Brain-Computer Interface and brain signal processing using a microchip

Subject: Research Methodology

Section: H

Group No: 07

Abstract: Brain-Computer Interface is an important part of human-computer interaction and of great interest to researchers nowadays. Hence this paper introduces the way of the brain to brain interaction which will remove the barrier of communication problems. This problem is solved for increasing communication performance and also for detecting and curing brain diseases a lot faster. This study describes the process of how a microchip can be designed and implanted into the brain and also various functionality of the device. The various advantages of using a microchip inside a brain are also discussed in this study. The synchronization of processes inside the microchip has also been described through a formal approach that stands on the basis of mathematical and signal processing formulas. The brain has the most complex functions and is therefore the most complex device in the world. This paper describes the functions of the axon of the brain and how it will communicate with the microchip to process and transfer data out of the skull through the microchip. The applicability of our microchip is demonstrated in the context of the human brain structure.

Keywords: Brain, axon, interface, microchip, computer

1.Introduction

1.1. General Description

Brain-Computer Interface refers to the controlling of a computer interface with the help of the human brain which is a sub-branch of Human-Computer Interface. In our research, we want to demonstrate a blueprint of how to input and output in both directions from the brain to computer and computer to the brain thus leading towards the progression of brain-to-brain communication. This process will also increment an additional foundation of symmetric synchronization of the sophisticated movement of robotic arms and sensory control systems with the Brain-machine Interface. This study will discuss the integration of all these sections in a microchip and inject it inside the human brain so that the brain will become a supercomputer and many diseases can be detected and cured easily, Parkinson could be solved and people can make the very big calculation and even interact with things without operating any computer devices with hand.

1.2. Problem Statement

The problem statement of the research is that we already know different approaches to collect data from the brain but collecting, processing, and transmitting brain data through the wireless channel is still unknown to researchers. From many conducted research it is known that there are possible ways to control computer devices with the help of the brain. But it has not yet been contributed to research that with the help of the robotic arm the brain can understand that a surface is hot, cold, hard, or soft and also the sophisticated motor movement of the robotic arm which will become a solution for Parkinson patients after the problem has been solved.

1.3. Motivation

The motivation for working in this research comes from the invention of robotic hands that can respond asymmetrically but not in real-time and also unable to feel the touching surface. As the brain is an input-output device and a signal can be injected from the outside world into the brain. So, it is possible to collect a signal from the sensory tissue and feed it into the brain which can be later improved by real-time signal analysis procedure which should be developed while scientific research has been conducted. Another motivation for this work is to make the brain a communication device by injecting a microchip inside the brain which will be resulting in brain-to-brain communication that will work by restoring and reconstructing brain signals and make the brain a supercomputer.

1.4. Research Target

Our main target is to describe the function of the axon of the brain and how it will communicate with the microchip to process and transfer data through the microchip. Thereafter, we introduce the system and working procedure of the system that will work. Moreover, for signal analysis, we try to develop a liquid sensory system that will be attached to a robotic arm and will sense the surface that has been touched. It will measure the temperature and hardness of the surface and send it to a microchip using a wireless channel. Through this device, the brain will be able to understand the signal.

I. What are the main characteristics of this research?
II. How can those characteristics improve this BCI research?
III. Is this characteristic effective or suitable for the next future life?

1.5. Objective

The main objective is that motor neuroprosthetics aims to either restore movement in individuals with paralysis or provide devices to assist them, such as interfaces with computers or robot arms. We try to implement real-time motor movement or real-time sensory control systems so that paralysis people when touching anything they can feel is soft, cold, hot, etc. Motor imagery involves the imagination of the movement of various body parts resulting in sensorimotor cortex

activation, which modulates sensorimotor oscillations in the EEG. This can be detected by the BCI to infer a user's intent. Motor imagery typically requires several sessions of training before acceptable control of the BCI is acquired. People may lose some of their ability to move due to many causes, such as stroke or injury. Several groups have explored systems and methods for motor recovery that include BCIs. BCIs for motor recovery has relied on the EEG to measure the patient's motor imagery. This article reviewed work within this project that further defined BCIs and applications, explored recent trends, discussed ethical issues, and evaluated different directions for new BCIs.

