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Mouse Cursor Control using EEG Signal and Machine Learning

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Abstract— Brain-Computer Interfaces (BCI) is a trending way for human beings to smartly interact with a computer by using only their brain. The work leads for a new concept to help the special people to use computer. The main aim is to control mouse cursor movement by eyes via brain signals. Electroencephalogram (EEG) marks and records brain wave pattern. The new technology Electroencephalography is to detect brain signals that help in controlling the mouse cursor. This project deals with machine learning techniques for classifying neural signals and their using them for Brain-Computer Interfacing.

Keywords—BCI, EEG Signals, Electroencephalography

I. INTRODUCTION

In today's world of high technology no human should be felt incapable of using technology, because this would be a defeat to technology itself. Hence, there is a multidisciplinary field of study Human-Computer Interaction (HCI) focusing on the design of computer technology and, in particular, the interaction between humans (the users) and computers. A connecting interface between a wired brain and an external device is given by BCI.

In each phase of a cycle the neurological signal keeps on changing, which is the main relation between BCI and HCI, The stages of the changes are Intention, Activation, and Actuation. Intention refers to reading from the brain (EEG). Activation refers to reading from the muscles (EMG), and actuation refers to the physical movement of the muscles. BCI is said to be the succeeding generation for HCI. This is because BCI relates to neurological signals only, and HCI does not have to be neurological. That is a vast inequality between HCI and BCI. In this paper, the design of an eye-controlled mouse system with an emphasis on the Brain-Computer-Interface (BCI) based on Electroencephalography (EEG) has been presented. First, some descriptions on brain is discussed. Second, all the topics related to the project are discussed including BCI and Machine Learning. Third, literature reviews of other essentially related papers have been discussed. Fourth, the methodology including the feature extraction, testing and training are discussed. Fifth, the result is discussed. Finally, the paper is concluded following the future scope.

Problem Statement: Our aim of this project work is to control Left and Right movements of mouse cursor using a brain.

Human Brain: The main part of the nervous system of human beings is the human brain, along with the spinal cord. The brain resides of the three parts.

1. Cerebrum- The bulkiest part of the human brain.
2. Cerebellum- The smallest part of the human brain carries out body activities such as balancing.
3. Brainstem- Every primary life functions originates inside the brain stem, like, beating of heart, pressure of blood, inhalation and exhalation.

The cerebrum is split into four lobes:

1. Frontal lobes- In control for problem solving, and decision making
2. Parietal lobes – Directs sensitivity, handwriting and body posture.
3. Temporal lobes- In control for memory and hearing.
4. Occipital lobes- Comprise the brain's visual processing system.

Each nerve inside the human brain is joined to thousands of different nerves, by dendritic connections. If the neurons connect, an electrical signal is passed through a dendrite. Where the axon ends this electric signal is transformed to chemical signal and the axon loses chemical messengers called neurotransmitters. The neurotransmitters pass and are converted back to electrical signals. When a current leaves there is a positive polarity and when a current enters there is a negative polarity. These currents are said to be primary currents that are set in the brain tissue and brain liquor and

gets to the skull and scalp. Interestingly the differences in voltage on the surface of the scalp can be detected by the EEG electrodes.

Electroencephalogram

An electroencephalogram (EEG) is simply a recording of brain actions.

On the scalp EEG bustle keep on altering by the mode of alertness of an individual. The frequency and spatial distribution of EEG are not same when a person is sleeping and when a person is awake. EEG's have 5 components of different frequencies:

1. A delta component if its dominant frequency component, f<4 Hz
2. A theta component if 4Hz <= f <8Hz
3. A alpha component if 8Hz <= f <12Hz
4. A theta component if 12Hz <= f <30Hz
5. A theta component if f >= 30Hz

BCI: Brain-Computer Interface or BCI has been the noblest range of study on human beings since 1970's. It can simply be defined as a connection among an enhanced brain and a gadget. Here, enhanced brain refers to combination of external wiring and sensors, or in other words a headset with electrodes. The basic goal of BCI is to assist to convert brain activity of a special person who is not capable of making motor reaction with a computer using his brain signals. BCI has entered into other domains like Robotics, health monitoring systems etc. there have been cases like patience with problems like paralysis, lost limbs and hands have been trained and successfully operated devices using EEG headsets.

Machine Learning: Letting the computer learn automatically without any other support is the actual objective of machine learning. Simultaneously it learns to accustom various actions appropriately. Machine Learning is used in two ways to train the models. They are:

1. Supervised Learning: This is a way to train models to predict future events depending on previous known facts, information or data. After enough training the learning algorithm correlate output with correct expected output to find errors and modify the model correspondingly.
2. Unsupervised Learning: This is a way to train models depending on unclassified or unlabeled information. Objective of this learning is to find patterns, which may be hidden from the unlabeled data.

