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A Review On Engineering with the Brain

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Abstract - **In today's world, the Brain Computer Interface is a prominent technology. Simply described, it establishes a connection between the brain and the machine, allowing the computer to receive information from the human brain. This technology has been in the air for decades, and while much has been accomplished, there is still much more to be done. This technique is mostly used in the realm of medicine. There is other work being done in the military and skill enhancement sectors. This technology is advancing at a rapid pace and is quickly becoming one of the most essential technologies in the contemporary environment. This review demonstrates about how Brain Computer Interfaces (BCI) function and how they might be applied in specific situations. And how EEG (Electroencephalography) was used to read brain waves, which were then processed to produce useful data for various applications.**

Keywords – BCI,Brain controlled machines, Brain machine interface, Brain controlled robots,Neuralink

I. INTRODUCTION

In many respects, a computer and a human brain are more similar than they are dissimilar. The central processing unit of a computer has billions of integrated transistors, much as the brain contains billions of integrated neurons. Scientists may be able to understand the secrets of brain function and develop methods to cure a range of neurological illnesses by seamlessly integrating electrical components into biological systems. However, successfully merging hard electronics with soft biological systems has proven to be a difficult conundrum for researchers. Electronic engineering and neurosurgery are becoming increasingly intertwined. Rapid developments in microelectronics and materials science are motivating and speeding the creation of a new generation of diagnostic, therapeutic, and prosthetic devices for implantation in the nervous system, thanks in part to consumer demand. This study examines some of the underlying science that has led to their creation, as well as some of the potential and limitations associated with their application in neurosurgery. Implanted deep brain stimulators (DBS) and brain-computer interfaces (BCI) are examples of neural engineering technologies that are fascinating and possibly transformational tools for enhancing human health and well-being. However, their current and prospective use create a number of ethical and philosophical issues. Brain-altering devices force us to consider a wide variety of ethical issues, including identity, normalcy, authority, accountability, privacy, and justice.

II. BRAINWAVE-CONTROLLED SYSTEM FOR SMART HOME APPLICATIONS

[1] This paper describes an EEG-controlled smart home system that is designed to help handicapped and elderly individuals. The system is comprised of a The EEG signal was measured using a NeuroSky MindWave headset (MW003) in this setup. With a sampling rate of 512 Hz, the headset's dry sensor captures 12-bit raw-brainwaves in the range of 3 – 100 Hz. The headset's on-board Think Gear chip analyzes and filters the sensor's brainwaves while also allowing it to connect to other Bluetooth-enabled devices. For sensing, the electrical potential between the head electrode and the reference point is detected. Signals may be analyzed using the NeuroSky EEG program to calculate the power spectrum density of seven frequency bands:delta, theta,alpha,beta, and gamma. The amplitude of these bands fluctuates depending on both internal mental states and external stimuli. Based on the NeuroSky EEG algorithm software development kit, an Android application was created using Android Studio. The application allows you to couple your phone with your headphone as well as the HC-05 Bluetooth module, which is connected to an Arduino Uno board. The Arduino Uno board is then linked to four home appliances and switched on and off using four relays (5 V DC JQC-3FF-S-Z). The Arduino Uno board is pre-programmed with programming that allows it to receive orders from the Android app and translate them into high and low output pin states, which operate the relays. The user's attention levels and double-blinking strength ratings are used to switch these gadgets on and off. To utilize the built-in Android application, the user must pair the phone with the HC-05 Bluetooth module and the NeuroSky MindWave headset. The raw EEG data is then analyzed with the NeuroSky EEG algorithm to measure signal quality. The software is designed to reject low-quality signals in order to avoid erroneous results. Moderate and high quality signals are used to derive the attention levels and double-blinking strength values, respectively. In this case, the software is in standby mode, waiting for the user's

commands. By double blinking with a strength of 90, the software may be put into command mode. To avoid any commands being given by unintended blinking, this double-blinking intensity threshold is rated higher than usual blinking levels. Because the connections between the EEG sensor, the Android application, and the Arduino board were made over Bluetooth, the system has a low power consumption and is portable for smart home applications.

