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Brain Gate Technology

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ABSTRACT

Brain Gate overpasses the gap between the brain and the computer. It is a mind-to-movement system that allows a quadriplegic person to command a computer using only his/her thoughts. Brain computer interface technology, used in Brain gate technology, is a brain implant system that came into existence by bio tech company called cyberkinectics in conjunction with the Department of Neuroscience at Brown University. It is found that people with long established, severe paralysis can generate signals in the area of the brain responsible for voluntary movement and these signals can be detected, recorded, routed out of the brain to a computer and transformed into actions enabling a paralyzed patient to perform basic tasks. It is none less than a scientific triumph that brain these signals can be reconnected, thereby allowing the patient to make movements of their limbs just by thinking about it. A fascinating goal which motivates one to work upon this technology is to enable naturally controlled movements of paralyzed limbs. The research done on Brain Gate is yet very limited as the system is still under trial and hence, this paper gathers information through several contributions provided and assembles them to form a single point of reference.

Keywords: Brain Gate, Cyberkinetics, Brain computer Interface and neuroscience

I. INTRODUCTION

Our brain is responsible for all the thoughts produced, but some of us don't have the capability to deliver these thoughts to others. The evolution of the brain gate system is to entitle those with severe paralysis and other neurological conditions to live more productively and to be all by one's self. The Brain Gate System is an investigational medical device which deliberately decodes neural signals, normally associated with movement commands, in order to permit a disabled individual to control a computer interface. A computer chip that's embedded into the brain, observes brain activity and then interprets the target of the user into computer commands. Presently, the chip makes use of about 100 hair-thin electrodes that recognize the electro-magnetic signature of neurons firing in particular areas of the brain. The task particularly thought is interpreted into electrically charged signals which is then sent and decoded with the help of a program, which can move any prosthetic device like a robotic arm.

Dr. Donald Humphrey of Emory University is the reason behind the discovery of the revolution of Brain Gate. He invented a method for brain-computer interfaces in the late 90's, which became the basis for a liberal and diverse patent. Following that, a Brown University spin-off known as Cyberkinetics was created to turn a set of laboratory tests into a regulatory accepted set of clinical trials for the first-generation neural interface system, which resulted into Brain Gate Neural Interface System. Subsequently in 2004, the first of two Investigational Device Exemptions was received by Cyberkinetics from the U.S. Food and Drug Administration to perform this research. This was a 12 month, protensive, feasibility clinical study carried out on the Brain Gate system. The study was designed to gather exploratory safety and efficacy data on the possibility of motor impaired patients using Brain Gate System to control a computer with thoughts. Subsequently in 2004, the first of two Investigational Device Exemptions was received by Cyberkinetics from the U.S. Food and Drug Administration to perform this particular research. This was a 12 month, protensive, feasibility clinical study carried out on the Brain Gate system. The study was designed to gather exploratory safety and efficacy data on the possibility of motor impaired patients using Brain Gate System to control a computer with thoughts.

II. BRAIN COMPUTER INTERFACE

Brain-computer interface uses electrophysical signals to control any prosthetic device. BCI is one of the most popular and assuring technologies as it helps in improving communication/control of quadriplegic people. It consists of electrodes which are applied to the scalp of the patient, the signals are then picked up by these electrodes and carried into amplifier. The signals are then amplified around ten thousand times and then passed through an analog to digital converter to a computer. The computer then processes the EEG signals, which will then help in performing tasks. This technology has applications in many sectors, including medicine, education, and psychology which helps in solving many health-related issues like cognitive deficits, slowness in processing speed, and movement capability decline among elderly people.

There are three types of BCI based on the electrodes used for measuring the brain activity: 1) *Non-invasive BCI*, where the electrodes are placed on the scalp (e.g., EEG based BCI), 2) *Invasive BCI*, where the electrodes are directly attached on human brain (e.g., ECoG based BCI), 3) *Partially Invasive BCI*, where the electrodes are positioned on the exposed surface of brain so that they measure electrical activity coming from the cerebral cortex. To construct a BCI system, five or six components are normally required: signal acquisition during a specific experimental paradigm, pre-processing, feature extraction, classification, translation of the classification result to commands and user feedback.

III. PRINCIPLE

The ultimate goal of Brain gate is to turn one's thoughts into actions. The principle of Brain Gate Technology is to produce neural signals even though these signals are not sent to the limbs. The signals produced with whole brain function is understood by the system. It can be an astounding invention for many.

IV. COMPONENTS USED IN BRAIN GATE

Brain Gate mainly consists of four hardware components:

1) The chip: This chip is a 4mm silicon chip, which is square in shape, and it is studded with 100 hair thin

microelectrodes. This chip is implanted in the primary motor cortex of the brain. Motor cortex of the brain is accountable for the control of movements.

