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NEUROLOGICAL NAVIGATION AND COGNITIVE MOBILITY: THE RESEARCH AND DEVELOPMENT OF BRAIN-CONTROLLED WHEELCHAIRS

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Abstract

The goal of brain-computer interface research is to convert neural instructions into control signals automatically. Applications like text input programs, electronic wheelchairs, or neuro prosthetics can then be controlled by them. For patients who are extremely incapacitated, a BCI system can operate as a communication channel. For healthy users, it can function as an extra man-machine interface. The traditional "operant conditioning" method required weeks or months of training for people to retrain their brain signals to use the system. The Berlin Brain-Computer Interface project (BBCI) has created an electroencephalogram (EEG)-based system that uses cutting-edge machine learning techniques to replace operant training. Even participants without prior BCI experience can obtain high information transmission rates from their first session by learning to modify classifiers to the very subject-specific brain signals. Nevertheless, brain signals are seldom sufficiently steady after an initial calibration that the first classifier may be used again in the same experimental session. Wheelchairs with intelligence are a big help to those who need it. Moving can be challenging for those who suffer from movement difficulties brought on by certain illnesses, such as multiple sclerosis or stroke. They therefore require the ongoing assistance of carers. In order to aid people with infirmities and paralysis, this article introduces brain-controlled wheelchairs. By deciphering data from an electroencephalogram (EEG), or brain waves, it manages the wheelchair. When using EEG, the user applies an electrode cap to their scalp to detect EEG signals. The Arduino microcontroller then interprets these data and uses them to generate motor commands that move the wheelchair. Enhance the quality of life for individuals who are paralyzed by using the Mind Controlled Wheelchair.

Keywords: EEG Signals, BCI, Classifiers, Neural Commands, Control Signals, fMR1, ECOG, Eyebro

1. INTRODUCTION TO BRAIN COMPUTER INTERFACE (BCI)

Brain signals are processed by a brain-computer interface (BCI), which then translates them into commands that are sent to an output device to carry out the intended action. Normal neuromuscular output channels are not used by BCIs. For those suffering from neuromuscular disorders including amyotrophic lateral sclerosis, cerebral palsy, stroke, or spinal cord injuries, the main objective of BCI is to replace or restore meaningful function. Since the first EEG-based spelling and single-neuron-based device control demonstrations, researchers have developed ever more sophisticated markers, robotic arms, prosthetics, wheelchairs, and other devices using EEG, intracortical, electrocorticographic, and other brain inputs. Brain-computer interfaces may potentially be helpful for stroke and other disease rehabilitation. They could enhance the abilities of surgeons or other medical experts in the future. Brain-computer interface technology is at the heart of an exciting and rapidly growing research and development endeavor that is of great interest to scientists, engineers, clinicians, and the general public. Signal collection equipment for brain-computer interfaces has to be lightweight,

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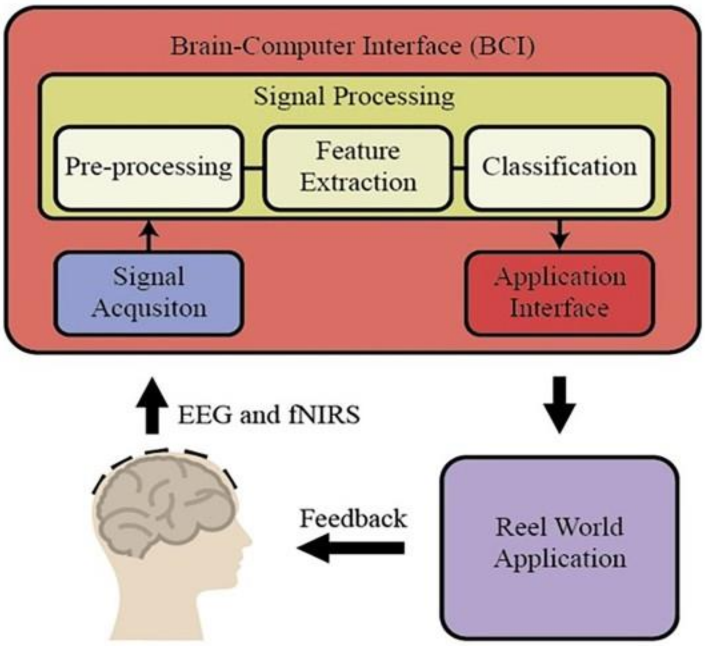
portable, secure, and capable of operating in any setting. Brain-computer interface systems should be put through extensive testing by real users with severe impairments in order to evaluate their efficacy. Once viable models have been established, they should be widely distributed.

