ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
Vol 5, Issue 3, March 2018

Brain Gate: An Assistive Prosthetic Technology

[1] Preethi.V, [2]Hemalatha.R, [3]Suganthi.N
[1][2][3] Information Technology, Kumaraguru College of Technology, Coimbatore, Tamilnadu, India

***Abstract* – Brain Gate is a brain implant system developed by the Bio-Tech company Cyber kinetics conjunction with the Department of Neuroscience at Brown University. The device was designed to help those who have lost control of their limbs or other bodily functions such as patients with spinal cord injury. The computer chip, which is implanted into the brain, monitors brain activity in the patient and converts the intention of the user into computer commands. Brain continues to send neural signals required for all voluntary actions even in paralyzed patients but due to spinal cord injuries or some kind of stroke, the relay of signals is disrupted from reaching the corresponding destinations. This Brain Gate Neural Interface system fetches these neural signals through fiber optic cables, feed them to neural signal processing software which uses appropriate decoder algorithms to interpret the brain neural signals and execute the corresponding commands with the help of robotic arms. Currently the chip uses 100 hair-thin electrodes that are targeted to the neurons in specific areas of the brain, for example, the area that controls arm movement. This Brain Gate technology is moving towards passing the neural signals through electrical nerve wires implanted inside human body thus eliminating the use of robots.**

Index Terms— Brain Gate Neural Interface (BGI), Invasive, Neurochip, Neuroprosthetic.

I. INTRODUCTION

Brain Gate Neural Interfacing device is one of the breakthroughs in the history of Neural Science and Neural prosthetics. The main aim of brain gate is to provide a user- friendly prosthetic which could help them turn their actions into thoughts. Many researches are currently working in the field of Neural Science to understand the brain neurons, their working and their functions. Understanding the brain activity, the concepts of interfacing external chips and neuronal tissues; feeding and processing computers with digital neuron signals and algorithms used behind them would provide us a better clarity of how the brain gate works.

II. BRAIN ACTIVITY

Brain is the center of nervous system where neurons form the basic functional unit. Each neuron is connected by synapses to several thousand neurons. Neurons communicate with each other through synapses in a process called neurotransmission. During this conduction, chemical reactions occurring in dendrites and neuron membrane surrounding axon produce electric signals. Normally, the membrane is said to be polarized when the potential of a neuron is -70 millivolts. The opening and closing of ions during neurotransmission will make the potential of the target neuron positive thus depolarizing the neuron. When this depolarization reaches the point of threshold, a large electrical signal is generated called Active Potential. When an array of electrodes is placed between these neurons, the difference in voltage between electrodes can be amplified to record and understand brain activity.

Brain activity is recorded either using Invasive methods or non-invasive methods. Former requires physical implants of micro electrodes in the cortex of brain which provides high resolution records or local field potentials, both temporal and spatial for every single neuron being recorded and the latter makes use of external sensors attached to the scalp e.g. Electroencephalography (EEG), Magnetic Resonance Imaging (MRI) but it has comparatively less resolution due to noise and distortion of signals due to blocking of the skull.

III. INTRACORTICAL ACQUISITION

Intracortical acquisition technique represents the most invasive method of implanting under the cortex surface of the brain which is 1.5 millimeters deep into surface of the brain. It can be achieved using single electrode, or array of electrodes (MEA) that measure the action signals or potentials from individual neurons. It has very high spatial resolution but intracortical acquisition could encounter long term signal variability. This is due to different reasons like neuronal cell death or increased tissue resistance. Besides these reasons, noise generated by other muscle movements like blinking of eye lids can further lead to signal distortions.

Other methods of interfacing with the brain using electrodes include electroencephalography (EEG) where interfacing occurs at the scalp and electrocorticography (ECoG) where electrodes are put under the skull. The advantage of intracortical acquisition is that it can trace activity of every single cell implanted with whereas the other implants capture the average activity of few

ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
Vol 5, Issue 3, March 2018

thousands of neurons. The efficiency of intracortical implants is 10 times better than that of EEG or ECoG.