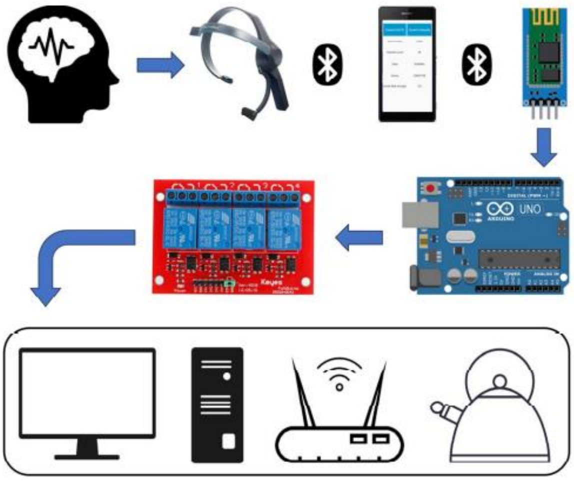

Fig 1. Block diagram of the brain controlled smart home applications [source:https://www.researchgate.net/profile/Marwan-Nafea/publication/328834634/figure/fig4/AS:691647276924929@1541912969361/Block-diagram-of-the-working-principle_Q640.jpg]

III. USING BRAIN WAVES TO CONTROL COMPUTERS AND MACHINES

[2] This paper provides an intriguing and informative review of current HCI technologies as well as emerging future ideas in the realm of brain computer interfaces. Recent advancements in cognitive neuroscience, particularly neuroimaging technology, have enabled direct communication between the human brain and machines. This capability is enabled by intrusive and sensors that can observe physiological processes exhibited in brain waves, which are then converted into control signals for external devices or machines over the internet. These brain-computer interfaces (BCIs) allow for direct transfer of brain signals to an output source without relying on the brain's motor output. They are frequently aimed at aiding, enhancing, or correcting cognitive or sensory-motor abilities in humans. Instead of employing muscular motions, users of BCIs intentionally modify their brain activity to create brain waves that may be utilised to control computers or equipment. The creation of effective BCIs and their integration into hybrid systems that combine well-established HCI and brain control methods will not only change how we conduct everyday activities, but will also improve the quality of life for those with physical limitations. This is especially crucial for those who have terrible neuromuscular injuries or neurodegenerative disorders that can leave them paralysed and unable to communicate through voice or gestures. Brain activity is often recorded using a noninvasive neuroimaging technique such as EEG, MEG, fMRI, NIRS, and ECoG in a BCI system. Scalp EEG data is acquired in the majority of BCI systems, and the kind of BCI system is classified depending on the measure of brain activity utilised for BCI control. In addition, it discusses the faults and drawbacks of currently existing BCI systems. explains how several BCI approaches are occasionally merged in hybrid systems to increase accuracy, eliminate mistakes, and overcome the drawbacks of each separate traditional BCI technology.

IV. A BRAIN COMPUTER INTERFACE BASED HUMANOID ROBOT CONTROL SYSTEM

[3] This paper proposes a humanoid robot control system based on a brain-computer interface (BCI). An EEG, a humanoid robot, and a CCD camera make up the system. This system may be used to examine the connections between complicated humanoid robot behaviours and human mental activity, as well as to test algorithms for controlling humanoid walking movements using brainwaves. Based on the robot kinematics, three types of robot walking behaviours were implemented: turning right, turning left, and going ahead. Turning right, turning left, and walking ahead are three mental processes that are associated with their robot walking behaviour equivalents and offer control of the three types of actions. This system includes a 32-microelectrode cap and the Cerebus, which includes an amplifier, an amplifier power source, and a neural signal processor capable of tracking from both surface and extracellular microelectrodes, a Kumotek KT-X PC humanoid robot with 20 degrees of freedom (DOFs), 12 DOFs on hips, knees, and ankles for humanoid robot walking, 6 DOFs on shoulders and arms for arms motion, and 2 DO The KT-X PC robot is controlled via BCI. The Cerebus Data Acquisition System uses an electrode cap on the scalp to collect brain signals from 32 channels. With a collection of band-pass filters or wavelet filters, the neural signal processing component filters away high-frequency noise and decomposes the filtered signals into delta, theta, alpha, and beta bands. To manage the robot walking movement, the behaviour identification and mapping portion identifies mental processes based on brain signal patterns. A C-means classification and a neuro-fuzzy network are included in the section on behaviour recognition and mapping. However, in this exploratory investigation, we employ the phase connection between neural signals recorded on the left and right brains to control robot walking forward, turning left, and turning right. The robot motion behaviour portion transmits a motion file to a microcontroller, which controls the robot's 20 actuators. The microcontroller's trajectory planning portion uses a cubic interpolation technique to construct robot motion trajectories between the configurations provided for the robot walking behaviours.

