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An exploratory research analysis on Brain Machine/Computer Interface

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Abstract *— BCI and its potential to enhance human cognitive abilities are investigated in this article. The findings indicate that BCI is one among multiple paths to super intelligence. BCI's have potential to help humans with various neuro and mental functional disorders when utilized as neuroprosthetic. BCI's provide humans with communication channels that do not depend on peripheral nerves and muscles [1], BCI converts intention-driven neural activity into a control signal that performs useful tasks. BCI paves path for Brain Driven Robot Controls [2] based on brain activity. Brain-actuated/assisted robot control brings benefits especially in difficult scenarios where robots cannot perform all functions successfully without human assistance, For eg., Dangerous missions with possible sensors and algorithms failure. Computer translation algorithms are used in modeling experiments to translate Brain activity signal to Device Command and controls to perform an activity, Transfer functions part of translation algorithms are classified into linear and non-linear. Linear Transfer functions are Linear Equations whereas Non-Linear Transfer functions are neural Networks. The idea of BCI may seem absurd at first glance, but it is based on decades of experimental study and is supported by scholars, scientists, and entrepreneurs such as Stephen Hawking and Elon Musk [3].*

Keywords: Brain Interface (BI), Brain Computer Interface (BCI), Brain Machine Interface (BMI), Neural Control Interface, NCI, MMI, DNI, artificial intelligence, data analytics. computer models

I. INTRODUCTION

Brain interfaces comprise system that aims to enable user control a device or task or activity based on brain neuro signal related to an activity, be it conscious or unconscious, voluntary or evoked, invasive or non-invasive. Brain Interfaces are classified into two main terminologies, *Brain-computer interfaces* (or BCIs) usually refers to brain-to-computer interfaces that use non-invasive technology whereas *Brain-machine interfaces* (or BMIs) often refers to implanted brain-interfaces. Until late 1990's Brain Interface area progressed slowly due availability of handful laboratories and largely due to limitations in Human understanding of brain electrophysiology, quality and cost of recording equipment, computer memory, processing speed,

performance of pattern recognition algorithms. The State-of-the-art in the field of Brain Interfaces have dramatically increased in last couple decades alongside of advancements in computation and processing power and wide spread advancements in the field of AI, Neural Networks, Machine learning. Brain Interfaces provides users communication and control channels that do not depend on the brain's normal output channels of peripheral nerves and muscles and can be treated as evolution from my sensors for controlling Prosthesis directly based on brain activity signal.

Brain Interfaces (BI) integration with Smart Home Devices will open up enormous possibilities in-terms of performing an activity by Senior Citizens, Physically Challenged humans [4] and can be valuable new augmentative communication option for those with severe motor disabilities BI research seeks to help persons with Disorder Of Consciousness (DOC) or Vegetative state (VS) or Minimally Conscious State (MCS) in different ways. A key initial goal is to identify patients who are able to perform basic cognitive tasks, which would lead to a change in their diagnosis. That is, some persons who are diagnosed with DOC may in fact be able to process information and make important life decisions (such as whether to seek therapy, where to live, and their views on end-of-life decisions regarding them). Brain Interfaces opens new prospect of allowing these patients to provide their views for medical decisions, there would seem to be a strong ethical pressure to develop this research direction to guarantee that DOC patients are given an opportunity to decide whether they want to live [5][6]. BI can be used for humans who may have lost some of their ability to move due to multiple causes like stroke or injury in the field of therapy which can measure motor movement activity when patient imagines [7]. BI research advances for better mechanisms of brain mapping capabilities for neurological disorders evaluations and decision making.

BI research made significant breakthroughs in the field of IOT, Connected Devices, virtual reality games by linking

Body with machines using BI with AI, Machine Learning algorithms, examples are Cyborgs, Brain to vehicle etc., opening lot of real-world possibilities like true intelligent mobility, neuron modulation therapies, EEG/EMG to monitor stress, Speech Generating Devices. BI enables humans and expands human bandwidth with access of Information using single thought in the age of Data and Information.

