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ARTICLE

BRAIN MACHINE INTERFACE USING ELECTROENCEPHALOGRAPHY

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ABSTRACT

Machine Learning a very popular and extremely useful technique in Brain Machine Interface. We explore the use of BMI for implementing electroencephalography for recording electrical activity of the brain. In this paper, we focus on developing a prototype that uses BMI to extract the current mood of the human brain. A BMI/BCI system provides a new method of communication to the brain through the computer. The brain consists of billions of neurons and these neurons communicate via minute electrochemical impulses which generate movement, expressions, emotions and words. Mental activity leads to changes of electrophysiological signals. Brain- computer interface (BCI) takes the input through the brain and link it to the device for some external activity, such as body movement, intelligence. The system opens a pathway for connecting the human brain and the matter that to be inhabited and is also helpful for treatment of severely paralyzed or locked-in people.

KEY WORDS
Machine Learning, Brain Machine Interface, EEG

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INTRODUCTION

Machine Learning is a field of Computer Science, which enables the computer to work according to its own intelligence without being explicitly programmed.

A BCI machine sometimes called a mind- machine interface, direct neural interface or brain - machine interface (BMI), these are gates for communicating and for the controlling the systems which translate the input received from the brain and send it in order communicate with the devices.

Using of computers had always struck the question of interfacing. The ways by which human has been interacting with computers has advanced from last few decades. The new designs of technologies and systems appear more and more every day.

The growth in Human-Computer Interaction (HCI) field has not only been in quality of interaction, it has also experienced different branching in its history. Instead of designing regular interfaces, the different research branches have had different focus on the concepts of multimodality rather than unimodality, intelligent adaptive interfaces rather than command/action based ones, and finally active rather than passive interfaces.

This paper provides an impact on the HCI systems and cover most important branches as mentioned above. In the next section, basic definitions and terminology of HCI are given. This is a description on the different architectures of HCI designs. The final sections give the description on some of the applications of HCI and future directions in the field.

Electroencephalography (EEG) is a method for translating and recording the data received from the brain as the source of the input.

Further to study the method electroencephalography and to implement how EEG signals are different for different subjects to another furthermore, the concept of transferring of data between subjects is examined.

The non-invasive technique works by placing the twenty-four electrodes all over the head; It measures voltage fluctuations coming from the neurons of the brain.

The main focus is of developing a prototype which uses available EEG signals from brain as a input, and do certain task –

1) Receiving the EEG signal 2) process with the EEG signal and 3) uses the signal to classify and control the playlist of the music.

The focus is in developing a prototype of a headphone, which changes the music in reference to the current mood of the listener.

This draft focuses on the doorway of the EEG signals from the brain and to be implemented for testing purpose for the model, and the output is a functional prototype that can use user brain signals to control the music in the headphone through the application with over 90% accuracy.

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Anatomy of brain

Human brain being the most complicated machine consists of neurons as many in number as there are stars in the galaxy [1]. It controls and regulates all functions and tasks performed by body. Our brain mainly consists of three, 1.cerebrum Cortex, 2.cerebellum cortex and 3.pons. Human mind consisting different lobe, the largest part of the brain is known as cerebellum see in the [Fig. 1]. [2]

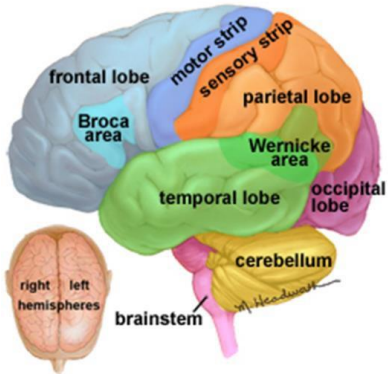

Fig. 1: Parts of Human Brain [2].

Cerebral Cortex is further branched into four lobes, which are: frontal, temporal, parietal, and occipital. Functions performed by each lobe are explained in [Table 1]. Further the lobes are again divided to the section that performs some particular functions. These brain cells are very complex in nature. Each lobe of the brain doesn't function alone.

Notice two important areas in cerebrum called sensory strip and motor strip. The sensory strip is in the parietal lobe, near the border of the frontal lobe. The strip is involved in registering sensation that is connected to specific body parts or body functions. Motor strip is located at the frontal lobe and controls all muscle movements including the ones that are necessary for speech.