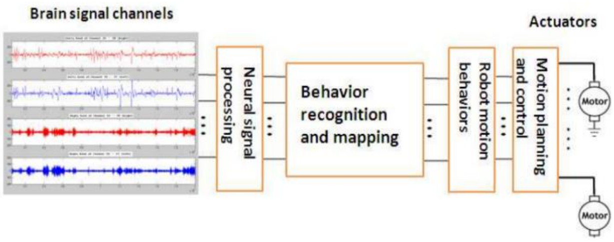

Fig 2. Control scheme of humanoid robot walking behaviour [source: https://html.scribdassets.com/9ibcy8p2tc632jip/images/4-35fe024d2d.jpg]

V. A DIRECT BRAIN-TO-BRAIN INTERFACE IN HUMANS

[4] This study describes the first direct brain-to-brain contact in humans, as well as the findings of six separate participants' trials. The non-invasive interface, first shown in August 2013, combines EEG for recording brain waves with transcranial magnetic stimulation (TMS) for sending data to the brain. A technique was demonstrated employing a visuomotor challenge in which two persons must work together to attain employing direct brain-to-brain connection to get an intended result in a computer game The brain-to-brain interface recognizes motor imagery in EEG signals from the transmitter and delivers it via the internet to the motor cortex of the receiver. This enables the transmitter to employ TMS to elicit a desired motor response in the receiver. The amount of data sent and the accuracies achieved in deciphering the sender's signals, as well as eliciting a motor response from the receiver following stimulation and completing the overall goal in the cooperative visual-motor task, were all utilized to assess the brain-to-brain interface's performance. The findings support the existence of a primitive kind of non-invasive direct information transfer from one human brain to another. The findings reveal that information retrieved from one brain using EEG may be sent to another brain using TMS, allowing two individuals to work together to complete a task utilising just a direct brain-to-brain interface (BBI). These findings indicate the first time a BBI has worked in people.To start with, the findings show that current technology may be used to create gadgets that allow people to send rudimentary brain-to-brain connections. These technologies have the potential to change not just how people connect and communicate, but also to offer up new areas for brain study. Second, the findings indicate that non-invasive methods for building functional BBIs could be used. Non-invasive technologies have a broader range of potential applications, and they might be utilized to build BBIs in people for a number of purposes since they are now easier and safer to use than intrusive, surgically implanted devices. Finally, these findings highlight the importance of accelerating discussions among ethicists, neuroscientists, and regulatory agencies about the ethical, moral, and societal implications of BBIs, whose future capabilities may go far beyond the rudimentary type of information transmission we have demonstrated here. When compared to invasive stimulation techniques, non-invasive stimulation technologies such as TMS or transcranial current stimulation are still limited in terms of the number of available stimulation sites and the spatial accuracy of activation targets. As a result, developing BBIs that can entirely replace or enhance current modes of human communication will need either significant advancements in these technologies or the development of new ones. Current established technologies, like as TMS, might, nevertheless, be employed in fascinating ways beyond what this work has shown.