2)The connector: Connector is responsible for passing the signals which it has received from the chip to the convertor. This connector is staunched firmly to the patient's skull.

3)The converter: The signal proceeds through an amplifier. Here it is transformed to digital data and then flinched by fiber-optic cable to a computer. This amplifier is shoebox sized.

4)The computer: Brain Gate gains an understanding to assist motive of brain movement with imagination movements. These movements like up, down, left, right is then connected to a cursor.

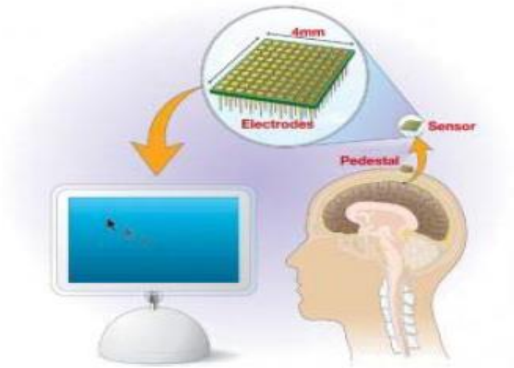

Fig. 1 : The sensor/chip used in Brain Gate

Brain Gate system uses various algorithms and pattern-matching techniques to smooth communication. The algorithms used in Brain Gate are written in C, Java, and MATLAB. The electrical activity of neurons is inspected by software algorithms that process signals and these signals are then translated into control signals for use in various computer-based applications.

V. WORKING

Brains are pervaded with neurons, which are connected to each another by dendrites and axons. Whenever we think, do any activity, or memorize something, our neurons are at work. Then at the speed of approximately 250 mph , small electric signals race from neuron to neuron. These signals are then provoked by differences in electric potential carried by ions on the membrane of each neuron. Few of these electric signals escape even though the paths, signals taken are insulated by something called myelin. Scientists have the ability to detect these escaped signals and explicate what they mean and use them to conduct some kind of device.

The Brain Gate neural interface system is a patent, investigational Brain-Computer Interface which contains an internal sensor. It identifies brain cell activities and external processors that convert these signals into a computerized output under the person's own control. Sensor/Chip is implanted on the motor cortex. Electrical signals are picked up from the electrodes which invade about 1mm into the surface of the brain, this is called neural spiking.

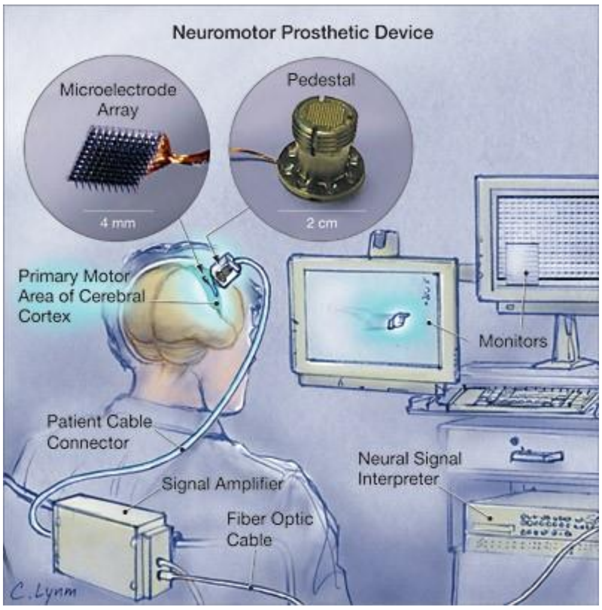

Fig. 2 : Structure of Brain Gate System

The brain gate system is a neuromotor prosthetic device. A Neuromotor prosthetic device is a type of brain-computer interface which extracts signals from central nervous system and thereafter deliver them to control various devices. These devices can be replacement for motor, sensory or cognitive functions that have been impaired due to neurological disorders. The device consists of an array of 100 silicon hair-like thin microelectrodes in which each electrode is 1mm long. The sensor is of the size of a contact lens. The electrodes are organized less than half a mm apart in the array. The electrolyte and the electrodes form a capacitor which have very high capacitance per area consequently granting voltage-sensitive sites for the entire surface in a spatial arrangement.

When we think about any particular action, electrodes on the silicon chip detect neural activity from an array of neural impulses in our brain's motor cortex. The impulses transfer from the chip and transmit them through thin gold wires to a titanium pedestal that protrudes about an inch above our scalp. These EEG signals produced are obtained from the brain through invasive or non- invasive methods.