Ultimately, in order to mimic natural muscle activity, the daily and transitory dependability of BCI performance needs to be optimized. One of the main challenges facing contemporary BCI researchers is the interface's underlying mechanisms. The easiest and least invasive method is to affix an electroencephalogram (EEG) device, which is comprised of many electrodes, to the scalp. The electrodes may read brain signals. But the majority of electrical signals are blocked by the skull, and those that do get through are distorted. For the purpose of obtaining high-resolution data, researchers can implant electrodes directly into the grey matter of the brain or on its surface beneath the skull. Because of this, it can receive electrical impulses more directly and places electrodes in particular brain regions to provide the right signals. This strategy, though, has a lot of issues. Electrodes need to be surgically implanted, and long-term device implantation often results in the creation of scar tissue in the grey matter. Eventually, the scar tissue stops signaling.



The essential process remains the same regardless of where the electrodes are placed, the electrodes monitor minute potential changes between neurons. After that, the signal is filtered and amplified. The signal is processed by a computer program in modern BCI systems, although you might be familiar with the older analogue EEG equipment that used a stylus to show the signal and an automatic printer to print the pattern on continuous paper. In terms of sensory inputs for BCI, the roles are inverted. Signals from cameras and other devices are converted by a computer into the voltages required to trigger neurons. If everything goes

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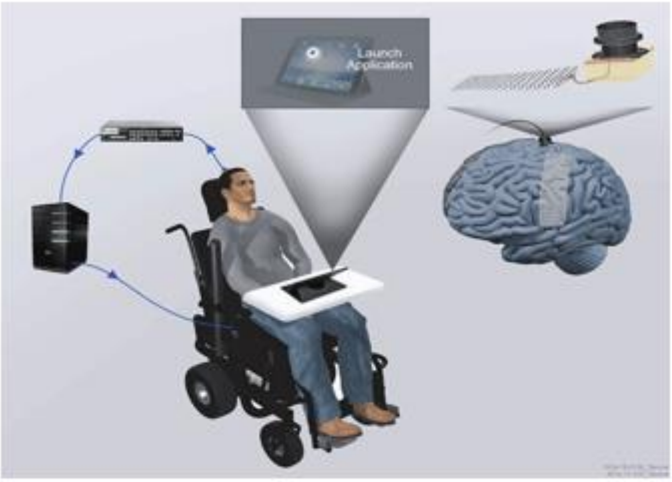
according to plan, signals are transferred to the implant in the appropriate part of the brain, whereupon the neurons activate and the person gets a visual representation of what the camera sees. Magnetic resonance imaging (MRI) is another method of measuring brain activity. An MRI machine is a big, intricate piece of machinery. Although it can provide high-resolution pictures of brain activity, a permanent or semi-permanent BCI shouldn't employ it. It is used by researchers to map the location of electrodes in the brain that are necessary to measure a certain function or to obtain hints about particular brain processes.

An MRI may be used to initially put the person under mental control of moving the real arm, if scientists were trying to implant electrodes so that someone could control a robotic arm with their thoughts, for instance. It will be easier to insert electrodes since the MRI will highlight the parts of the brain that are active during arm movements.



2. BACKGROUND STUDY OF HOW BRAIN WAVES ARE CLASSIFIED AND ARE USED IN BCI SYSTEMS

In recent decades, the goal of developing brain-computer inter face systems has been to enable people with partial or total disabilities to control and communicate with external parameters through brain signal processing. Totally disabled and paralyzed people need non-muscular communication. Brain-computer interfaces a provide communication facilities using only brain waves. The Common Brain-Computer Interface System uses EEG electrodes as the signal acquisition system.

