b): L293D circuit diagram

To control the direction of the motor, the input pins are connected to the microcontroller. By providing the input pins as indicated in the Table 1 and Table 2, the motors are controlled.

Table 1: Motor inputs for clockwise rotation

Input	Output	Motor
I/P 1 (0V)	O/P 1 (0V)	Motor 1 rotates in Counter Clock wise Direction
I/P 2 (5V)	O/P 2 (5V)	
I/P 3 (0V)	O/P 1 (0V)	Motor 2 rotates in

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I/P 4 (5V)	O/P 2 (5V)	Counter Clock wise Direction

Table 2: Motor inputs for anti-clockwise rotation

Input	Output	Motor
I/P 1 (5V)	O/P 1 (5V)	Motor 1 rotates in
I/P 2 (0V)	O/P 2 (0V)	Clock wise Direction
I/P 3 (5V)	O/P 1 (5V)	Motor 2 rotates in
I/P 4 (0V)	O/P 2 (0V)	Clock wise Direction

Brainsense headband is to be strapped around the forehead. It consists of three electrodes of which the active electrode is placed at the centre of the forehead (FP1 position) and ground and reference electrodes are clipped to the earlobe.

Eyeblinks generate micro-voltages in the brain and these micro-voltages are captured by the electrode placed on the forehead. The Thinkgear chip embedded within the headset processes these voltages by amplifying them and converting them to digital packets. The headset also measures the attention values and meditation values along with eyeblink values. The program is written in a way so as to receive only the eyeblink values from the headset.

IV. RESULTS AND DISCUSSIONS

A Graphical User Interface (GUI) helps the patient to select the required direction by blinking. The received eye
blink values from the headset are processed and a plot of raw EEG power spectrum is displayed on the GUI. The same signals are analysed and sent to the microcontroller via Bluetooth.
The microcontroller is programmed in such a way that depending on the received data the motors attached to the wheelchair can be moved in four basic directions viz., front, left, right and reverse. Ultrasonic sensors are used to detect the obstacle in the vicinity of the wheelchair. The wheelchair does not move if an obstacle is detected.

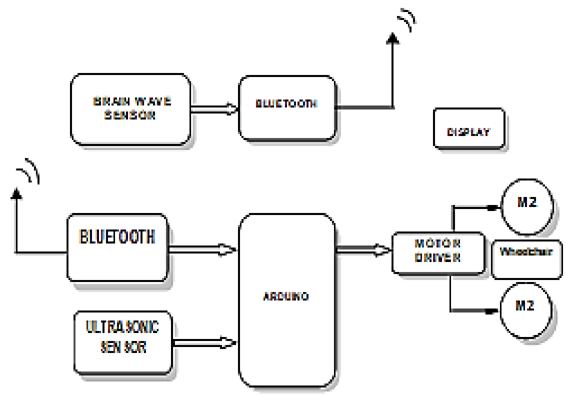

Fig. 10: Wheelchair Control using BCI

Fig. 11 shows the GUI initialization window. The plot on the right hand side displays the raw EEG signals detected from the headset. User is provided with the choice of four directions indicated by the respective arrows. The first display box gives real-time updates to the user as of what process is currently being executed and when to blink.

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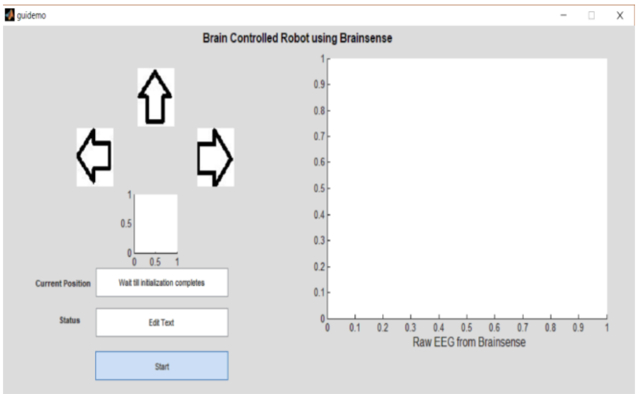

Fig. 11: GUI initialization

The above figure represents the GUI initialization in process. During initialization the connection of the wheelchair with headset is verified. If the setup is not connected to Bluetooth an error is displayed.