Table 1: Functions performed by different Lobes of Cerebrum

Lobe	Function
Gyrus Lobe	Personality of the user, Behavior of the user, Emotions of the user, Judgment capability, Planning and strategy, Problem Solving capacity.
Parietal Gyrus gland	Interprets the language, Sensitivity, Temperature (*Sensory strip*), Interprets signals from Vision, Hearing capacity etc.
Temporal gyrus Lobe	Memory storing, Hearing capacity, Sequencing and Organization ability
Occipital gyrus Lobe	Memory Storing, Hearing capacity, Sequencing and Organization ability

ELECTROENCEPHALOGRAPHY

Basic of EEG

Electroencephalography (EEG) is a technique for continuously monitoring brain's activity. German psychiatrist Hans Berger first observed it in 1924. It involves placing electrodes on the scalp and measuring the electrode potential of each electrode.

Neurons, which are basic building blocks of our nervous system, send their energy or "talk" to one another through tiny spaces called synapse. Whenever a neuron receives a signal, its membrane generates electric potential changes. Generating action potentials along the neuron passes along these signals. This electrical activity always occurs inside a live brain that is whenever there is any sensory, imagery or motor action happening or even during sleep. The electrodes of EEG on scalp detect the weighted effect of this electrical activity of pyramidal cells (i.e. neurons just under the scalp). Being a weighted measurement of many nerve cells, EEG has lower spatial resolution but good temporal resolution.

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Measurement system (international 10-20 system)

There are many methods which EEG places electrodes. The standard10-20systemis usually used to collect the instant EEG. In this method 21 electrodes are specified on the scalp, as shown in [Fig. 4A, 4B]. The positions are as follows: Source points are mansion, that is an apparatus on the nose, aligned with the eyes; and inion. From these references, the skull specifications are calculated in the transverse and median planes [3]. Electrode positions are known by separating these values into 10% and 20% breaks, this is the reason it is called 10-20 systems. Tracing this pattern, we will get the electrode layout as shown in [Fig. 2]

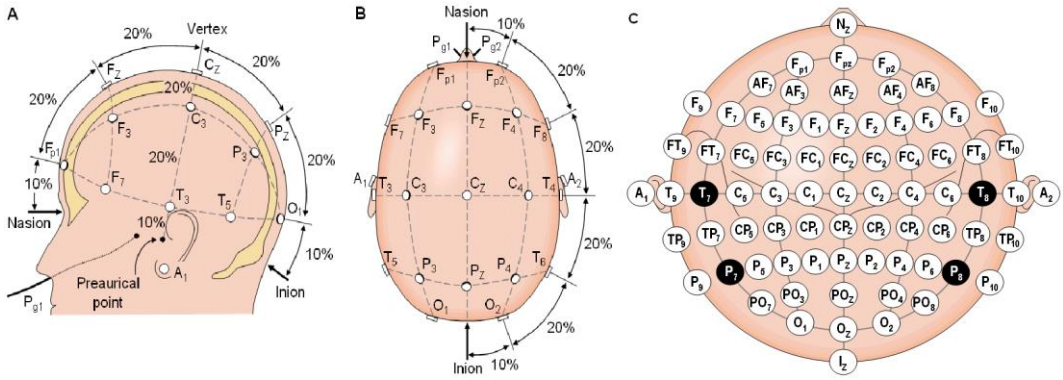

Fig. 2: International 10-20 system Electrode Placement [4].

All the positions and specifications of these electrodes are specified and standardized by the American Electroencephalographic Society. In this diagram the circles containing numbers and letter represent the electrodes. Letter represents the region of brain like F for frontal and C for central and numbers indicate the place. The numbers, which are odd, are on left side and even numbers are on right side. Lower the number means it is close to centerline and center line is represented by letter 'z' indicating zero.

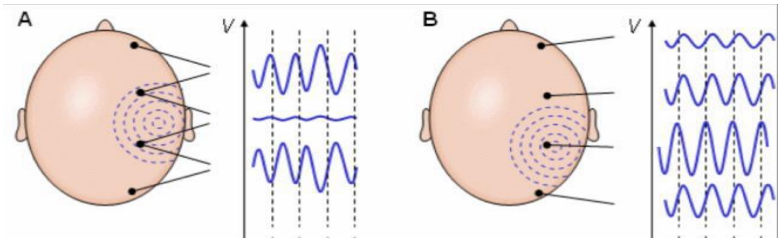

Fig. 3: EEG measurement (A) Bipolar (B) Unipolar [5].

EEG signal strength is very small, in the order of microvolts. Therefore, to increase the signal and noise ratio, we take differential measurement of two electrodes using differential amplifier with high input impedance to remove the common-mode noise. Thus, EEG is relative measurement. The measurement can be bipolar [Fig. 3A] in which the potential drop between a pair of electrodes is mapped or it can be unipolar as shown in [Fig. 3B] in which potential of each electrode is compared either to a neutral electrode or to the average of all electrodes. Frequency spectrum of EEG reveals frequency content of signal. It has bandwidth about 50Hz.