II. RELATED WORK

We have done a number of literature reviews throughout our work. A number of journal papers as shown below are found important for our work.

In 2016, V. R. Kannan and A. Mariyammal[1] mentioned in their paper about a brain-controlled robot is based on Brain Computer Interfaces(BCI). BCIs are systems that can bypass conventional channels of communication (i.e., muscles and thoughts) to provide direct communication and control between the human brain and physical devices by translating different patterns of brain activity into commands in real time. With these commands a mobile root can be controlled. The intention of the project work is to develop a robot that can assist the disabled people in their daily life to do some work independent on others.

In 2017, P. S. Vaidya and P. P. Sahare[2]designed "Office Boy Robot" basically for working in offices as per the name of the project. Designing and implementation of "Office Boy Robot" is controlled using an App which is used in android mobiles in which we can use Bluetooth communication to interface Arduino UNO and Android. Arduino Uno can be interface to the Bluetooth module through UART protocol. According to command received from android app, the robot motion can be controlled. An "Office Boy Robot" is a line follower robot which follows line either black or white for finding the path. This robot is programmable and can be interchanged to provide multiple applications.

"Android mobile phone controlled bluetooth robot using 8051 microcotroller"[3]. A robot has been designed which is operated by an Android App with the help of Bluetooth Technology using UART protocol. According to commands received from android App the robot motion can be controlled. The consistent output of robotic system along with quality and repeatability are unmatched.

"EEG-Based Brain Controlled Robo and Home Appliances" [4]. This paper discusses about designing of appliances which can be operated using an EEG Headset. And these appliances relate to various other appliances using the concept of IOT.

"Electroencephalogram- based brain controlled robotic wheelchair"[5], In this paper, an EEG- based Brain controlled Wheelchair has been developed using BCI with the help of Neurosky technology. The Event-Related Potential (ERP) offered the Neuro-signal information with the help of P300 component. BCI system consists of a Bio-sensor to capture the EEG/EMG signals. The signals will be processed by the ThinkGear module in MATLAB. The Level Analyser Technique is performed on all the training signals and Alpha and Beta waves are extracted for controlling the wheelchair. The command signals are transmitted to the Microprocessor via RF medium. The robotic module designed consists of ARM 7 Microprocessor coupled with DC motor to perform the command. The Eye blinking strength and attention level were used to control the direction of the wheelchair without any complexity, provided it is more enhanced, portable and wearable.

"Fundamentals of EEG Measurement"[6]. This paper discussed about the history related to EEG and its evolution since late 1800's until now. In the later stages the paper describes how EEG signals can be recorded efficiently.

In 2007 Arslan Qamar Malik, and Jehanzeb Ahmad [7], in this paper presents a product to control computer mouse cursor movement with human eyes with an emphasis on the Human-Computer-Interface (HCI) based on Electro-oculography (EOG) has been presented.

In 2018, Debashis Das Chakladar and Sanjay Chakraborty [8] proposed three algorithms of cursor movement using three well-known clustering methods (Minimum distance, DB-Scan and Gaussian Mixture Model). In this work, performed the comparative analysis of these three proposed algorithms based on internal & external validation indices and identified the best one for multi-target based cursor movement.

In 2015, Mr. Nilesh Zodape, Dr. Narendra Bawane and Pratik Hazare [9] proposed a system that could be helpful for disabled people as they can control computer functions via the imagination of 1D-cursor movement.

In 2014, Mohammad H. Alomari, Ayman AbuBaker, Aiman Turani, Ali M. Baniyounes and Adnan Manasreh [10] proposed a system that could be helpful for disabled people as they can control computer applications via the imagination of fists and feet movements in addition to closing eyes for a short period of time.

In April 2019, Manne Vamshi Krishna, Gopu Abhishek Reddy, B. Prasanthi and M. Sreevani[11] very recently Writes a paper on advance for Human-Computer Interaction (HCI) where to handle the cursor movements a real-time camera is used.