The electrical signals generated by the brain are recorded by these electrodes. Ionic currents flowing in nerve cells are measured electronically across the scalp. The pre- recorded signal is processed by a series of filters and amplifiers. A high-gain instrumentation amplifier is used because the EEG signal has much lower power, measured in microvolts. The filter used is selected according to the requirements of the treatment system. It is used for brain activity during sleep, thinking, moving body parts, concentration, etc. It produces different frequency bands. The brain produces auditory and visual stimuli using signals called homeostatic evoked

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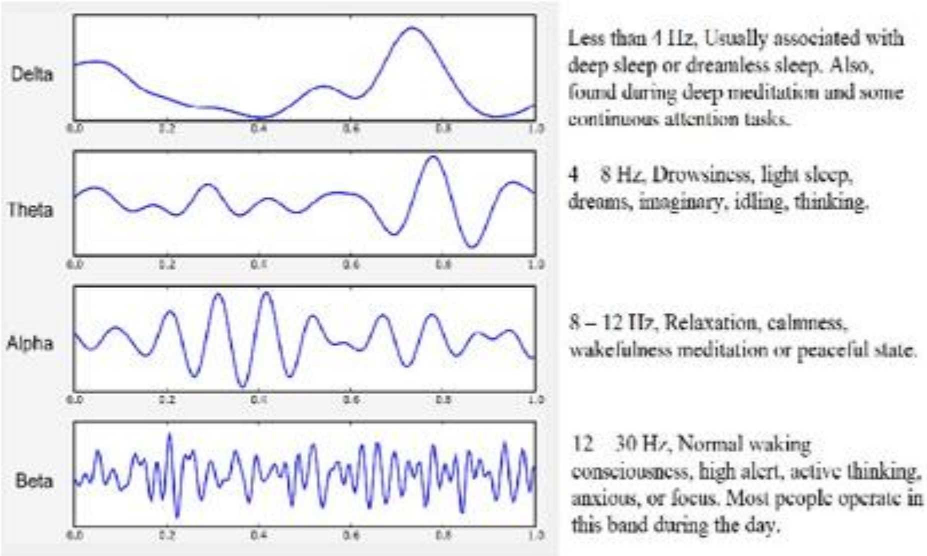
potentials. For completely disabled people, the functions used are slow cortex potentials, sensorimotor rhythm potentials and event potentials.



Depending on the human brain's focal point, wheelchair speed can improve performance. The function is extracted from the signal using Fourier transform. Statistical analysis with wavelet transform is used to compare two signals for classification purposes. Brain signals can be divided into frequency bands such as alpha (7 to 13 Hz), beta (12 to 20 Hz), and gamma (20 to 5 Hz).

In humans, the electrical activity of nerve cells generates an electrical current that travels through the head. These currents manifest as voltage variations and magnetic fields at the scalp's surface, which are both non-invasively measurable. These voltage changes on the scalp are measured as an electroencephalogram (EEG) and the magnetic field measured on the scalp is called a magneto encephalogram (MEG). Disorders of the nervous system can gradually prevent physical movement. It eventually leads to complete paralysis.

3. CONFIGURATION OF THE BCI WITH THE WHEEL CHAIR USING MAT LAB SOFTWARE

BCI connects the brain to a computer to obtain information about the brain, structure and function. An electrical brain wave (EEG) is a type of communication between the brain and a computer; with the help of EEG, we can get the signals. In this project, we use an electroencephalogram (EEG) sensor to create a connection with the brain, a neural brainwave sensor. With the assistance of a low-cost actiCAP active electrode system sensor headset, we get the signals and after tracking and enhancing them, we get the brain signals in the right form. These signals are used to move the wheelchair. Wear an EEG helmet on your head to get EEG signals.