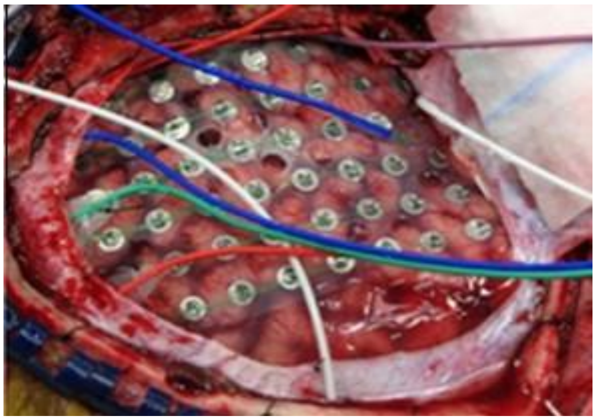


Fig. 1: Electrocorticography(ECoG) acquisition

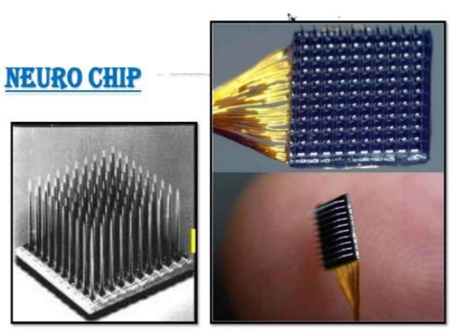
IV. PRINCIPLE

The principle behind the Brain Gate Neural Interface system is that the brain continues to generate and send neural signals in quadriplegics though those signals could not reach the arm or legs due to damaged spinal cord. These signals are interpreted by the system where a cursor is shown using which the user can control the system thus providing "Brain Gate Pathway".

V. COMPONENTS

1. Chip

The chip consists of Micro Electrode Array containing 100 hair thin silicon electrodes, each of them responsible for recording neural spiking of each different neurons, embedded in the motor cortex of the brain



Chip uses 100 hair-thin electrodes that 'hear' neurons firing in specific areas of the brain.

Fig. 1: Neurochip - MEA

2. Connector

The neural signals captured by the electrodes are transmitted to the system through thin gold wires to titanium pedestal plug attached to the skull.

3. Converter

The neural signals are transmitted to the amplifiers like Electroencephalogram, where they are converted to digital data and those data are then passed through fiber optic cables to the system.

4. Computer

The digital signals received are interpreted to move the cursor shown to the user in the particular directions – up, down, left, and right.

VI. BRAIN CHIP INTERFACE (BCHI):

Brain Chip Interface is a hybrid system where brain cells and chip-based Microelectromechanical Systems (MEMS) establish a close physical interaction allowing the transfer of information in one or both directions. It is used in multisite recording of neuronal activities "invitro" simultaneously.

Levels of BCHI:

There are three levels of BCHI – neuron, tissue, and brain. The neuron level interfacing implies that single cells or neurons are signaling to the silicon electrodes e.g. project Brain Storm - where a tight electrical coupling between neurons and chip was achieved through gold microelectrodes that were embedded inside neurons. Tissue level interfacing is achieved by placing a tissue slice several hundred micrometers thick in contact with the chip e.g. MTA recording of tissue slices from the rat. In these cases, individual microelectrodes sample the activity of a population of cells(tissuese) rather than that of single neurons. Signals are in the form of Local-Field-Potentials (LFPs. Finally, the third level of interfacing is represented by chip implants in the brain, spinal cord, peripheral nerves or sensory organs e.g.
CyberRat project.

Working:

The neural tissue interfacing for extracellular recording of neural signals is made between MEA and neurons at multiple sites simultaneously. The chip is placed 50nm above the tissue. The chip consists of noble metal (silicon) electrodes arranged laterally in a 2D Multi Electrode Array (MEA) with an electrolyte substrate

ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
Vol 5, Issue 3, March 2018

insulating the electrodes. The electrolyte and the electrodes form a capacitor with very high capacitance per area thus providing voltage-sensitive sites throughout the surface in a spatial arrangement.

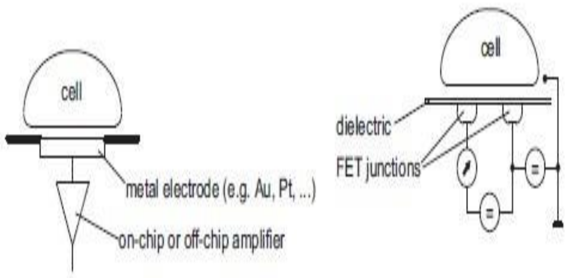


Fig. 2: Neural Tissue Interface

VII. BRAIN COMPUTER INTERFACING (BCI)

Brain Computer Interfacing literally means interfacing the electrophysiological signals of brain to the computer. It consumes potentials produced due to the excitations of neural spiking as input while rejecting the noise produced by other muscle movements or signal escapes due to barriers, transmit the input to amplifiers like EEG, process the signals to extract the features and finally produce required output. The output is used for various applications like controlling the cursor displayed on the screen where user's thoughts move the cursor or used as neural prosthetics