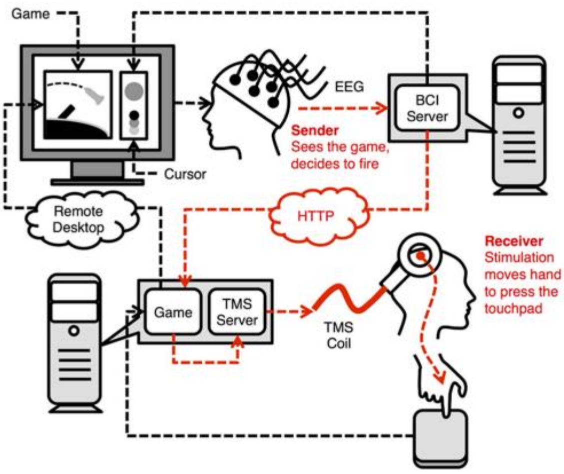

Fig 3. A Direct Brain-to-Brain Interface -Schematic diagram [source:https://journals.plos.org/plosone/article/figure/image?size=large&id=10.1371/journal.pone.0111332.g001]

VI. BRAIN COMPUTER INTERFACE BASED WHEELCHAIR: A ROBOTIC ARCHITECTURE

[5] The focus of this research is on a non-invasive brain-controlled wheelchair. The wheelchair's motion is guided by EEG signals. The proposed concept offers a novel method to employing BCI technology to drive a wheelchair. A robotic module that can move under the influence of human ideas was constructed to test the notion. EEG signals from the brain's scalp are collected using brainwave sensors.It's a one-node sensor that uses gold-plated dry electrodes to gather brainwaves from the scalp. EEG, Reference, and Ground are the three points of contact on the sensor, which is made up of a single channel. The frontal, parietal, and occipital lobes send Mu waves to the FP1 node, which collects them Mu signals are sent to the computer system through Bluetooth connection. The information is provided in the form of a digital depiction of brain activity. The data obtained from the sensor by the computer system is subjected to Matlab-based data analysis. An ANN-based classifier is used to make decisions. This classifier compares the sensor's data to the reference level in order to create a command that allow the wheelchair to move.The suggested technology was tested using a wheelchair model.The motor driver controls the movement of two motors, one for each wheel. The motors are controlled by interrupt signals sent by the ARM7 controller. By adjusting the bit combinations sent to motors, they may be pushed forward or backward. Data is sent from the computer system to the robotic module through a serial connector. Control instructions are generated using bit combinations. Eye blinking with full sense and the concept of a movement are evaluated combined for the impact of executing multiple activities at the same time. The user's mental focus level drops when they blink their eyes. The degree of focus in the user's brain rises when he stops blinking. This demonstrates that performing a wheelchair manoeuvre requires concentration. A minor delay between user thoughts and wheelchair movement was detected during an actual attempt to operate a wheelchair using EEG data.

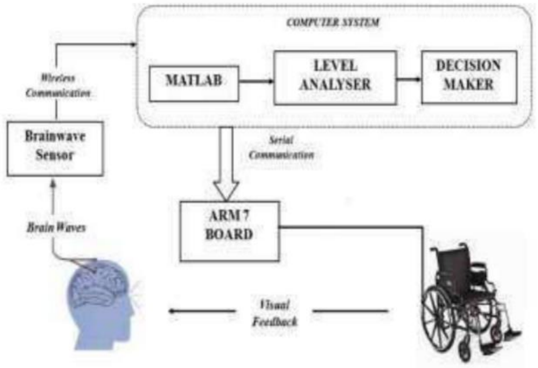

Fig 4. Block diagram of BCI based wheelchair system [source:https://html.scribdassets.com/30plcet16o5s4tcr/images/2-3a9e992ed5.png]