II. RESEARCH PROBLEM

The main problem this exploratory study seeks to resolve is to explore schematic overview of BI, various categorization of BI along with need of Brain Interfaces for creating inclusive communities and societies through connected devices, Brain to vehicle, speech recognition and generation etc., for senior citizens, physically challenged humans, down syndromes, Neuro/Mental disorders and also in the fields of Games, marketing, education, security

III. LITERATURE REVIEW

A. Schematic Overview

Brain activity signals are recorded through any one of the BI method (mentioned in Section B) and enhanced further through amplification, common mode rejection, antialiasing filtering and then digitized.Digitized Brain wave signal are further processed to increase the signal to noise ratio by applying frequency band filters, spatial filters etc., Several Data points per second will be collected (once Digital brain wave signal is further processed) and fed to Machine learning algorithms like feature selection algorithms (e.g., support vector machines, linear discriminant analysis, nerofuzzy inference, genetic algorithms, cluster overlap indices, etc.) depending on Data Domain. In case of BI to connected devices, Digitized Data point were converted to Robotic commands which will then be fed to Connected Devices for execution of Brain activity.

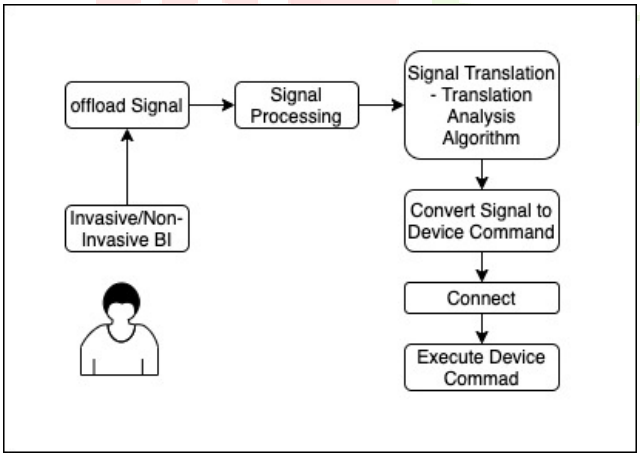

Fig i: Schematic Overview Of Brain Interface System

B. BI Categorization

For BI's are further categorized as below and many accepted BI's falls under any one of the following :

- *Invasive and non-invasive*

The obvious difference between invasive interfaces and non-invasive is, Invasive interfaces are implanted in Brain and non-invasive are the ones that goes on skin surface or farther from the body. Electroencephalography, Magnetoencephalography can be considered non-invasive, whereas Neuralink, NIRS (near-infrared spectroscopy), MRI (magnetic resonance imaging), PET (positron emission tomography) can be considered as invasive.

- *Dependent and independentDependent [8]*

Dependent BI's are Speech, Facial expression, Limb movement etc., does not require the usual ways of brain output to express the internal mental state but still require some functionalities like gaze control etc., remain beyond the brain. In practice Dependent BI's are not entirely reliant on brain signal alone. In case of *Independent BI* would be able to infer the user's mental choices by looking at the brain signals and signals are independent of whether or not the human has any control any body parts examples are mental navigation, mental arithmetic or imagination of limbs etc.,

- *Spontaneous and evoked and event-related [9]*

spontaneous potentials are thoughts in general for example it can be related to movement intentions in the sensory motor cortex not a result of specific input. Brain responses to a given stimulus that user is aware of or interested in the stimulus or not is termed as *Evoked potentials* (EPs), for example a flashing letter, a sound, etc. In case of EP the observed brain signal will contain features that are consistently timed with respect to the stimulus. *Event-Related potentials* ' (ERP) are related to evoked potentials but includes brain responses which are not directly evoked by the stimulus. I.e., it can be due to spontaneous or deliberate thoughts and have controlled time window to monitor brain signals

- *Synchronous and asynchronous [10,11,12]*

Above mentioned three BI categories can also referred with two other terms, synchronous and asynchronous interfaces.

BI's based on EPs and ERPs are *synchronous* due to the nature of interaction, user is allowed to convey an intention or command to the machine when the machine allows it with monitored signal is a response to a computer-timed stimulus, or be it a mental task executed only when computer monitors gives 'go ahead 'to the user, typically by means of a tone or an object on the screen. *Synchronous BI*'s are often called '*cue-based*'. *Asynchronous* BI's , use brain signals that are produced by user any time, with or without a specific computer-controlled stimulus. Asynchronous BI's the ultimate aim of BCIs. Invasive or Non-Invasive BI can be tagged as Asynchronous BI's example will be Neuralink

C. Medicine

BI can play vital role in the field of medicine, areas that can reap major benefits are Prediction or Diagnosis and Treatment or Rehabilitation or Assistance if BI's are adopted in the field of medicine. [13,14,15]

- *Prediction, Diagnosis*

BI based risk prediction models are progressive and are being adopted for better clinical aid decision-making, these risk models can be to estimate probability of having certain diseases or complications based on individual demographics, test results or disease characteristics. Brain activity generated and captured by BI can be processed using risk prediction models to predict health problems such as sleep disorders,

seizures, attention deficit hyperactivity disorder, epilepsy, Brain Injuries. Another major benefit will be diagnosing neural degenerative disorders or early detection of Alzheimer's or Parkinson's disease.