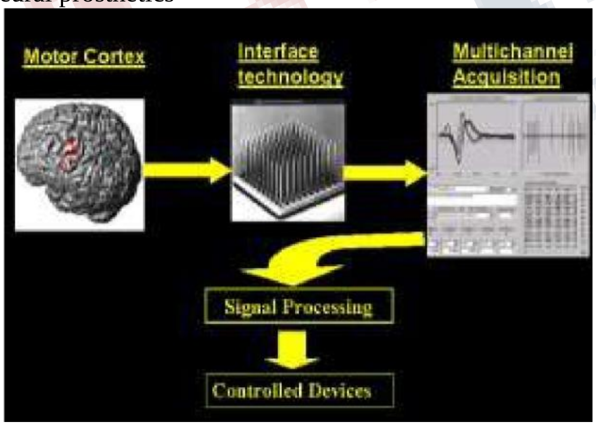


Fig. 3: BCI Structure

BCI in animals

Intracortical invasive acquisition have been successfully tested in animals like monkeys, rats and even in some paralyzed human beings. The rats were implanted with silicon chip at the cerebral. The thoughts of rat for e.g. to eat, whose corresponding neuron signals were converted to digital EEG signals. These signals were used to move the robotic arm to feed the mouse. Similar research was conducted by Pittsburgh University, on monkeys. Monkeys were able to move the cursor towards eight directions in a virtual cube. This research helped in developing a good adaptive movement prediction algorithm.

BCI in humans

Fig.5: Tetraplegia patient typing words with the help of BCI

Fig. 4: Matthew Nagle, a 25year paralyzed old man who was the first to undergo Brain gate implant surgery

The BCI silicon chip developed by Neurotechnology Systems, CyberKinetics was first implanted to cerebral cortex of two patients. The first patient Matthew Nagle who was paralyzed due to a knife injury was able to move the cursor in the screen, change the Television channels, work with mails etc., with his thoughts and the robotic arm connected to BCI, after the neural implant. From one

ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
Vol 5, Issue 3, March 2018

such research, it has been found that the classification accuracy increases gradually increases by increasing the number of electrodes.

VIII. ALGORITHM

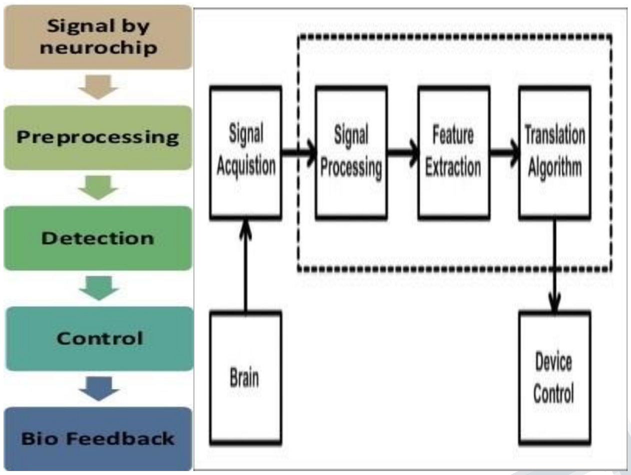


Fig. 6: Algorithm behind Brain Gate

1. Pre-processing

The pre-processing done before extracting features includes removing unwanted frequency bands, averaging the current brain activity level, transforming the scalp potentials to cortex potentials and removing noise.

2. Detection

Detecting signals means identifying the action to be performed based on the EEG signal either in time domain, detecting varying amplitudes or in frequency domain. Detection performs sampling of data using digital signal processing methods, band pass filtering and classifying signals either in time or frequency domains using several classification algorithms.

3. Control

The user controls the systems by providing signals and the cursor in the screen moves accordingly.

4. Bio-feedback

Feedback is given by the user to the system and vice-versa e.g. When user types in the virtual keyboard using his/her thoughts, the letter interpreted by the system is displayed to the user in the message box.