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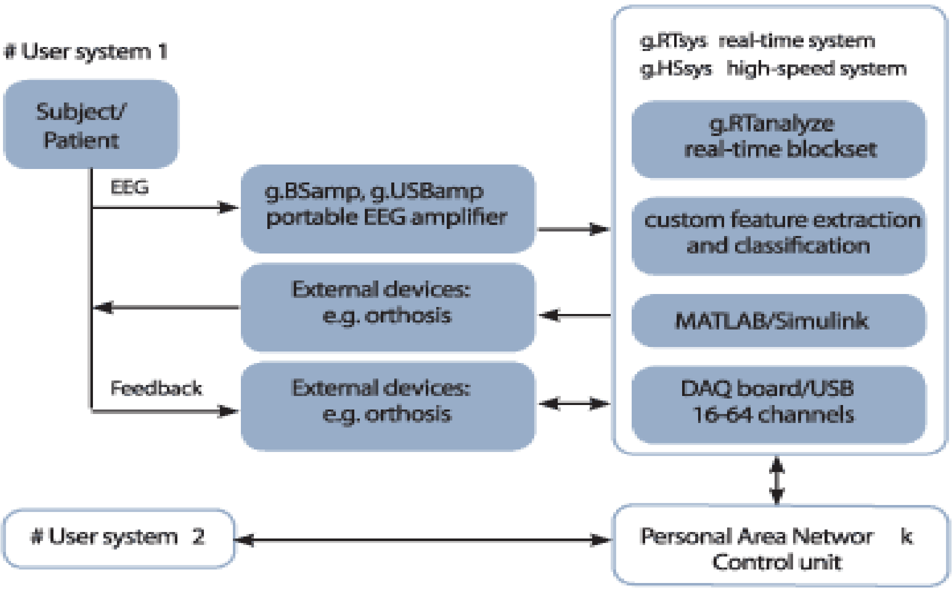
From the immediate brain, we obtain raw signals of very small amplitude, so these signals are amplified and plotted over a range of frequencies using MATLAB software. To connect the software part of the signal to the hardware part of the wheelchair, we used the Arduino software with which we were able to make the connection. Mental wave-controlled wheelchairs are useful for paralyzed and disabled people.



4. INTERFACES OF THE BCI WITH THE WHEEL CHAIR USING MAT LAB SOFTWARE

The input portion of the system, which consists of sensors, is the first component that we divide into. The following section is the exit where the wheel chairs are placed. We use two sensors, and it is also possible to add more sensors. The main part of the project is the EEG sensor, that's going to be put on the head. There are many EEG sensors on the market, but we use the sensor. The ACTi CAP active electrode system sensor which is a phase sensor with only one electrode in the frontal lobe of the brain and the sensor block is attached to the ear.

Wheelchairs attached to any area of the body are guided by accelerometer sensors. Flicker sensors are another option for turning on and off the system. Because the actiCAP active electrode system sensor is Bluetooth compatible, it can be linked to a laptop, which subsequently has application to link the sensor to an Arduino board. The wheelchair devices and the computer are connected via the Arduino board. To accomplish this, we'll need two Arduino boards in order to use an RF transceiver to establish a strong link between the hardware and software. The wheelchair is moved by two DC motors. In doing so, the link between the sensor and the device is established. MATLAB and Arduino software are being used.

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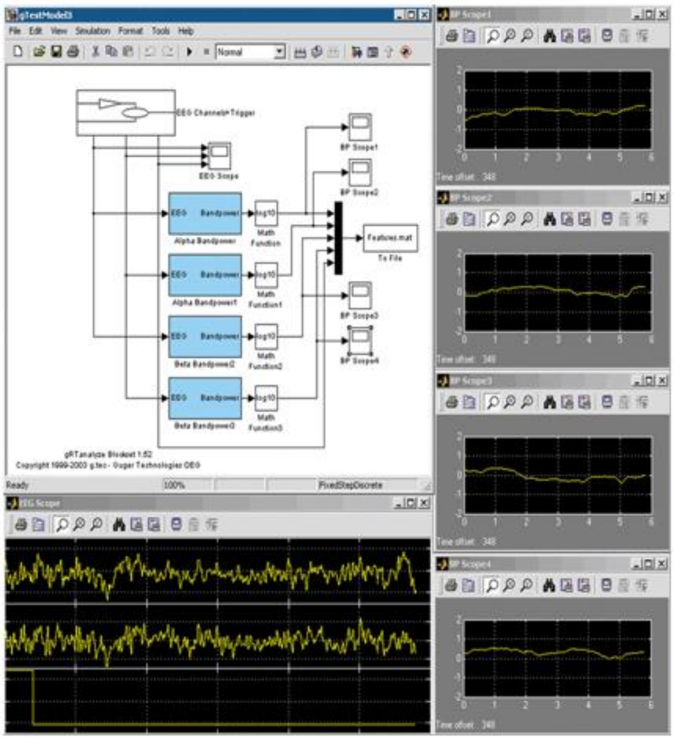
MATLAB is used to obtain signals from brain sensors and accelerometers. Signal processing and specifying input commands in MATLAB. Then the control is passed to the hardware part through the Arduino processing board. Arduino is useful for connecting devices to MATLAB.