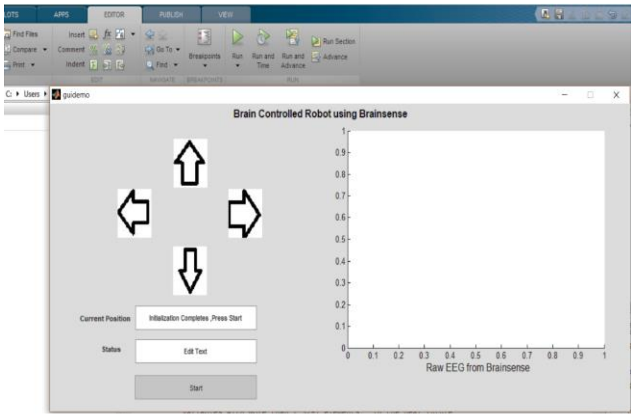

Fig 12: Waiting for user command

Once the initialisation is complete, the same is indicated on the first display box with the message ‘Initialisation completes, Press start’. The GUI window waits for the user’s command. The process begins when ‘start’ button is pressed.

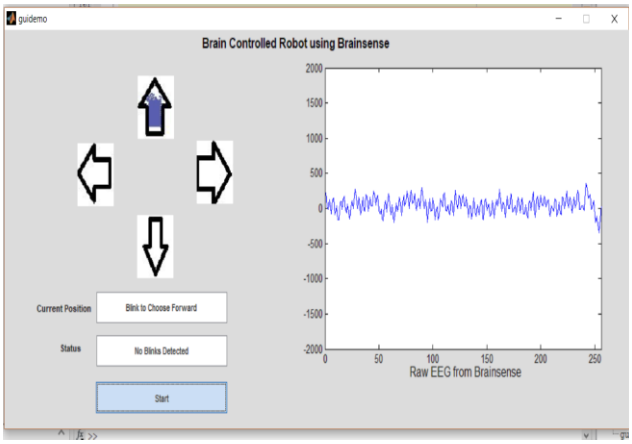

Fig. 13: Waiting for user’s eyeblink

As soon as the ‘start’ button is pressed the EEG signals collected from the headset is plotted on the graph and the user is allowed to choose the direction. The first display box indicates this with a message ‘Blink to choose forward’. If the user wishes to move forward then they can blink. The blue colour of the arrow indicates that the system is waiting for user’s blink to be detected. This figure represents the case in which the user does not wish to move forward and thus does not blink his/her eyes. This is acknowledged by the message ‘No blinks detected’ in the second display box.

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The time for blink detection window is kept small so that the user does not face any difficulty in controlling his/her blinks for a longer duration. The user can blink normally during all other times. This aspect in the project provides flexibility to the user with respect to eyeblinks.