VII. ROBOT NAVIGATION USING BRAIN-COMPUTER INTERFACES

[6] This paper identifies the user's approach on brain-controlled systems and the ability to control brain generated events in a closed neuro-feedback loop. To do so, a workable system based on off-the-shelf components for commanding a robot in both the actual and virtual worlds has been constructed. Two headsets are used in this system: Neurosky headsets and Emotiv EPOC Headset. The Lego Mindstorms NXT kit was utilised for the robot, along with a Java Virtual Machine. Touch and light sensors are utilised as sensors. Based on the type of headset utilised, the system is separated into two prototypes. The first prototype is based on the Neurosky headset, whereas the second is based on the Emotiv headset, which has more sensors and accuracy. The user's Attention and Meditation levels were extracted using Neurosky headsets. The eSense Meters are generated by the headset using a Neurosky-patented algorithm that calculates the raw EEG data. By turning EEG signals into control commands, sophisticated algorithms are used to assess the patterns of electrical activity. The Neurosky headset uses a single dry sensor mounted on the forehead outside the cerebral cortex in the frontal lobe of the brain, which is in charge of attention and short-term memory. Through a two-axis gyroscope, the Emotiv EPOC Headset uses 14 saline sensors to detect not just brain impulses but also user facial expressions, eye movement, and head position. Emotiv classifies certain facial emotions as Expressive, degrees of engagement, frustration, meditation, and enthusiasm as Affective, and the training and detection of particular cognitive brain processes like push, pull, rotate, and lift as Cognitive. These headsets can infer the user's mental state by monitoring their brainwaves. The user can obtain a closed neuro-feedback loop by providing all of the specifics of their brain activity on a computer. This is a sort of biofeedback that may be used to analyse and build tools that can aid people with severe brain injury, as well as those who want to operate a computer programme or a robotic equipment.

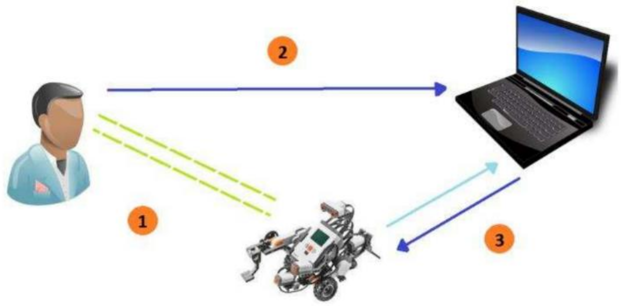

Fig 5. Overview of BCI based robot navigation system [source: https://www.researchgate.net/profile/Fotis-Liarokapis/publication/236683786/figure/fig1/AS:340877202477079@1458282866984/Overview-of-the-system_Q320.jpg]

VIII. AN INTEGRATED BRAIN-MACHINE INTERFACE PLATFORM WITH THOUSANDS OF CHANNELS

[7] Neuralink's first attempts toward a scalable high-bandwidth brain-machine interface system are described in this study. The arrays of tiny and flexible electrode "threads" were constructed, with up to 3072 electrodes per array dispersed among 96 threads. They have created a neurosurgical robot that can inject six threads (192 electrodes) every minute. To bypass surface vasculature and target particular brain areas, each thread may be individually introduced into the brain with micron accuracy. The electrode array is housed in a compact implantable device with specialised chips for on-board amplification and digitising at minimal power: The package for 3072 channels is just 23*18.5*2 cubic meter in size. A single USB-C cable allows full-bandwidth data streaming from the device, as well as simultaneous recording from all channels. In chronically implanted electrodes, this technique has obtained a spiking yield of up to 70%. In a therapeutically appropriate package, Neuralink's approach to brain-machine interface boasts unmatched packing density and scalability. A brain-machine interface with a high channel count and single-spike resolution was disclosed in this research. Flexible polymer probes, a robotic insertion device, and unique low-power electronics make up the system. This system has two primary functions: It's a rodent-based research platform that also acts as a prototype for potential human therapeutic implants. Devices, industrial processes, and software can all benefit from the capacity to swiftly iterate designs and test them in rodents. Because it's a research platform, the system relies on a wired connection to optimise raw data streaming capacity. This is critical for the development of signal processing and decoding algorithms, as well as for performance evaluations. Medical devices derived from this platform, but at the other hand, will be fully implanted, requiring hermetic packaging, and will have on-board signal compression, decreased power usage, wireless power transfer, and data telemetry through the skin without the use of percutaneous leads. Modulating cerebral activity, for example, to offer a sensation of touch or proprioception to neuroprosthetic movement control, will be a key aspect of next-generation therapeutic brain-machine interfaces. As a result, every channel of the Neuralink ASIC was designed to be capable of electrical stimulation. Compared to prior techniques, this brain-machine interface technology offers significant advantages. Thin-film probes' size and composition are more similar to the material qualities of brain tissue than routinely employed silicon probes, suggesting improved biocompatibility. Because the location of electrodes may be changed based on the job requirements, this characteristic is important for establishing a high-performance brain-machine interface. Finally, the Neuralink ASIC's compactness and architecture allows for a lot of freedom in system design and allows for extremely high channel counts within realistic size and power limits. Our approach to brain-machine interfacing is, in principle, quite adaptable and scalable. In this study, researchers reported simultaneous broadband recording from over 3000 implanted electrodes in a freely moving rat. If you have a bigger brain, you'll be able to do more. Multiple devices with this architecture may be easily implanted, allowing us to communicate with a much larger number of neurons without requiring substantial reengineering. Further advancements in surgical robots may enable us to do this without significantly lengthening operation times. Although considerable technological obstacles must be overcome before a high-bandwidth device can be used in clinical settings, it is possible that a patient with a spinal cord injury may dexterously manipulate a digital mouse and keyboard with such a device. This strategy, when paired with fast advancing spinal stimulation techniques, might potentially restore motor function in the future. A range of unique therapeutic options should be enabled by high-bandwidth brain interfaces.