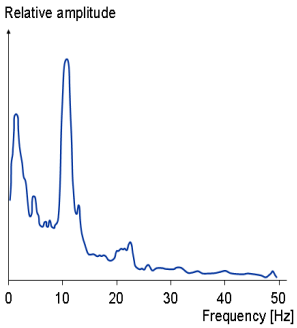

Fig. 4: Frequency Spectrum of typical EEG signal [6].

The bandwidth is further divided to more commonly observed frequency beats, which is further explained in [Table 2].

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For example, if we take EEG measurement of person sleeping we will see most of the frequency content will be less than 4 Hz, which is called Delta band. Likewise, we have Theta, Alpha, and Beta mu bands. Note that Mu waves diminish with movement or imagination of movement. We will see later that this property is used in control applications.

Eeg based bmi system architecture

Architecture is converted into statement that operates a command in the device. The important point to notice here is that this whole system involves two adaptive controllers i.e. Brain and BMI machine. It is the responsibility of the user to create and maintain a well co-relation between his/her intent and the frequency signal featured employee by the BCI, and the BCI should select and extract the features that the user can control efficiently. [7]

Table 2: EEG wave bands [8]

Frequency Location Uses			
Delta (ϱ)	0.5-4 Hertz	Common	Sleeping / coma
Theta (θ)	4-8 Hertz	Temporal-lobe & parietal-lobe	All kind of Emotional Stress (Anger, Sadness)
Alpha (**α**)	8-13 Hertz	Cerebral-cortex	Visualizing Problem(Hearing, Imagining)
Beta (β)	13-30 Hertz	Parietal and frontal	Increases the amplitude at the time Of intense mental activity
Mu (μ)	8-13 Hz	Frontal-lobe (motor cortex)	Diminishes to the behavior that Is preparatory to another behavior

Output

Output device can be any controllable machine. The system can be used to answer the yes/no questions or for type processing. It is being used for control objects like wheelchair or can be channel of communication in games or virtual reality. Usually, computer screen is used for visual feedback and the output is the selection of target.

PRESENT-DAY BMI SYSTEM

BMI is a highly multidisciplinary field. After its first successful implementation in 1999, that enables the cortical neurons that could directly control a machine manipulator, the field has shown remarkable progress. Given below are few present-day applications and current research trends in BMI technology.

Visually evoked potentials

Visually Evoked Potentials (VEP) is type dependent BCI system and uses the concept of evoked potentials. The system detects the EEG patterns in primary visual cortex. Example of such system involves stimulating the user with a light having certain frequency. The EEG signals around visual cortex will have peaks in spectrum at that frequency component and its harmonics. [Fig. 5] shows one implantation. In this application, user faces a screen displaying several virtual buttons that are flashed at different rates. Once the user directs his/her gaze at screen.

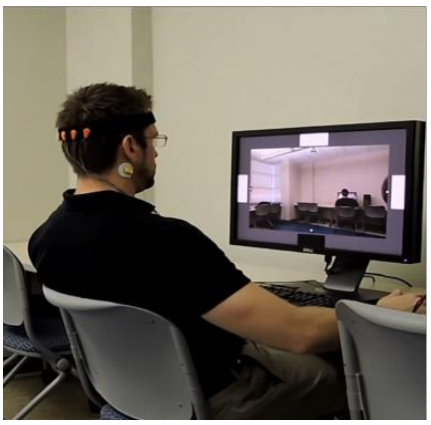

Fig. 5: Visual Evoked Potentials [9] (Left) EEG Spectrum (Right) Application [10].

P300 evoked potentials follows the concept of independent BMI. The P300 is a (+ve) deviation on the (EEG). Neural Interface Engineering Brain Machine Interface using EEG