5. MOTION OF THE WHEEL CHAIR USING ELECTRIC MOTORS INTER FACED WITH BCI (BRAIN COMPUTER INTERFACE)

The use of the human brain for wheelchair propulsion and control has gained a lot of attention in the research community recently, among other BCI applications, because of its flexibility and potential to improve the quality of life for the helping the elderly and disabled gain independence. Many procedures were put out and an enhanced algorithm was put into place following the first demonstration of the viability of "the human mind can control a wheelchair" in order to expand the applications of EEG-based BCIs to wheelchair movement and control.

A wheelchair is categorized as a two-dimensional mobile robot under the definition given in this section. An EEG-based wheelchair system is a form of brain-computer interface technology in which electroencephalographic signals obtained from the human brain are used to drive this specific mobility robot. With this technical technique, the aim can be accomplished with only brain impulses. The introduction of the brain-controlled wheelchair (BCW), which can increase a person's autonomy and enable them to move around in a real environment, has sparked a lot of interest. However, because creating a wheelchair this complex requires a lot of work, very little science has been contributed to this field. The Al-qays and Fernández-Rodríguez groups examined a number of current BCW solutions, including hybrid-based

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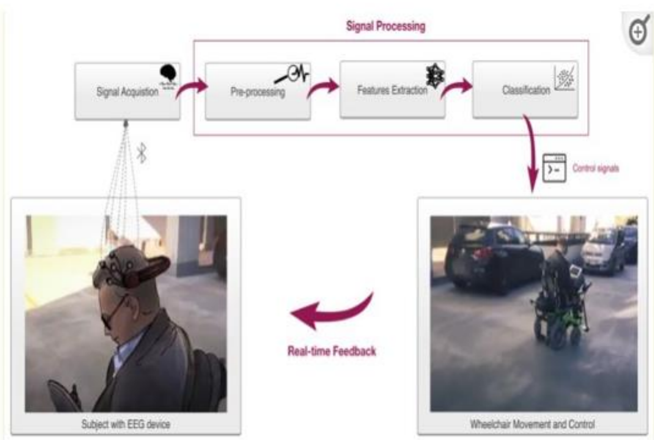
BCW, P300-based BCW, SSVEP-based BCW, and MI-based BCW. They also presented the backdrop of recent wheelchair control research employing brain activity acquisition. In relation to BCI, hybridization is a relatively recent concept that offers intriguing and promising outcomes in a number of domains. It achieves more accurate and comprehensive systems by combining multiple methods of tracking the body and brain. A straightforward, comprehensive, and widely recognized definition characterizes a hybrid brain computer interface (hBCI) as "a system that combines two or more signals from different origins, including at least one input recorded directly from the brain." In order to move and control a wheelchair, a hybrid-based BCW system combines several channels (such as motion detection, electromyography (EMG), electrooculography (EOG), or EEG) with a single EEG input. All of these studies demonstrate a typical signal acquisition (EEG) technique of controlling the system, but with distinct structural elements: user duties, the amount and kind of commands on the device, and the particular signals utilized to execute the BCI system.

As previously indicated, with patients with reduced motor skills as the intended audience, it is in our goal to demonstrate the viability and practicality of a brain-controlled wheelchair in the real world. As a result, the motor imagery task-based EEG control signal models are the best suitable option to accomplish the desired outcome out of the four EEG control signal models utilized for BCI wheelchair processing. The user can actually operate the wheelchair on their own since the motor imagery paradigm doesn't depend on visual cues or obstruct the visual navigation job. There is no chance of weariness because the target is not stimulated.