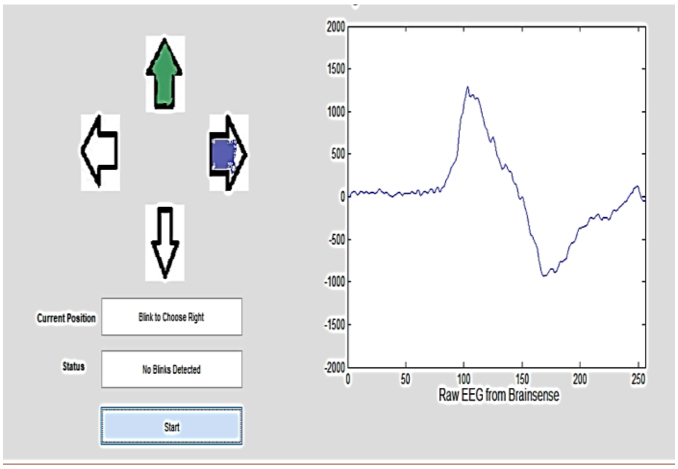

Fig. 14: Blink is detected

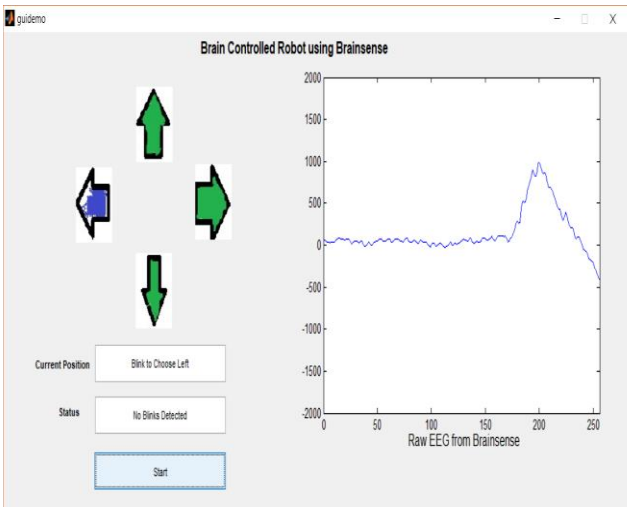

Fig. 15: EEG signal peak

The above two figures i.e., Fig. 14 and Fig. 15 are the cases when user chooses to move in a particular direction. When the user blinks for a particular direction, the second display box displays the message "Blink detected". The result can also be seen in the EEG plot. The eyeblink causes an increase in the user's brain activity which results in amplitude peak of the EEG signal. This peak can be observed in both of the above figures where the user has decided to move in that particular direction. The successful detection of blink causes the arrow to change into green colour from the pre-existing blue colour.

These are the ultrasonic sensor readings that continuously monitor the distance of the wheelchair from any obstacles in Fig. 16. The measurements are not explicitly visible to the user. It can be viewed in the Arduino serial monitor. 'Obstacle detected' message is displayed when there is an obstacle in the vicinity of the wheelchair.

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Fig. 16: Ultrasonic sensor readings

Current threshold for the prototype is set to 10cm and can be changed in the code depending on the requirement. If the distance is below 10cm and blink is detected, the wheelchair does not move, thus providing additional safety to the user.

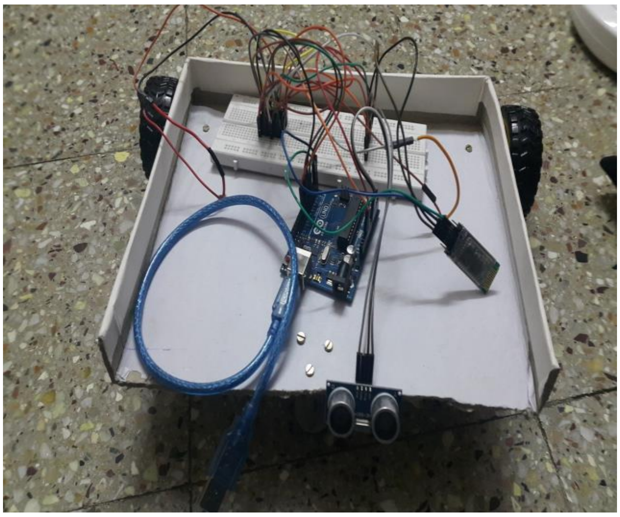

Fig. 17: Wheelchair prototype

Wheelchair prototype as in Fig. 17 is constructed using DC motors fitted onto a platform using L brackets, screws and nuts. The microcontroller, Bluetooth module and ultrasonic sensors are mounted on this platform.