IX. PROGRESS IN BRAIN COMPUTER INTERFACE: CHALLENGES AND OPPORTUNITIES

[8] This study discusses the obstacles that neurosensors and computational tools face, as well as a number of ground-breaking advancements. The advancements in nerosensors bode well for more complex and user-friendly BCI devices that require no or no maintenance. Aside from high-fidelity signal capture, major advancements in signal processing and machine learning tools, as well as their complimentary functions, high computation power, and enhanced computer mobility, have all aided in the development of BCI technology. Also discussed is the future of BCI technology, which will rely heavily on solving crucial elements such as designing less intrusive sensors with reliable signal capture and resolution, while taking portability, ease of maintenance, and cost into account. Identifying the psychophysiological and neurological elements that may have an impact on BCI performance.

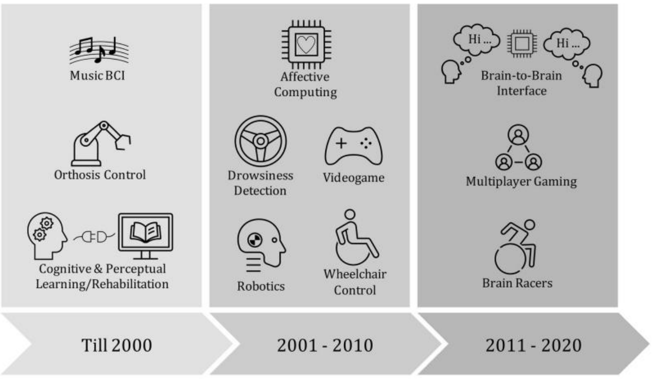

Fig 6. Schematic illustration of evolution of the BCI applications [source: https://www.frontiersin.org/files/Articles/578875/fnsys-15-578875-HTML/image_m/fnsys-15-578875-g002.jpg]

X. BRAIN COMPUTER INTERFACES FOR IMPROVING THE QUALITY OF LIFE OF OLDER ADULTS AND ELDERLY PATIENTS

[9] This study discusses the physical and physiological changes that aging people go through. Changes in memory and brain function are referred to as "changes." Many external devices and gadgets have been developed to assist elderly people and patients in leading regular and enjoyable lives. They have benefitted the aged, physicians, carers, and family and friends. Elderly people's cognitive abilities can be assessed and improved through interactive gaming testing. Modern wheelchair and other technologies were created to assist elderly persons with everyday activities while also providing therapy for muscle and motor function loss. The elderly can benefit from smart home settings that help them live freely and safely in their own houses.The technologies covered in this article will spur the development of new BCI-based technologies and devices for the older adults. BCI technology has already shown promising performance in giving cognitive and physical assistance and rehabilitation, as well as future advancements in this important field of research that will eventually affect us all.