Furthermore, the motor imagery paradigm-based brain-controlled wheelchair is better suited for usage in unknown settings, and many categories of recognized motor imagery may be immediately transferred to the robotic wheelchair's directional control. Lastly, because myocardial infarction affects a region of the brain that may have become redundant, using it in patients with traffic difficulties makes sense because this paradigm does not impact the patient's remaining abilities. This comprehensive study focuses on the main problems with motor imagery as the key paradigm for wheelchair control and mobility in noninvasive BCI-based EEGs.



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6. SURVEY OF PEOPLE DIAGNOSED WITH PARKINSON DISEASE AND THUS USING WHEELCHAIR

Paralysis is a condition that severely limits a person's movements. It usually occurs in due to nervous system damage. Stroke (29%), spinal cord injury (23%) and multiple sclerosis (17%) are the leading causes of paralysis. A paralyzed person faces many difficulties. About 16 million, people are partially paralyzed in Bangladesh. Developing technology to provide piloting assistance to a completely paralyzed person is a big challenge.

Smart wheelchairs assist the operation of, disabled people. Pilot assistance is essential to make them independent. Additionally, reduces the amount of care a family need. The smart wheelchair is integrated with various humanoid computer interface technologies, such as voice, head movement, electromyography (EMG), wrist movement, and EEG, for self-guided course planning, obstacle avoidance, and additional features.

In the past, numerous technologies, including voice control and finger movement recognition, have been put forth to help impaired persons interface with physical equipment. However, most of them rely on muscles, body movements, or voice commands. These acts are not easy for a paralyzed person.

For the majority of people with spinal cord injury (SCI), a wheelchair is not only their primary mode of transportation, but also the foundation of their activities around the world. Their daily routine usually begins early with a transfer to a wheelchair, where they spend most of the day. Spending most of the waking hours in a wheelchair and fully engaged in daily activities poses several often-invisible risks to individuals with SCI. Pressure ulcers are one such hazard. Because of their immobility, lack of body sensation, and diminished control over their bowel and bladder functions, pressure ulcers provide a constant risk to those with spinal cord injuries. How minute-by-minute choices impact the integrity of the skin.

In patients with spinal cord injuries, the ischium, sacrum, coccyx, trochanters, and heels are the most often injured skin regions. Crucially, wheelchair components come into contact with the first three of these locations. Literature on the relationship between pressure ulcer risk and wheelchair use in individuals with spinal cord injury. Clinical practice can benefit from a deeper comprehension of the everyday uses of mobility devices by individuals. Results such as these could affect the way these devices are prescribed as well as how educational and rehabilitation programs are created for individuals with spinal cord injuries. Wheelchair design could be impacted as well.

7. BRAIN WAVE ANALYSIS THROUGH THE USER INPUT DATA BY USING AARDUINOKIT INTER FACED WITH BCI ELECTRODES

a. Analysis based on the concentration of the user controller

In this analysis, we take into account the attention of the user and the corresponding motion that our system generates. If the attention span of the user is very low, our system will result in poor performance, as there shall be a large amount of noise, that shall be generated within the

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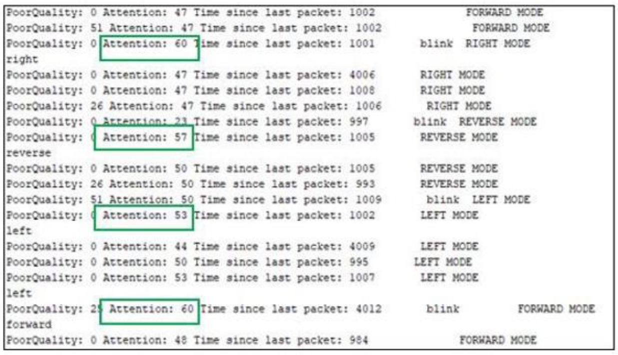
system. On the other hand, if the user is paying more attention to the system and is concentration on the movement of the wheelchair in the thought about direction, then our system can give a large and a higher accuracy as noise levels decrease.