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IX. CONCLUSION

This work dealt with engineering an interface between the human brain and an electric wheelchair using a portable EEG brainwave headset, signal processing and filtering. Compared to conventional methods, wireless communication between headset and user provides hassle-free setup of wheelchair. A prototype was developed and tested for working. The results were satisfactory and illustrated in the Figures 11-15.

A display can be mounted on the wheelchair which provides visual interface to the user. The functions performed by the laptop can be integrated onto a high-end processor such as RaspberryPi.

Location of the patient can be shared with the caretaker thus allowing constant monitoring of the patient's location..

Further, BCI can be implemented to provide entertainment to a healthy person by designing mind controlled games. It can be implemented to control appliances at home (home automation), self-driving cars, playing musical instruments etc.

REFERENCES

[1] Kaira Matsuzawa, Chiharu Ishii, "Control of an electric wheelchair with a brain-computer interface headset," Advanced Mechatronic Systems, IEEE, International Conference 2017

[2] Utkarsh Sinha, Kanthi.M, "Mind Controlled Wheelchair", IJCTA, 9(39), 2016, pp. 19-28

[3] Ivan Halim Parmonangan, Jennifer Santoso, Widodo Budiharto, Alexander Agung Santoso Gunawan, "Fast brain control systems for electric wheelchair using support vector machine", First International Workshop on Pattern Recognition, 11 July 2016

[4] Rahib H.Abiyev, Nurullah Akkaya, Ersin Aytac, Irfan Gunsel and Ahmet Cagman, "Brain-Computer Interface for control of wheelchair using Fuzzy Neural Networks", BioMed Research International Volume 2016

[5] Jonathan R. Wolpaw, Dennis J. McFarland, "Control of a two-dimensional movement signal by a noninvasive BCI in humans", Proc Natl Acad Sci USA. 2004 Dec 27; 101(51)

[6] Brice Rebsamen, Cuntai Guan, Haihong Zhang, Chuanchu Wang, Cheeleong Teo, Marcelo H. Ang, Etienne Burdet, "A Brain Controlled Wheelchair to Navigate in Familiar Environments", IEEE Transactions on Neural Systems and Rehabilitation Engineering, Volume 18, Issue:6. Dec. 2010. Pages 590-598

[7] Abdul R Satti, Damien Coyle, Girijesh Prasad, "Self-paced brain-controlled wheelchair methodology with shared and automated assistive control', Computational Intelligence, Cognitive Algorithms, Mind and Brain (CCMB), 2011 IEEE Symposium

[8] Nikhil Shinde, Kiran George, "Brain-controlled driving aid for electric wheelchairs", Wearable and Implantable Body Sensor Networks (BSN), 2016 IEEE 13th International Conference

[9] Huggins JE, Moinuddin AA, Chiodo AE, Wren PA, "What brain-computer interface users want: opinions and priorities of potential users with spinal cord injury", Arch Phys Med Rehabil. 2015; 96(3 Suppl)

[10] Awais, M. A., Yusoff, M. Z., Yahya, N., Ahmed, S. Z., & Qamar, M. U. (2020, April). Brain Controlled Wheelchair: A Smart Prototype. In *Journal of Physics: Conference Series* (Vol. 1529, No. 4, p. 042075). IOP Publishing.

[11] Zgallai, W., Brown, J. T., Ibrahim, A., Mahmood, F., Mohammad, K., Khalfan, M., ... & Hamood, N. (2019, March). Deep learning AI application to an EEG driven BCI smart wheelchair. In *2019 Advances in Science and Engineering Technology International Conferences (ASET)* (pp. 1-5). IEEE.

[12] Elliott, M. A., Malvar, H., Maassel, L. L., Campbell, J., Kulkarni, H., Spiridonova, I., ... & Rifley, J. (2019). Eye-controlled, power wheelchair performs well for ALS patients. *Muscle & nerve*, *60*(5), 513-519.

ISSN: 2233-7857 IJFGCN