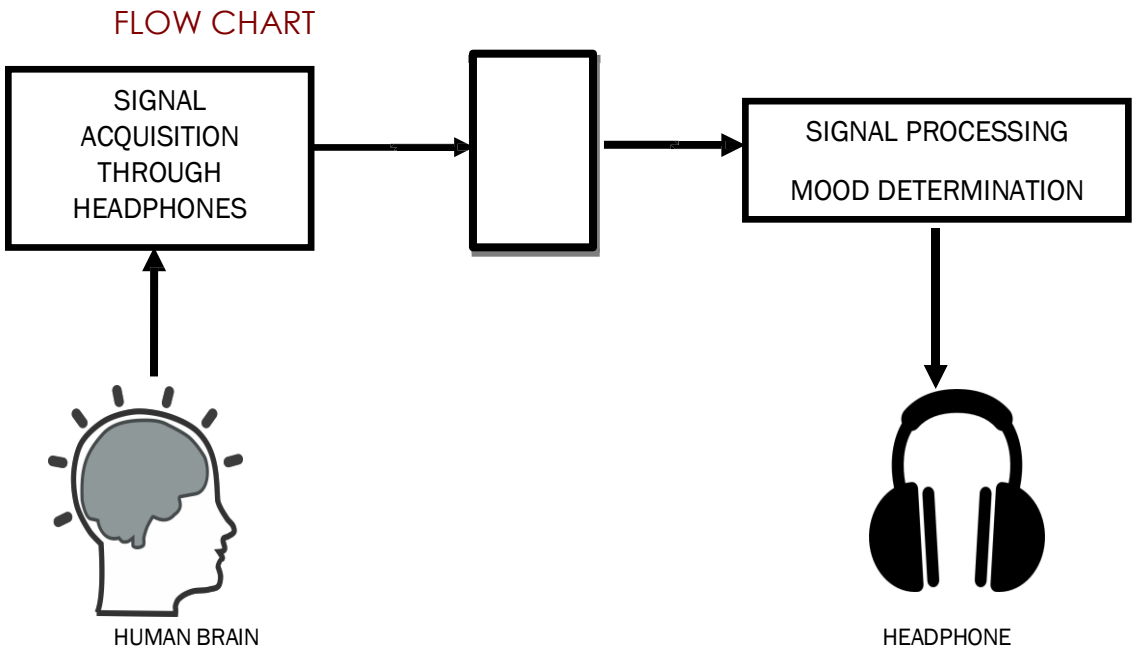

Fig.6: Signal acquisition and processing

As described in Fig-6, the process begins with 'Signal Acquisition'; the brain electrodes connected to the head of the person through headphones capture the electrical activity from the brain. Signals from the brain once collected are then sent to the 'Signal Processing' phase of the process in the mobile application where, the system developed by K. Ishino and M. Hagiwara [12] applying FET, Once the mood of the person is identified it is then compared to the music database, where it determines which type of music would best suited the person's current mood based on Thayer's mood classifications.

Algorithms used:

Principal component analysis: This idea of the (PCA) Principal component analysis is to reduce the chance of the variables and the data sets, which co-relates, (high or low), assessing the data from the data sets, it is extent to the maximum. This can be done by the transforming the data sets into variables, which are known as the principal components (or simply, the PCs) and are orthogonal. This is the way to retain the data sets and to use it. The principal are components are the Eigen-vectors of a co-variance matrix, and hence they are orthogonal. The results are also sensitive to the relative scaling. The PCs are essentially the linear combinations of the original variables, the weights vector in this combination is actually the Eigen-vector found which in turn satisfies the principle of least squares.

- PCs are already discussed.
- As we move to the 1st PC to the last PC the variation present at it decreases and with it the importance, the unwanted PCs are sometime important in the regression, outlier and detection.

Wavelet transform:

CWT: The Continuous Wavelet Transform transforms a continuous signal into highly redundant signal of two continuous variables: 1. translation and 2. Scale. The resulting is the transformed signal, the signal is easy to interpret and valuable for time frequency analysis.

DWT: The Discrete Wavelet Transform has become a powerful technique in biomedical signal processing. It can be written on the same form as (1), which emphasizes the close relationship between

CWT and DWT. The most obvious difference is that the DWT uses scale and position values based on powers of two.

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Table 3: Moods classifies according to musical components [13]

Feeling	Power	Sound	Tone	Rhythm
Cheerful	Average	Average	Extreme	Extreme
Exuberant	Excessive	Average	Excessive	Excessive
Energetic	Extreme	Average	Average	Excessive
Frantic	Excessive	Extreme	Little	Extreme
Depressed	Average	Extreme Low	Extreme Low	Little
Sorrow	Little	Little	Little	Little
Calm	Extreme Low	Extreme Low	Average	Extreme Low
Contentment	Little	Little	Excessive	Little

Many other algorithms and technique can be used to make this system more accurate and efficient. At last the songs are played from a large library of songs matching the mood of the person and making him feel better.

CONCLUSION

Brain Machine interface is very interesting field which gives us chance to expand the capabilities of human brain, potential to bring science fiction into reality. EEG based BMI systems are the hope for severely and partially paralyzed patients in that one day they do the basic communications and the motor control, it helps in the communication process with the brain. It holds the promise of bringing sight to the blind, hearing to the deaf and words to unspoken emotions, even increasing the level of interaction between human and machine. We will add more features like changing the color of headphones depending on the state of the user in addition to that we can also try to determine the type of music which helps the human brain to lessen the effect of stress.

CONFLICT OF INTEREST

There is no conflict of interest.

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FINANCIAL DISCLOSURE

None.

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