III. METHODOLOGY

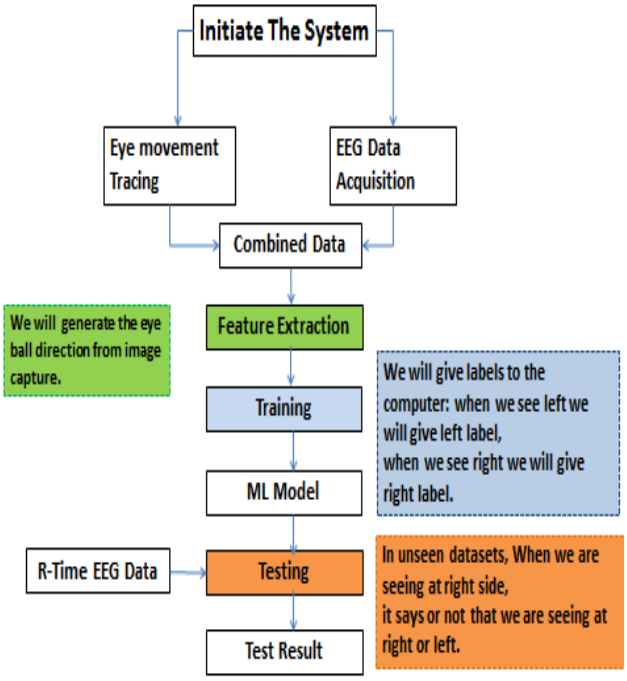


Figure 1. *System Model*

Figure1 shows the overview of the processes that are used in this project.

EEG Data Acquisition:

In the EEG data acquisition process an EEG headset, NeuroSky MindWave Mobile, has been used to record EEG signals generated from our brain through the scalp in real time. The recorded data can directly be exported to other applications like NeuroView for analysis of data later on and for processing the data. The recorded data is in a Comma-Separate-Values (CSV) file, and is opened in programs such as Excel. These EEG signals are of different frequencies. These frequencies differ by the state of our mind.

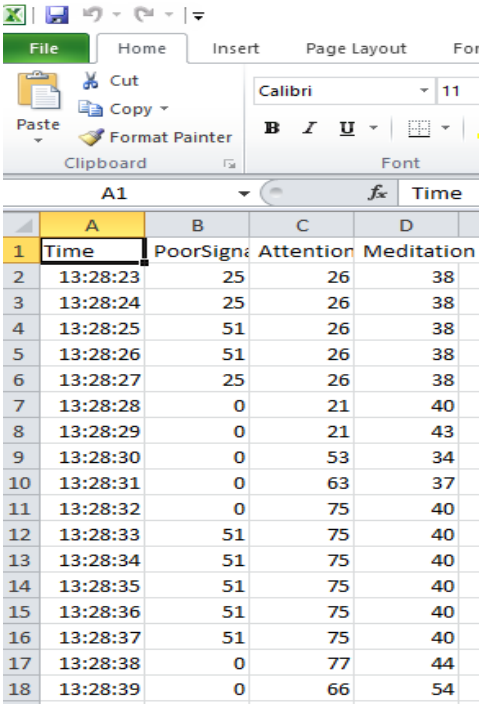
Neurosky headset gives us data about :

- Attention level
- Meditation Level
- Raw Signal
- Power Spectrum.

Figure 2. *Neurosky MindWave Mobile EEG Headset*

It resides five main parts namely, Rubber sensor arm, Rounded forehead sensor tip, T-shaped Adjustable headband, Ear-Clip and Ear Loop. Figure 2 shows how it looks.

Figure 3 shows the data recorded from NeuroSky with the help of an application called NeuroView.



	A	B	C	D
1	Time	PoorSigna	Attention	Meditation
2	13:28:23	25	26	38
3	13:28:24	25	26	38
4	13:28:25	51	26	38
5	13:28:26	51	26	38
6	13:28:27	25	26	38
7	13:28:28	0	21	40
8	13:28:29	0	21	43
9	13:28:30	0	53	34
10	13:28:31	0	63	37
11	13:28:32	0	75	40
12	13:28:33	51	75	40
13	13:28:34	51	75	40
14	13:28:35	51	75	40
15	13:28:36	51	75	40
16	13:28:37	51	75	40
17	13:28:38	0	77	44
18	13:28:39	0	66	54

Figure 3. *Screenshot of recorded data from NeuroSky*

Eye Movement Tracing:
In the process of eye movement tracing Python Language is used along with the Anaconda 2.0 IDE. For eye movement tracing there are two phases:

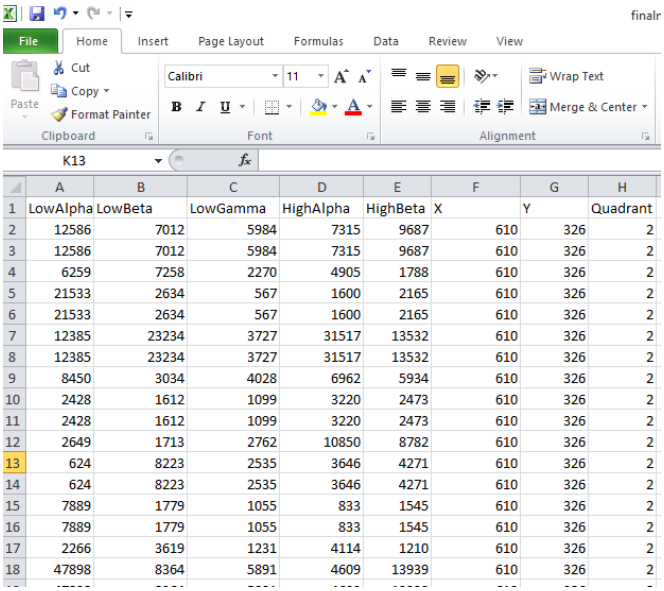
1. Face and Eye Detection.
2. Eye movement controlling cursor

Face and Eye Detection: To accomplish this task OpenCv has been used. It is a library of programming functions. It contains many pre-defined classifiers for face, eye, etc. For eyes detection there is a specially one classifier called Haar Cascade Classifier.

Eye movement controlling cursor: To accomplish this task a Python module called PyAutoGUI is used to programmatically control the mouse.

After data acquisition and eye movements tracing both the data are combined using NeuroPy. NeuroPy is a library scripted in Python used for connection, interaction and access data from Neurosky MindWave EEG Headset. Mainly the Alpha Values of EEG signals are associated with visualization and optical activities. But low Alpha, low Beta, low Gamma, high Alpha and high Beta Waves of the power Spectrum are retrieved as a data from Neurosky for further work.

Database: This data can also be exported to a file in CSV format using Pandas. Figure 4 shows the data.



	A	B	C	D	E	F	G	H
1	LowAlpha	LowBeta	LowGamma	HighAlpha	HighBeta	X	Y	Quadrant
2	12586	7012	5984	7315	9687	610	326	2
3	12586	7012	5984	7315	9687	610	326	2
4	6259	7258	2270	4905	1788	610	326	2
5	21533	2634	567	1600	2165	610	326	2
6	21533	2634	567	1600	2165	610	326	2
7	12385	23234	3727	31517	13532	610	326	2
8	12385	23234	3727	31517	13532	610	326	2
9	8450	3034	4028	6962	5934	610	326	2
10	2428	1612	1099	3220	2473	610	326	2
11	2428	1612	1099	3220	2473	610	326	2
12	2649	1713	2762	10850	8782	610	326	2
13	624	8223	2535	3646	4271	610	326	2
14	624	8223	2535	3646	4271	610	326	2
15	7889	1779	1055	833	1545	610	326	2
16	7889	1779	1055	833	1545	610	326	2
17	2266	3619	1231	4114	1210	610	326	2
18	47898	8364	5891	4609	13939	610	326	2

Figure 4. *Preview of database*

Feature Extraction: Here feature Extraction can be simply described as how machine learning differ various features as responses or outputs and other features as inputs. Here are the alpha, beta, gamma values and the X and Y coordinates are taken as inputs and quadrant is taken as response.

After the feature extraction process, the extracted value are classified into two pre defined target classes for training purpose which are defined by "1" for first quadrant or Right side of the screen and "2" for second quadrant Left side of the screen.

Training: In this process the model is made to learn that for some values of EEG signals it refers that the object is looking to the right side and for other values of EEG signals it refers that the object is looking to2 the left side. This way the model is trained for 30 folds in cross validation using SVM classification algorithm of Machine Learning. SVM is used for it gives the maximal accuracy and precision among all others.

Testing: The trained model is then tested with a dataset of data which were not used for training the classifiers.

Tools/Environment/Experimental Platform: Python2 is used as the programming language. Anaconda 2.0 is used as the IDE for Python2. NeuroPy is used for getting the dat from Neurosky. Scikit-learn is used for supervised learning algorithms that allows different types of classifications plotting of functions and data, creation of user interfaces etc. During the whole project windows 10 operating system is used.

IV. RESULTS AND DISCUSSION

We have trained a system to detect if the object is looking at the right side of the screen or left side of the screen. To do so we have used low alpha, low beta, low gamma and high alpha, high beta values for many X and Y coordinates. We have tested the system with 20 such rows for both the quadrants in preliminary phase. We have got an accuracy of 65%.

V. CONCLUSION AND FUTURE SCOPE

We have completed detection of two quadrants namely first and second with success. In future we will train and test the system to detect four quadrants like first, second, third and fourth in real time. Also we will try to increase the accuracy of the system more than now achieved 65%.

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