Structure

1. Introduction
    1.1. General Description
    1.2. Problem Statement
    1.3. Motivation
    1.4. Research Target
    1.5. Objective
2. Literature review
3. System Overview
    3.1. System Functional Behavior
    3.2. System Physical Description
4. Discussion
5. Conclusion
6. Reference
7. Contribution

2.Literature Review

In [1] this report, they have compared auditory and tactile BCIs in terms of training effects and cross stimulus-modality transfer effects and they have utilized a streaming-based P300 BCI. It was developed as a low workload method to avoid potential BCI-inefficiency where in this experiment they have assigned 20 fit participants in two groups where each participant received three sessions of training either using an auditory BCI or using a tactile BCI and all participants were able to control at least one BCI version. In this research, they have mainly worked with patients that are suffering from Locked-in syndrome (LIS) and struggle to communicate using vision independent brain-computer interfaces which is a severe form of paralysis that can lead to extreme problems regarding vision. P300 (BCIs) offers users a non-muscular way of communication using control signals recorded via electroencephalography (EEG) and has been successfully applied to various applications such as word spelling, smart home use, brain painting, or gaming. A g.USBamp amplifier and 16 Ag/AgCl active g.Ladybird electrodes were connected with a g.Gamma cap which was used for electroencephalography (EEG) recording for data collection from the nerve cells The limitation of their study was the sample size as they choose a very small sample consists of healthy participants between 20 and 41 years. They mentioned that the future study would include just a slightly altered paradigm of this study to get better and improved results.

One of the main problems that have been realized is that this research has been conducted by only using the g.Gamma cap for data collection which may result in an inaccuracy of signal amplitude values and can cause side effects later while reconstructing the signals.

In [2] this research, they have investigated the human brain sensory activities related to the previous research which lead towards the needs of an efficient method to improve the human brain sensory activities which are mainly measured by brain signal that is acquired from the brain sensor electrodes positioned on several parts of the cortex of the brain. The complete process of this research has been conducted using a proposed neuroheadset device and with the help of the efficient method which will be established using several methods like signal acquisition method, signal processing system, signal improvement method, and also brain activity development approach that is conducted in related research areas. They have reviewed the previous research framework based on the sensor activities of the human brain and found some interesting frameworks which include: Neurally and ocularly informed graph-based models which were designed to search 3D environments, SVM classifier, and Hjorth Parameters which were used to recognize the emotion based on the EEG signal, Design and implementation of BCI for wheelchair control, etc which were all established using a well-known framework. In the analysis section, they have observed that most of the researchers have focused on the signal acquisition, processing, and classification and in the classification level the SVM classifier was commonly used to classify data, but they have introduced an improved method to improve the brain activities. In this study they have decided that the non-invasive EEG signal achievement method will be the better option to acquire the signal data, ICA can be used to lessen artifacts and noise from the signal data and Fast Fourier Transformation can be considered to reduce poor signal quality.

In this study, the whole research has been conducted with a proposed neuroheadset device, which may become a shortcoming problem for the proper validation of the result if another neuroheadset device is being used.

This [3] research has shown that BCI research has been increased greatly due to a wide variety of applications, including neurorehabilitation, robotic devices, domotic systems, and exoskeletons. They have also reviewed that several VE developments have been made in BCI to control virtual cars, navigations through virtual flats or virtual bars, walkthrough virtual streets, and shops even controlling wheelchair and manipulate 3D virtual objects such as turning on/off light, TVs, or lamps, etc. They have reviewed the motivation of VE in BCI through the improvement of Attention, Learning, and Motivation, Laboratory for Prototyping BCI Systems, Diagnostic and Therapeutic Purposes. They have also found that the control tasks become much more differentiable that the modulation of EEG signals using MI activity greatly depends on the user's mental balance so users' mental state is a key element for a stable performance system at the moment of the interaction. The paper indicates that to control a BCI system the skill of learning must be acquired through the process of learning in current BCI paradigms which generally stimulates only one sensory pathway, either visual or auditory. Though humans gather information from five-sensory pathways (vision, hearing, touch, smell, and taste) and react accordingly research shows that learning is much more effective in sensorially enriched environments. They conclude that the strength of the user's motivation and maintenance of attention for longer periods and the implementation of a constant feedback mechanism is the concerned BCI research.

This study although reveals some of the ways of the virtual environmental sensorial system but they don't give any proper justification or mathematical formal approach for the signal propagation of the process in this study which may arise shortcoming problems for other researchers.