• *Treatment, Rehabilitation, and Assistance*

Field of medicine can gain benefits in the area of treatment, rehabilitation and assistance with adoption of BI's beyond Prediction or Diagnosis. In the area of Treatment, feedback loops created through BI based brain Stimuli recording can enhance better decision-making ability while treating patients with Neurological disorders or patients with vegetative (coma) consciousness. In the area of rehabilitation better visual engagements can be achieved through BI adoption to keep patients with disorders engaged with activities. In the area of assistance BI adoption can enable patients with vegetative consciousness (COMA) share their thoughts with their immediate Family members also can enable patients with motor or neurological disorders operate connected devices like sending an email, command a robot to perform an activity.

D. Neuroergonomics and Smart Environments

The Progress in the field of sensors and information technology led to the feasibility of smart and inclusive environments through Neuroergonomics [16]. Neuroergonomics paradigm enables humans interactions with digital environments which are adaptive and responsive. BI assistive technologies like Brain Driven Robot Controls, Brain Driven IOT, Connected Devices, Games, Brain to Vehicles will have promising impact to create smart environments and inclusive communities/societies [17]. The future generation of human compatible systems powered BI's helps despaired humans gain higher standards of living condition and ensuring great comfort through intelligent usage of resources, Significance of Neuroergonomics adoption at workplace will help in designing physical activities and work demands based on physical, cognitive capabilities of the individual for eg., Human with Down syndrome or Parkinson paves a way for creation of inclusive smart communities and also provides a solution to include such physical and cognitive challenged humans part of a countries economy. Real-time monitoring of individual cognitive abilities can alert individual when certain behaviors are triggered.

E. Games and Entertainment

Gaming and Entertainment industry may benefit more with adoption of BI by designing/developing portable BI device that can enable humans to control or perform activity based on brain signal activity while playing games, whereas similar design of BI devices in the field of entertainment can be mobile VR headsets or Brain Controlled smart devices. [18]

F. Neuromarketing

Neuromarketing is an emerging discipline, initially introduced by Ale Smidts as study of cerebral mechanism to understand customers behaviors and improve marketing strategies based on customer behaviors. Cognitive and emotional responses to various stimulus related to marketing are assessed in the field of Neuromarketing. Any one of the BI methods (refer BI Categorization Section) is used to study customer behavior, for example BI device can be used to collect Brain Signal responses to analyze individual engagement for a particular commercial. Similarly, individual thoughts, emotions, feelings, motivations can be captured though Brain signal to further analyze individual behavior while purchasing. Nearly 300 companies are working across the globe in the field of neuromarketing [19]

G. Education

BI discipline may bring multiple benefits in the field of Education, Non-Invasive BI can be used track student cognitive, concentration, attention and motivation performance to improve learning experiences, where as teachers detect same performance metrics visually in traditional teaching methods posing lot of limitations. Neural techniques can provide feedbacks on the mental level of students in real time for teachers to make better decisions on how to keep students engaged. [20]

H. Security and Authentication

Although BI use in the field of security are in still in initial proposal phase with multiple strategies being proposed, BI discipline can bring multiple benefits in the field of Security and authentication, brain activity signal generated for a particular stimulus recorded using either Invasive or Non-Invasive BI methods can act as biometric trait in cryptography and biometric security frameworks. Security frameworks can make decision based on presence or absence of stimuli and stimuli's can be visual evoked potential or mental task or emotional, will be game changer in the world of Brain to Connected Devices for creating smart communities [20,21]. Major benefit can be reaped if BI based security and Authentication implemented to verify authenticity of the voter voting in an political election as only Living Human being can generate Brain signal Stimuli for security and authentication frameworks to make decision.