It is compulsory to clean the signals once they are obtained. Only once the signals are cleaned, they will be processed. Hence, the pedestal first filters out unwanted signals or noise and then sends the signal to an amplifier. An external cable, which is 13 cm long, connects the pedestal to computers, signal processors, and monitors. The signal is grabbed by the acquisition system and is sent through a fiber optic cable to a computer. The computer then classifies the signals and then using a suitable algorithm, translates the signal into an action, resulting into the desired action/movement.

Brain Gate is able to sense the electrical activity of numerous individual neurons at one time, the data is transmitted from the neurons to computer, where it is analyzed, and the thoughts are then used to control any prosthetic device.

Fig. 3 : Thoughts of a man being analyzed by the computer

The whole process requires two surgeries, one is to implant the Brain gate, and another is to remove it. Before the surgery, several precautions are taken to prevent infections; patients need to bath daily using antimicrobial soap and consume antibiotics, even MRI scans are done in order to find the exact place for the sensor in the brain. In aseptic condition and under general anesthesia, the surgeon drills a small hole in the skull and implants the sensor. Post-operative care is extremely required, which also includes a CT scan, blood tests, and care of wound in the hospital for about a week. Even After the implantation, regular medical checkups are required.

Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions. Authors are strongly encouraged not to call out multiple figures or tables in the conclusion—these should be referenced in the body of the paper.

VI. PROMINENT RESEARCH SUCCESSES

It all started in the year 1995, when Dr. Donald R. Humphrey along with Dr. Leigh R. Hochberg studied 'INTRACORTICAL RECORDING OF BRAIN ACTIVITY FOR CONTROL OF LIMB PROSTHESES'. This research was done to find the evidence that whether the signals derived directly from the motor cortex of the brain can be used for controlling prosthetic devices or not. The study cleared the way for two areas which required more research, for brain imaging studies of candidates for a neural prosthesis and for finding stable neural signals for prosthesis control.

Later, in the year 1997, D. R. Humphrey2and L. R. Hochberg along with M. Burrow, J. Dugger and D. J. Reed conducted research where a Time Delay Neural Network was used for cortical control of robot. The research acquired success as a robot arm could track the actual wrist position of a monkey when it was given corresponding neurological signals from the animal's motor cortex. This was a green signal for further research and several studies were done and finally in the year 2003, Brain Gate was found by Cyberkinetics in combination with the Brown University.

Clinical trials On Brain Gate system began in the year 2004 and continued till 2006 where 4 patients with tetraplegia were studied. The very first patient, a 25-year-old patient, Matthew Nagle, had spinal cord injury and was paralysed down from the neck since the year 2001. Then after taking part in the clinical trial of this system, he was able to open emails, switch tv channels and even move a prosthetic am using his wheelchair. This was the first time that neural signals were recorded and decoded in a human with paralysis. After conduction of these trials, it was observed that the participant had immediately gained control of a computer interface, could operate the cursor while performing other voluntary motor tasks and required no special training. It was also observed that modulation of neural activity is possible in motor impaired patients.

Fig. 4 : Clinical trial being performed on Matthew Nagle

Thereafter in 2009, Brain gate earned the rights and virtues from this technology and intellectual property from Cyberkinetics. In July 2009, clinical trials began under the name 'BrainGate2 Neural Interface System' and has been continued since then. In November 2009, Toyota launched its wheelchair which worked on thoughts. Toyota teamed up with Japanese research foundation RIKEN for the development of this mind-controlled wheelchair. This is the very first use of EEG signals. EEG(Electroencephalography) is an efficient modality which helps to acquire brain signals corresponds to various states from the scalp surface area.

Subsequently in the year 2012, a research teams of neuroengineers performed a clinical trial where two people who had lost the use of their limbs were able to move a robotic arm just by thinking about it. Using this technology, for the first time in 15 years a participant was able to raise a bottle to her mouth and take a sip.

Fig. 5 : The woman who was able to raise a bottle using Brain Gate

The main disadvantage of this system was that the wires coming out of the patient's brain attached to the cables. The research for making the device wireless went on for a long duration. Making the device wireless, it involved too many complexities and there were even chances of patient being infected. The aim was to make the device completely user controlled so that almost all the requisite requirements of the paralysed would be solved.

Finally in April 2021, Brain Gate became the first technology to transmit wireless commands from a human brain to a computer. This proved to be a milestone for Brain Gate technology.

VII. WIRELESS BRAIN GATE SYSTEM

The size of the wireless device is about 2 inches and weight is about 1.5 ounces. The significance of this is that the device is attached to the computer wirelessly. So we still have the micro electrode array which is now attached to the bandwidth pedestal mounted wireless transmitter. This bandwidth has a wireless receiver which receives the signals from the patient's brain. The information then goes to a digital hub and that is then delivered by a fiber optic cable to the neural signal processor. The information is then decoded, and it is used to control the computer system used by the patient.