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PoorQuality: 0 Attention: 47 Time since last packet: 1002          FORWARD MODE
PoorQuality: 51 Attention: 47 Time since last packet: 1002          FORWARD MODE
PoorQuality: 0 Attention: 60 Time since last packet: 1001      blink  RIGHT MODE
right
PoorQuality: 0 Attention: 47 Time since last packet: 4006      RIGHT MODE
PoorQuality: 0 Attention: 47 Time since last packet: 1008      RIGHT MODE
PoorQuality: 26 Attention: 47 Time since last packet: 1006      RIGHT MODE
PoorQuality: 0 Attention: 23 Time since last packet: 997      blink  REVERSE MODE
PoorQuality:  Attention: 57 Time since last packet: 1005      REVERSE MODE
reverse
PoorQuality: 0 Attention: 50 Time since last packet: 1005      REVERSE MODE
PoorQuality: 26 Attention: 50 Time since last packet: 993      REVERSE MODE
PoorQuality: 51 Attention: 50 Time since last packet: 1009      blink  LEFT MODE
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forward
PoorQuality: 0 Attention: 48 Time since last packet: 984          FORWARD MODE
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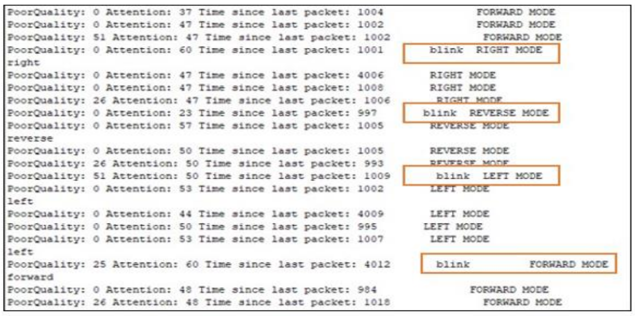

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PoorQuality: 51 Attention: 47 Time since last packet: 1002          FORWARD MODE
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reverse
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PoorQuality: 25 Attention: 60 Time since last packet: 4012      blink       FORWARD MODE
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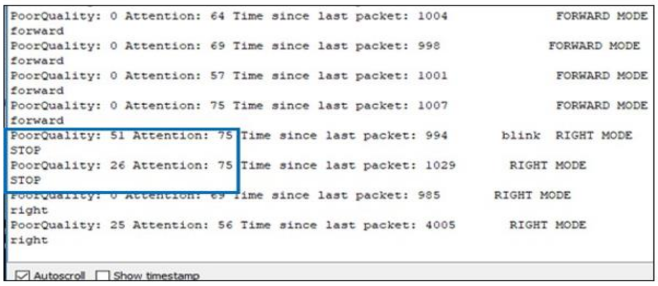

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PoorQuality: 0 Attention: 75 Time since last packet: 1007          FORWARD MODE
forward
PoorQuality: 51 Attention: 75 Time since last packet: 994      blink  RIGHT MODE
STOP
PoorQuality: 26 Attention: 75 Time since last packet: 1029      RIGHT MODE
STOP
PoorQuality: 0 [illegible]: 69 [illegible] since last packet: 985      RIGHT MODE
right
PoorQuality: 25 Attention: 56 Time since last packet: 4005      RIGHT MODE
right
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b. Analysis based on the gender of the user using the BCI wheelchair

An independent-samples t-test was performed to compare attention scores for each aspect of movement between males and females at level significance α = 0.05. Assumptions of normality and homogeneity of variance were made before performing independent-samplest-tests. Data were analyzed with SPSS. Due to the small sample size of n=15, the Shapiro-Wilk test is used to test the normality of the samples. If the p-value is above the significance level, the distribution of the sample is normal. Attention levels for each gender level were normally distributed as assessed by the Shapiro-Wilk test (p > 05). The results show Levene's and t-tests for independent- samples t-tests. The Levene test tests the null hypothesis that two groups have equal variances. If the significance value of Levene's test is greater than the 0.05 significance level (p > 0.05), the equal variances assumption is satisfied and the t values in the top row of the output table are selected.