IV. FUTURE IN THE U.S

BCI research is a fast-developing subject that is becoming more of a clinical interest among people with neurological problems due to technologies that enable them to autonomously connect with their surroundings. In the future, BCI companies in the U.S will be able to offer people insights on their brain — such as stress level, tiredness level, and concentration — by tracking heart rate, oxygen saturation, and step count. Previous breakthroughs have included the use of signals obtained from chips embedded in the brain to operate robotic devices. As a result, these implants have been used in a few clinical instances since the use of these implants requires significant medical and surgical skills. A non-invasive robotic device control system developed by researchers from Carnegie Mellon University in partnership with the University of Minnesota has discovered a solution that allows the system to track a computer cursor without ever contacting it. In many different ways, BCIs will revolutionize how we interact with our gadgets. Facebook, and others, are placing a great deal of confidence in BCIs [23]. Recently, it purchased the brain-computer interface company CTRL-labs, which is believed to

be valued between $800 million and $1 billion. Wrist-worn hardware utilizing EMG sends nerve impulses from the skin to an internal control module where the information is collected and utilized to create movement signals that may be used to control digital devices. Instead of clicking on a window in a software application to open or close it, users will be able to do the same tasks using a simple gesture instead.

The desire to discover new methods of managing electronic gadgets like virtual reality games, augmented reality hardware, like Google Glass, has also recently seen a surge in popularity. These new gadgets have emphasized the need for non-intrusive interfaces that provide users with a way to operate with minimum physical interaction. Immersing ourselves in a virtual world in which one has to hold clunky controls while the play takes away from the sense of feeling like they're there.

Several BCI businesses are looking to boost memory and mental sharpness by using their systems. Additionally, consumer electronics manufacturers are now exploring the use of transcranial direct current stimulation (tDCS), which has shown great promise in enhancing cognitive performance. Although many firms currently offer brain-machine interfaces (BMI) devices that are mounted on the head, the idea goes that they are capable of modulating brain function.

BCI companies recognize that neurofeedback may be used to regulate mood or stress, and in the future, it could be utilized as an additional type of information for the quantified self. The use of just thoughts to operate robotic devices without the need for intrusive procedures has the potential to offer a broad range of advantages for people with mobility problems. It is anticipated that the researchers will perform further clinical studies in the near future. In a recent conversation with ZDNet, Jamie Alders, VP of product at Neurable, said that BCIs might eventually be a "FitBit for the brain" kind of solution.

V. ECONOMIC BENEFITS TO THE U.S

The implementation of BCI is financially advantageous to the United States since the industry within neuroscience and information and communication technology has seen an increase in demand. BCI technologies in entertainment, gaming, and communication, as well as in the healthcare sector, are one of the main drivers behind the BCI industry. With funding focused on researching a treatment for serious brain diseases and traumas, the industry is anticipated to see rapid growth. The market's development is being fueled by a high market penetration among people worldwide as a result of rising accidents and deadly illnesses. Multibillion-dollar funding is being raised in various ways in the research and innovation of brain-computer interface systems [24]. Expansion in the national economy will spur market growth tremendously. Although it does have certain constraints that will limit market development, it still has access to qualified manpower, valuable data that may be misused, and ethical concerns concerning brain-computer interface technology.

The market is growing quickly due to a rise in demand, which is making the industry more competitive. With a competitive environment that offers the fundamentals of a program and a financial investment, organizations will have more opportunities. Neurable has partnered with Trimble to introduce a brain-computer interface (BCI) to enhance transportation and construction, architectural, and engineering solutions. These two firms have a shared goal of utilizing neurotechnology to help businesses successfully adapt to the digital revolution by creating a bi-directional feedback loop, increasing productivity and safety.

VI. CONCLUSION

This paper explored the concept of BI and its various categorization as well as the application of BI technologies in improving human cognitive abilities in various fields. These fields include medicine, neuroergonomics, and smart environments, neuromarketing, education, gaming and entertainment, security, and authentication. The findings of the study demonstrate that brain-computer interfaces (BCI) are a significant technological breakthrough since they offer people communication channels that are not dependent on peripheral nerves and muscles. BCI is a system that processes brain function aimed at achieving a goal into a control signal capable of carrying out relevant functions. BCI opens the way for Brain-Controlled Robotic Controls that are based on cognitive function. Brain-actuated/assisted robot control has advantages, particularly in challenging situations when robots cannot effectively execute all tasks without human help. BCI is growing throughout many sectors in the U.S. The market is growing quickly due to a rise in demand, which is making the industry more competitive. With a competitive environment that offers the intricacies of a plan and a financial investment, organizations will have more opportunities. Neurable has partnered with Trimble to introduce a brain-computer interface (BCI) to enhance transportation and construction, architectural, and engineering solutions.

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