With this wireless transmitter we have about a 36-hour battery life, so the data could be recorded for 24 hours. Soon this could become a more prominent treatment option for patients dealing with difficult neurological disorders.

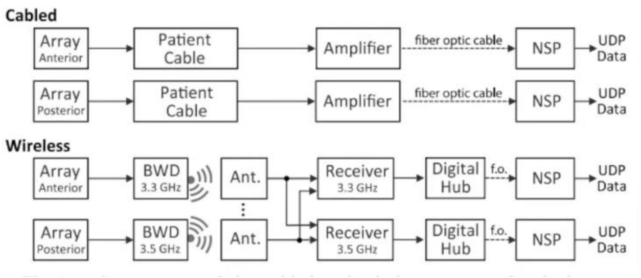

Fig. 6 : Components of cabled and wireless systems for dual-array recording. Ant.: Antenna, f.o.: fiber optic

From the study, scientists concluded that the wireless brain computer interface was as efficient and as effective as the wired brain computer interface. They both are comparable in terms of decoding the neural signals and even in terms of the bit rate they both have a similar speed of processing. From the recordings of a single electrode in the brain computer interface, scientists concluded that both the systems have similar amplitudes and so the signal strength is just as strong in the wireless and the wired system.

VIII. ADVANTAGES

1. Brain Gate can be used in an interactive environment as the user's ability to operate the system is not affected by their speech, noise or eye movements.
2. The chip can safely be implanted in the brain for at least two years and later, it can even be removed safely.
3. Tetraplegic patients get the ability to easily control external devices, user can easily learn to control a cursor with basic training as the system is not complex and makes it easy to interact with computer.
4. The speed, accuracy, and precision are comparable to a person with no disabilities.
5. Patients using Brain Gate system can communicate by thinking of what they want to say, their thoughts are then translated through text or a robotic voice and this works almost every time.
6. The system uses an invasive method where active potentials of every single neuron are recorded more accurately compared to other non-invasive methods.

IX. DISADVANTAGES

1. Currently, it is essential to recalibrate the device before every use by the patient. Scientists are working on automated calibration to allow more independence to the patient.
2. The chip needs to be surgically implanted in the brain which is a very risky process as it requires a surgery and can be dangerous even though the chip is extremely small.
3. The device is not yet available in the market and is very complex and highly expensive as it uses advanced technology. Scientists estimate that the technology might cost hundreds of thousands of dollars.

4. The system still takes a lot of time as one must think of each letter individually which will then be translated into text or voice.
5. As brain is exceedingly complex, there are approximately 100 billion neurons in a human brain and each neuron continuously sends and receives signals through a complex web of connections. Chemical processes are also involved and hence EEGs obviously can't understand everything.

X. FUTURE SCOPE

Brain Gate system is still an investigational device and thus indicates what is likely to be possible in future. Currently the focus is to improvise the basic process of converting thoughts to computerized actions. Once this is done, the potential uses for this technology are almost limitless for instance, a robotic hand could be placed by robotic braces which would help in joining individual's own limbs, thereby allowing them to move and directly interact with the environment. If this led to a positive outcome then the gates would be open for more advance uses, like, things could be accomplished in a way where there's no need of a robotic part. Signals could be sent to the appropriate motor control nerves in the hands, bypassing a damaged section of the spinal cord and allowing actual movement of the subject's own hands.

Brain Gate system has allowed individuals to control wheelchair or operate a robotic hand. The system will connect the brain gate sensor with functional electrical stimulation (FES) system. FES system uses electrical impulses to trigger muscle and limb movement. The initial version will allow one to perform simple actions such as eating or drinking using their own arms and under the natural control of their own brains. Later versions, however, won't require supports and will allow users to do more efficient activities, such as using cell phones or remote controls.

We can highly expect that soon, Brain Gate System could be even used by those users who have less severe injuries. There's a high chance that the next generation products could be able to provide one with the ability to control devices that allow breathing, bladder, and bowel movements but currently, the system is still in its early ages and is not yet approved for sale.

XI. CONCLUSION

The wickedness of the deficits caused due to paralysis is a very strong motivation to go after Brain-Machine Interface solutions. The research is still on its way to gradually increase the adaptability of the algorithm, like to read more characters per minute even in the absence of software using statistics of English language. The aim is to replace the robotic with user's own arms where electrical wires will replace the damaged nerves. The sole purpose of brain gate still being under research is to make the device faster, reliable, completely user controlled. This would solve almost all the crucial needs of the paralysed. The idea to move robotic devices not by manual control, but by mere thinking has been a fascinating approach.

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