For example, in the forward moving table, the p-value is 0.03, which is below the significance level and violates the equal variances assumption, so the bottom row of the output table is selected. Based on the SPSS results, the homogeneity of variance achieved by Levene's test is not only for forward motion. Scores between men and women. Therefore, data results associated with unacceptable equal variances are used for advancement. The null hypothesis of the independent-samples t-test is that there is no difference in mean attention scores between men and women, whereas the alternative hypothesis is that there is a difference in mean attention

c. Thre shold value for the BCI automated wheelchair

According to the results of the attention value analysis of people of different age groups and gender, different thresholds of wheelchair movement can be established for brain wave integration according to gender and age of the user (see table 5). The mean threshold of attention levels for all measures was the cutoff condition for each sex and each age. After the user changes the status of the blink- detection wheelchair, the integrated wheelchair moves when the signal quality is good, that is, the value is 0 and the attention level of the 'user is greater than the lower limit. The stop mode can be implemented when the user raises the eyebrows or arms, because it will produce a signal of quality 26 or 51, and also reduce the value of human attention.

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Table 5. Threshold value for brainwave integrated wheelchair

	Male	Female
Children	60	50
Teenager	70	50
Adult	40	30

CONCLUSION

In conclusion, a wheelchair controlled by human brain waves has been developed to assist paralyzed people using a BCI system. In this study, the efficiency of integrated brainwave wheelchairs was improved by using human attention values, eye association detection, and eyebrow movements to control the wheelchairs.

We also analyzed human attention values across genders and age groups to improve the accuracy of wheelchair brain wave integration. According to the results obtained from the experiments carried out, it has been shown that gender and age categories affect the level of interest that people generate.

Men were more likely than women to focus on all movements except left and back. Teenagers have the highest attention values when moving to the right and back. During jumps and stops, the child class has the highest attention value, while the adult class has the lowest attention value. Since attention values for all aspects of movement vary with age and sex, the global motor threshold for WM-controlled wheelchairs is determined differently by gender and age group age of the user. 60 years for children, 70 years for teenagers, 40years for adult men, 50 years for girls, 50 years for teenagers and 30 years for adult women.

When the flash intensity value is greater than 110 and less than 250 is detected, the status of the wheelchair changes in the following order: forward (F), right (R), backward (B), and left (L). As an additional safety measure when moving a wheelchair with human attention levels, eyebrow movement is used to force a stop condition when the signal quality value is 26 or 51.

This research it will open up a whole new possibility for people with disabilities., who may be able to control a wheelchair with just the power of their thoughts. With proper control, this product can be of great benefit to people with disabilities in the case of a multi-functional companion robot, even fit is a driving control or any locomotive equipment. Thus, the continuation of the program will have a greater long- term impact on improving everyone's quality of life.

FUTURESCOPE

BCW's design and implementation is summarized as follows: With the help of analytics, people with disabilities can now access any device placed in their environment, reducing their dependence on caregivers, nurses, relatives, etc.

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This work is preliminary and has some limitations.

1) We are making use of only 2 channels namely the BCI sensor output along with the hand-controlled stimuli. As we have a smaller number of the sensor inputs, it can directly correspond to a lesser accuracy. By incorporating multiple sensors located throughout the entire body, we can take an accurate map of the brain response and do the needful action

2) The design of the wheelchair can be modified in such a semi sleeper position so that, the posture of the patient is maintained and can help in more relaxation. Furthermore, we can create additional kind of motions like moving up a staircase and changing elevation of the bed, while tryingto shift position from resting to sitting upright. We can also make our system less prone to the noise levels, and can thus change our threshold value.

3) In addition, future modifications will allow you to connect adisplay, as amonitoring device, that can display not only the current action that the user is taking but also canalsoserveasaninformationCentreonthevariousdiet plans and the various medications that the patient is currently undertaking.

4) Advanced processors can reduce processing delays. The system is easy to set up and can also be developed to be user-friendly. Users simply select a destination anddeal with any unexpected situations that may arise. This system requires minimal effort and concentration. Since the wheelchair repeats the same parts over time, the movement is predictable and you can move whilerelaxing. The system is intended for people who cannot move at all and are usually in bed. Their concept of timeis different from ours and being able to move independently in their environment means that their quality of life is greatly enhanced.

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