Working:

Brain Gate Interfacing System consists of sensors to detect neural signals transmitted and external processors to decode and interpret neural signals, process them for execution. Neurons keep on sending signals whenever we think, move, sit, do some work etc. These signals move from neuron to neuron at the speed of 250mph. The silicon sensors penetrating 1 mm into the surface of the brain, detect action potentials produced due to these neuronal excitations and transmit them to pedestal plug which then passes signals to EEG where neural signals are converted to digital signals which are then fed to the computers for processing, detection and control.

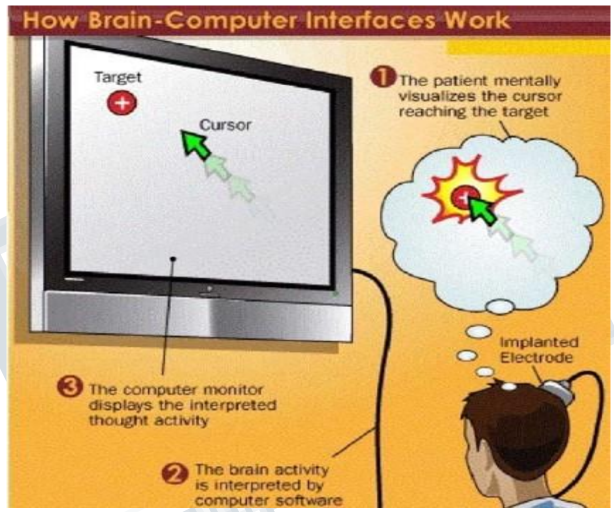


Fig. 7: Working principle

Advantages:

1. Easy to interact with computer. User can easily learn to control the cursor with some basic training.
2. Invasive method where active potentials of every single neuron are recorded more accurately compared to other non-invasive methods
3. Making thoughts into actions
4. It acts as neural prosthetic for quadriplegics, whose urge to move their limbs or hands could be done with help of robots, for which the commands are the user’s thoughts

Disadvantages:

1. There are billions of neurons transmitting and receiving signals at a time. Even a small distortion like blinking of eyelids might have a drastic impact on the result. Hence it is not possible for EEG to accurately measure very tiny voltage differences in such cases
2. The device is very complex and expensive

3. Research is still on its way of understanding the brain codes and there is no good algorithm which can understand and stimulate the brain signals

IX. CONCLUSION AND FUTURE SCOPE:

The main drawback of brain gate is that the wires coming out of the patient's brain attached to the cables. This device might change wireless for which research is already ongoing. But still it possesses some risks of sending a person to home with such a complex and wireless device expecting the chances of infections. The research is still on its way to gradually increase the efficiency of the algorithm, to read more characters per minute even in the absence of software using statistics of English language. The robotic arm has to be replaced with patient's own arms where electrical wires replace the damaged nerves. The ultimate aim of brain gate is to make the device faster, reliable, wireless fully user-controlled which would solve almost all the indispensable requirements of the paralyzed.

REFERENCES

[1] Ankita Komavar, Asavari Dudhe, Gauri Ajmire, "Brain Gate Technology, International Journal of Research in Science & Engineering, e-ISSN: 2394-8299, p-ISSN: 2394-8280, Special Issue: Techno-Xtreme 16".

[2] Stefano Vassanelli, NeuroChip Laboratory, Dept. of Human Anatomy & Physiology, University of Padova, 35131 – Padova, Italy, "Brain-Chip Interfaces: The Present and The Future", The European Future Technologies Conference and Exhibition 2011, Procedia Computer Science 7 (2011) 61–64.

[3] Vivek Yadav, Rakesh Patel, Priya Bag, "A Review on Blue Brain - The Future Artificial Brain", IJSRD - International Journal for Scientific Research & Development, Vol. 2, Issue 09, 2014

[4] Vivek Pandit, Suraj Naikwad, International Journal for Engineering Applications and Technology (IJFEAT), "Brain Gate Technology: A New Step Towards Technology", February, ISSN: 2321-8134.

[5] Robert Stufflebeam, "Neurons, synapses, action potentials and neurotransmission"- The Mind Project.

[6] Erik Andreas Larsen, "Classification of EEG Signals in a Brain- Computer Interface System", Norwegian University of Science and Technology (NTNU).

[7] https://krazytech.com/technical-papers/brain-gate

[8] https://sites.stanford.edu/nptl/

[9] http://med.stanford.edu/ news/all news/ 2017 /02/listening -in-o n-the-brain-a-15-year-odyssey.html

[10] https://news.brown.edu/articles/2012/05/braingate2

[11] https://www.scientificamerican.com/article/brain-computer-int erface-allows-speediest-typing-to-date/