In [4] this report, they have concentrated on an asynchronous Electroencephalogram that depends on BCI frameworks. Asynchronous BCI is a self-guided framework that works freely of significant improvement. The issue of the current EEG based BCI framework is its exhibition inexactness and time reaction. The principal target of this survey study is to lead a writing audit on the impact of the offbeat plan to the precision and time reaction of BCI frameworks and to survey pertinent explores on nonconcurrent EEG-based BCI framework with the goal that the presentation of their framework configuration can be examined. It is huge for specialists or designers seeking an EEG-based BCI framework to improve the exactness and time reaction. The next segment will clarify further the strategies utilized in checking on related investigates. This survey paper will investigate the impacts of chosen autonomous factors to a BCI framework execution.

In this paper, they only focused on the asynchronous Electroencephalogram not focused on synchronous. If they focused on synchronous and asynchronous both then maybe this paper is much more efficient and gives more information.

In [5] this research, they have mainly shown the BCI is a typical example of a measurement and control unit. The authors have talked about how the BCI system reads the

user's intention by decoding certain features of the EEG signal. Those features are then classified and translated into commands used to control a computer. The main object of a brain-computer interface is to allow communication with the outside world for patients with severe stages of neurological diseases. Humans normally communicate with the outside world to use some individual muscles of the human body. The human brain is transmitted through the nervous system to select parts of the body and stimulate their movement. Similarly, using Man-machine communication where the same principles can be applied. Man machines are a combination of Human-computer interaction and Brain-computer interface which will give very great benefit to us in the next age. Shortly, this research suggests innovative developments.

But the problem is they have talked about how the BCI system reads the user's intention by decoding certain features of the EEG signal, an EEG signal is ready for feature extraction. They said there are several feature extraction algorithms but don't mention which algorithms they are used for their research if they mentioned then readers could understand why this algorithm is used and what are the exact purpose to use that algorithm.

In [6] this research, they have mainly discussed fundamental aspects of BCI system design advantages and drawbacks. They have reviewed the neuroimaging modalities used in the signal acquisition step and have also reviewed different electrophysiological control signals that determine user intentions including some techniques. They have discussed neuroimaging approaches that provide acceptable quality signals with high portability. Shortly, this research also suggests innovative developments. BCI systems may become a new design of human-machine interaction that is similar to other current interfaces.

Despite the recent important advances in the BCI field, some issues still need to be solved. The relative advantages and disadvantages of the different signal acquisition methods are still unclear. Their clarification will require further human and animal studies. Moreover, the electrophysiological and metabolic signals that are best able to encode user intent should be better identified and characterized.

In [7] this article, they have examined the idea of the brain-computer interface alongside introducing its definition, description, and classification of BCI frameworks. Additionally, gives bits of knowledge on the Neuroimaging modalities for BCI frameworks. Moreover, this part tends to EEG signal handling for BCI from the alternate points of view of preprocessing strategies that manage EOG/EMG artifacts, including extraction approaches for BCI structures, arrangement techniques, and Post-preparing. Moreover, this gives a short study of classifiers utilized in BCI research alongside arrangement execution measurements used for BCI frameworks. At long last, finishes up with illustrating progressing research headings for Brain-PC interface frameworks. In the future, it is trusted that this sort of exploration will make historic strides in our reality.

Through this paper, they have discussed many fields of Brain-Computer Interface and exposed different approaches but the way they have progressed that was not sufficient to understand. Moreover, Classifier's performance can be improved using a post-processing stage. Some parameters of the classifier can be optimized, according to some measurements in the post-processing block, to reduce the number of false detections.

In [8] this report, they're mainly focused on Brain-computer interaction research at the computer vision and multimedia laboratory. The effect of such top-down signals on local processing within the primary cortical area remains poorly understood. Visual selective attention operates through top-down mechanisms of signal enhancement and suppression by an alfa-band oscillation. In this report, they characterize the interplay between large-scale interaction and native activity charges in the cortical region and (PCA) analysis of the EEG source signal. The task required participants to either attend to or ignore oriented grating. They have observed that Bottom-up-Gamma-band influence from visual areas rapidly increased in response to attended stimuli while the distributed top-down alfa-band effects were created from the parietal cortex in response to ignore stimuli. They have found that the parietal cortex selectively realizes attention by disrupting cross-frequency coupling at target regions, which then prevents them from propagating task-irrelevant information.

This paper is not good. They can add more features like animal BCI research, Diagram, flowchart many things. They can show mathematical explanations. There is so much improvement needed. There is much more work needed which is incomplete.