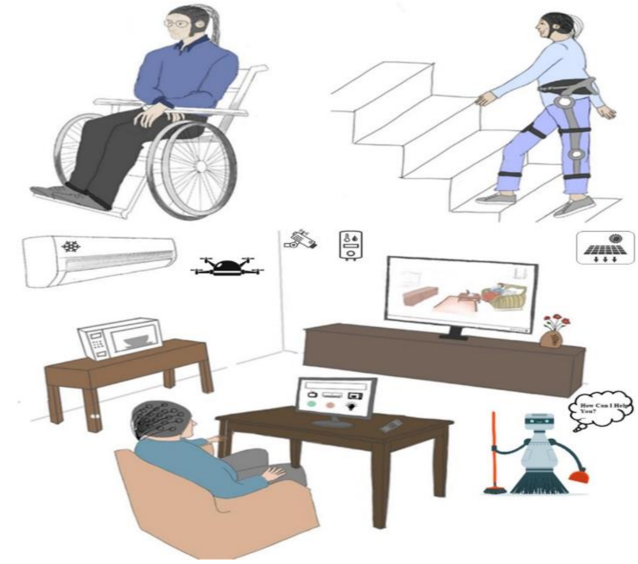

Fig 7. Possible assistive applications of EEG-based [source:https://www.ncbi.nlm.nih.gov/pmc/articles/instance/7339951/bin/fnins-14-00692-g001.gif]

XI. BRAINWAVE CONTROLLED ROBOT

[10] This paper explored the use of brainwaves in the construction of a completely automated and controlled robot or wheelchair utilizing a Mind wave sensor that detects Beta waves. A microcontroller called Arduino may be used to drive a robot or a wheelchair. The EEG and Eye-Blinking data are provided utilizing a BCI in this study. The use of a simple unipolar electrode to capture EEG signals from the forehead in order to construct a BCI that primarily operates electric wheelchairs for unfit people through Bluetooth is a common approach in this system. It picked up on two different signals: meditation and concentration. BCI's eye-blinking signals were also recovered. As an outcome, using a Bluetooth interface and therefore the electrically interface in the electric chair, attention and eye-blinking signals are gathered as management signals.

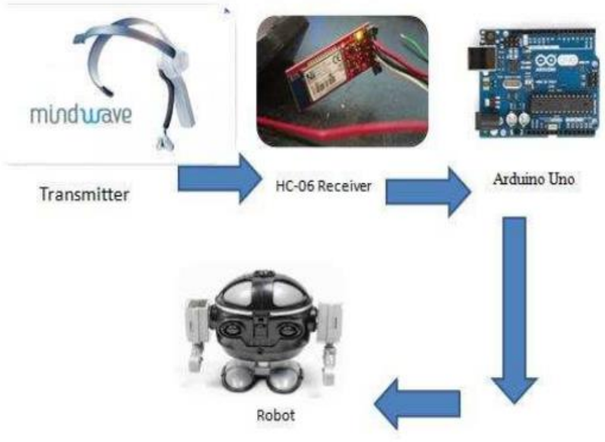

Fig 8 Block diagram of brainwave-controlled robot system [source:https://html.scribdassets.com/88jwf3pwu84llxgh/images/3-a056b90c16.jpg]

The trial findings revealed that this system will provide a straightforward means of controlling an electronic wheelchair.The architecture for EEG signal processing with Bluetooth interface is described. EEG securing was used to retrieve the EEG signal. In this system, we employ the NeuroSky Mindset headset to record EEG and eye blinking data, as well as headphones on the sensor to detect brain waves, which are then sent over Bluetooth wireless modules. On the receiving section, we employ a Bluetooth module in a personal computer with a MATLAB-based software interface.

XII. CONCLUSION

We studied neurophysiologic signals, signal processing and ML approaches, as well as BCI applications, in this work, in an attempt to provide an introduction to BCI research. As we've seen, there are many different types of demonstration of idea of systems. None of the methods described in the scientific literature, however, are suitable for use by impaired people on a daily basis or in multimedia contexts. This is because the technology that underpins BCIs is not yet developed enough to be used outside of the lab. As a result, many tough and intriguing problems in BCI research remain unanswered.The several breakthroughs in neurosensors and computational tools herald the arrival of increasingly complex and user-friendly BCI systems which require little or no maintenance. Apart from high-fidelity signal collection, significant advancements in signal processing and machine learning tools, as well as their complementary functions, as well as high computing power and enhanced computer mobility, have all aided the advancement of BCI technology.

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