Brain-computer [9] interfacing is a steady growing area of research. It is a direct communication pathway between an enhanced or wired brain and an external device. During this report they present BCI differs from neuromodulation therein it allows for bidirectional information flow. Their monitoring of mental states and decoding of convert user states have seen a robust rise of interest. Here, they show some examples of such novel-applications that give evidence for the promising potential of BCI technology for non-medical uses. They discuss distinct methodological improvements required to bring non-medical applications of (BCI) technology to a diversity of layperson target groups, general usability, short control latencies. Paradigms of interaction allow even more possibilities for BCI and build new fields of study, like neural imaging for computational user experience.

This paper flow-chart is not clear. Classification is not good. Signal-acquisition hardware, BCI validation, and dissemination, and reliability things that are needed to justify, and some mathematical explanation is better.

In [10] this report, they present a unique idea for user authentication that they call pass-thoughts. Recent advances in Brain-Computer Interface (BCI) technology indicate that there's potential for a new sort of human-computer interaction: a user transmitting thoughts on to a computer. Given that these brain signals will be recorded and processed in an accurate and repeatable way, a pass-through system might provide a quasi-two-factor, changeable, authentication method immune to shoulder-surfing. Would seem to be unbounded in theory, although in practice it'll be finite because of system constraints. During this paper, we discuss the motivation and potential of pass-through authentication, the establishment of BCI technology, and the description of the look of what we believe to be currently feasible.

This paper is good but has a lot of disadvantages. Surgery to the brain might be risky and cause brain death. There are chemical reactions involved in the brain which BCI devices cannot

pick up. Research is still in the beginning stages. Electrodes placed inside the skull create scar tissues in the brain. These things need more improvement.

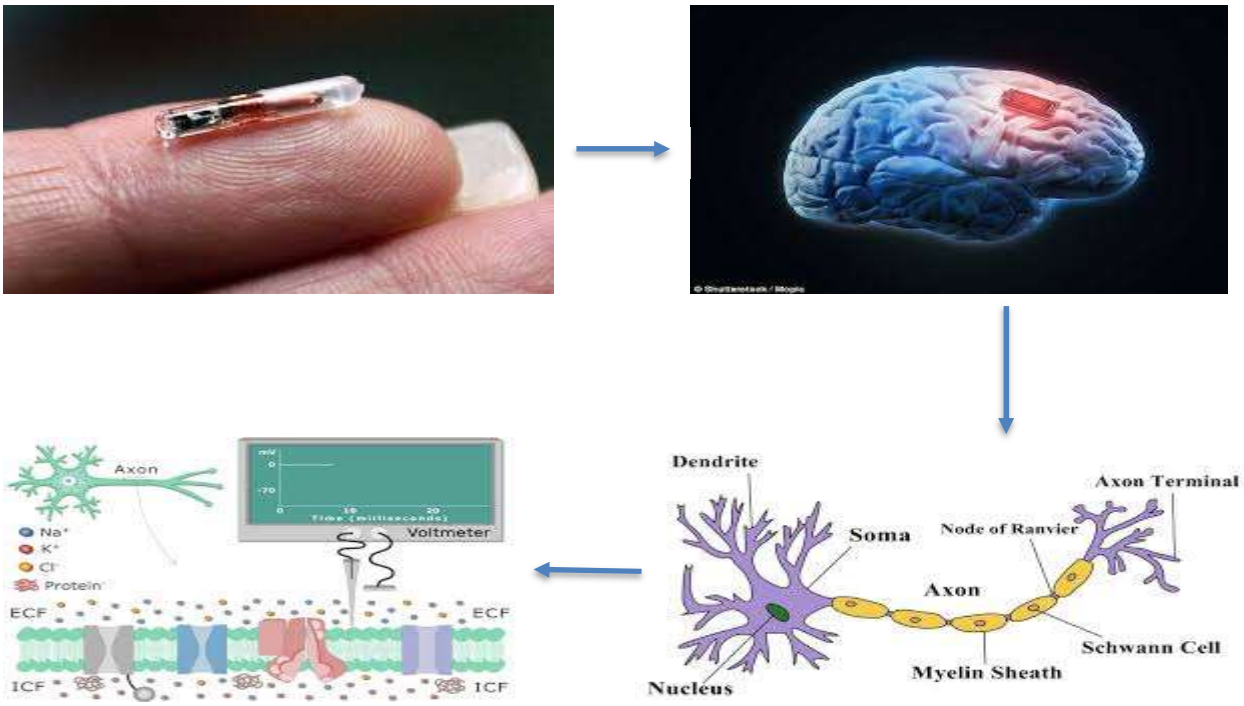
3.System Overview

3.1. System Functional Behavior

In this research, we are mainly trying to develop a system that can be injected into the axon of the brain as a communication device. It will help the brain to communicate with the outside world directly without any help from external devices. This device is a small microchip that will receive input data (spikes) from the axon and can work as per the command of the brain signals. This device also can send and receive data as brain signals and also convert and transmit these signals from the outside world to the brain and vice versa. This sending and receiving signals will be through a wireless medium. This device will be designed in such a way that the brain will not become dependent on the device rather the device will become dependent on the brain. This device will be designed to be a part of the brain and it will become permanently damaged once it fails to receive synaptic potentials from the synapses of the brain which will only happen after 6 hours of death. Other than that the device will never get damaged. The reason for this design is to avoid unethical activities. This device will be powered by the synaptic potentials so it does not require any extra power supply. This device will be designed in such a way that it will not create any damage to the brain if it fails. In our work, we are mainly trying to develop a system that will integrate all these processes into a microchip. We are mainly focusing on real-time signal analysis which will also give the brain the flexibility to choose among multiple input signals that have to be received. We will also try to lead our research in the direction of the brain to brain interaction, which will introduce a new way of communication and delineate a huge contribution to the brain-computer interface research area. In this research, we have to formulate a mathematical formula and implement some complex machine learning and artificial intelligence algorithm through which the microchip can understand the brain signals and reconstruct the brain signals to recover data if needed. We have to also construct a model so that the device can learn from brain activities and can be easily manageable by the brain itself. The device and the brain have to communicate in such a way that the device is a part of the brain. The research will stand based on the mathematical and procedural formulas which will lead to scientific research in the future. Our main target is to introduce the system and the working procedure of how the system will work. As a part of signal analysis, we have to also develop a liquid sensory system that will be attached to a robotic arm and will sense the surface that has been touched. It will measure the temperature and hardness of the surface and send it to the microchip using a wireless channel. Through the device, the brain will be able to understand the signal that has been sensed. As a method of research, we want to choose the grounded theory research method which will be conducted through an iterative process. We will have an initial observation or hypothesis and in every iteration, we will observe, verify, test, and change results if needed. We have applied semi-structured techniques as a method of data collection where I have talked with different types of people whom I didn't plan to interview. The main theme of our research has been described along with the method of research and data collection that we want to follow.

3.2. System Physical Description

The microchip will be placed inside the axon of the brain. In the last image, they are measuring the potentials of the membrane with the help of an electrode. We have to replace the electrode with a microchip in such a manner so that we are to measure the membrane potentials and also feed data that are being passed to the dendritic tree.



4.Discussion

As an inductive process, we gather data and try to build a theoretical formula based on the data. At first, we have some initial observations and a hypothesis on the initial state of the observation. Later in every iteration, we have tested, verified, and changed our results with respect to time. The first time we only try to develop a microchip that can be implanted into the brain and can deliver the outside world signal to the brain and vice versa so that the brain can understand the signal in a systematic manner. We tried to develop a way so that the liquid sensor will be attached to a robotic arm and as a part of real-time signal analysis a signal will be passed to the brain through the microchip when a surface has been touched. The signal is the information about the surface hot, cold, dry, wet, hard, or soft which will be defined by machine learning algorithms and sensed through the liquid touch sensor. We also show the way of real-time signal analysis as a sophisticated movement of a robotic arm. Later we came with a decision that we can even control other devices and also we can communicate with other devices through this microchip. We also introduce a way of the brain to brain communication which will be a great

contribution to brain-computer interface research areas as well as communication research areas. The microchip will perform various functions and will work as an assistant to the brain. The brain will not become dependent on the microchip rather the microchip will become dependent on the brain We have to design the microchip and implant the microchip in the brain such a way that the microchip will be powered by the synaptic potential and will, be permanently damaged once it fails to receive the synoptic potential from the brain. There will be a modulator at the sending end and a demodulator at the receiving end of the microchip. The microchip will be placed vertically aligned with the axon so that the signal that has been created in the axon can be modulated by the modulator of the microchip and by following digital to analog conversion it will convert the digital signal into an analog signal. Then the signal will be transmitted through a wireless medium and at the receiving end the signal will be demodulated and the original message signal will be recovered. All this process will be coded inside the microchip through complex machine learning and artificial intelligence algorithms. The device will be automated synchronized with the brain which will provide flexibility to the brain. We can calculate a very big number in no time only with the help of the microchip without operating any external device. We can even call and talk with other people having a microchip in their brain whenever we want.

5.Conclusion

We want to discuss a simple design of working input-output in both directions from the brain to computer and computer to the brain thus leading towards the progression of BCI communication. One of the most exciting areas of BCI research is the development of devices that can be controlled only through brain signals. Moreover, BCI is directed to the robotics industry that is the best suitable solution to come up with a robot that senses and acts like a human. Moreover, currently, scientists study the ways a human user can get feedback on what the robot hand is experiencing. We try to describe the functions of the axon of the brain and how it will communicate with the microchip to process and transfer data through the microchip. We have introduced the system and the working procedure of the system that will work. For signal analysis, we try to develop a liquid sensory system that will be attached to a robotic arm and will sense the surface that has been touched. It will measure the temperature and hardness of the surface and send it to a microchip using a wireless channel. Through this device, the brain will be able to understand the signal. We hope that in the next future, BCI systems may therefore become a new model of human-machine interaction with levels of everyday use that are much more effective to other current interfaces.

6.Reference

[1] Ziebell, P., Stümpfig, J., Eidel, M. *et al.,* 2020. *Stimulus Modality Infuences Session-To-Session Transfer Of Training Efects In Auditory And Tactile Streaming-Based P300 Brain–Computer Interfaces*. [online] Available at: <https://www.nature.com/articles/s41598-020-67887-6> [Accessed 13 September 2020].

[2] Chowdhury, R. and Saifuddin Saif, A., 2019. Efficient Method to Improve Human Brain Sensor Activities Using Proposed Neuroheadset Device Embedded with Sensors: A Comprehensive Study. *International Journal of Software Engineering and Computer Systems*, 5(1), pp.52-66.

[3] Luz María, A. and Víctor Rodrigo, M., 2017. Enrichment of Human-Computer Interaction in Brain-Computer Interfaces via Virtual Environments. *Computational Intelligence and Neuroscience*, 2017, pp.1-12.

[4] Nooh, A., Yunus, J. and Daud, S., 2011. *A Review Of Asynchronous Electroencephalogram-Based Brain Computer Interface Systems*. [online] Available at: <https://www.researchgate.net/publication/215600594_A_Review_of_Asynchronous_Electroencephalogram-based_Brain_Computer_Interface_Systems> [Accessed 13 September 2020].

[5] Rak, R., Kołodziej, M. and Majkowski, A., 2012. *Brain-Computer Interface As Measurement And Control System The Review Paper*. [online] Available at: <https://www.researchgate.net/publication/258509662_Brain-Computer_Interface_as_measurement_and_control_system_the_review_paper> [Accessed 13 September 2020].

[6] L. Luis, "Brain Computer Interfaces, a Review", 2012. [Online]. Available: https://www.researchgate.net/publication/221967606_Brain_Computer_Interfaces_a_Review. [Accessed: 13- Sep- 2020].

[7] Fouad, M., Amin, K., El-Bendary, N. and Hassanien, A., 2014. *Brain Computer Interface: A Review*. [online] Available at: <https://www.researchgate.net/publication/_Brain_Computer_Interface_A269898782_Review> [Accessed 13 September 2020].

[8] T. Pun, T. Alecu, G. Chanel, J. Kronegg and S. Voloshynovskiy, "Brain-Computer Interaction Research at the Computer Vision and Multimedia Laboratory, University of Geneva", *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, vol. 14, no. 2, pp. 210-213, 2006. Available: 10.1109/tnsre.2006.875544.

[9] J. C Shih, D. J Krusienski and J. Wolpaw, "Brain-Computer Interfaces in Medicine", 2012. [Online]. Available: https://www.researchgate.net/publication/221823801_Brain-Computer_Interfaces_in_Medicine. [Accessed: 13- Sep- 2020].

[10] Y. Singh, "A Review Paper on Brain Computer Interface", *Ijert.org*, 2015. [Online]. Available: https://www.ijert.org/a-review-paper-on-brain-computer-interface. [Accessed: 13- Sep- 2020]

7.Contribution

1. Baidya Samson P (18-37649-1) - 41.5%
2. Dohan, Din Mohammad (17-34465-2) -31.5%
3. Tanvir Ahamed (18-37519-1) -27%