BRAIN COMUTER INTERFACE-A SURVEY

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Abstract -*In the field of brain computer interface (BCI) the human beings have dreamt about communicating with machines and make machines understand our thoughts. Neuroscience and various brain imaging techniques have made these dreams transfer to reality. In the technological advancements BCI plays a significant role in Mind Machine interface. Brain computer interface is process of direct communication of brain and devices which are outside the body. The applications of BCI have reached beyond the medical applications; it is used to enhance, restore or replace functions and used as a research tool. This paper significantly provides detailed survey and information about brain computer interface. It provides knowledge about steps involved in BCI like acquisition of data, pre-processing of information and data acquired in acquisition phase, extraction of features from the data, classification algorithms and final application. The aim of this paper is the survey of significant and relevant information about BCI and its applications.*

Key Words: Electroencephalography, microcontroller, Brainwave, Signal acquisition, Intra-cortical surface, Cortical-surface.

1. INTRODUCTION

Communicating with machines and transforming thoughts into actions through robots was a fantasy for human beings few generations ago. There was need of advancement in the field of neuroscience that would help disabled people to express their thoughts and emotions with help of machines. Later, advancements in science and neuroscience made this dream a reality. In order to meet these needs, many solutions were developed. One technology that was developed was Brain Computer Interface.

BCI uses sensors in order to identify human thoughts and emotions. These thoughts are transformed into actions. Brain computer interface is called as neural-control interface. It's a communication conduit between human brain and devices external to the body. The neurons in the brain capture thoughts of the human which are transmitted to the external device by using various algorithms and data extraction features.

The first step of BCI is signal acquisition. Invasive technique, partially invasive technique and non-invasive technique are three techniques of signal acquisition. In invasive technique, electrons are implanted neurosurgically inside the brain of human. It provides high spatial and temporal resolution. It increases the quality of acquired signals. Intracortical method is one of the most used Invasive method. In non-Invasive technique, external sensors are used to record activity of the brain.

Thus, it avoids surgical methods. Electroencephalography is a widely used technique that accesses electrical activity happening in the brain. It's a non-invasive technique. These non-invasive electrodes are also called as electrocorticography. This paper provides information about robotic arm movement using non-invasive techniques. The next step is processing the signals that have been acquired. Output of pre-processing is given to feature extraction unit. The features are classified through classification algorithms and finally output is given to the robotic arm.

The robotic arm functions accordingly. Earlier robotic arms had simple functionality and were not much accurate. Later, advancements were made that made the arms more movable. However, the arms did not look like a human arm. With advancements, the hands became more natural. Today, robotic arms are operated with ease through BCI techniques. The use of this technique is highly beneficial for patients having arm and hand disabilities. These patients are completely conscious but cannot perform certain movements of hand and wrist like rotation, moving fingers, holding objects, etc. Thus, BCI enables patients to use robotic arm and perform daily tasks by controlling the arm through mind and brain.

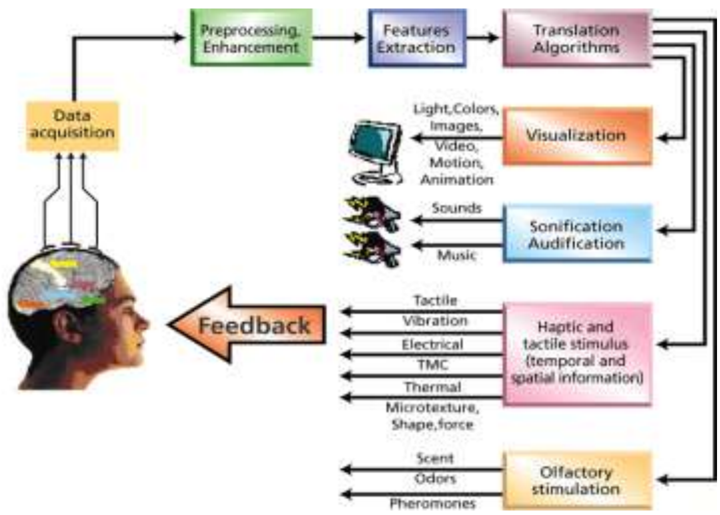

Fig.1. Block diagram of BCI [6]

2. LITERATURE REVIEW

The application of machine is controlled based on imagination of the person, then the brain activity is monitored. For this, various methods like functional

Magnetic Resonance Imaging, magneto encephalography, Single Photon Emission Computer Tomography (SPECT), Positron Emission Tomography are used. These signals are highly used in robotics. Given below is the literature survey of two papers:

Mind Controlled Robotic Arm

(Devashish Salvekar, Et. Al (year 2015))

Observations:

This paper provides information about Mindwave headset used to detect brainwaves for robotic arm action.

Mindwave Headset has the following: A power switch to switch the headset on and off, a flexible ear arm that can be placed comfortably on your ear, a sensor tip and a ground connection Ear clip. A non-invasive sensor is used by this headset. Thus, no headache or side effects will be caused to the user. The data is transferred to the computer through wireless Bluetooth connection. The data is analysed by Matlab software. Afterwards, data is transmitted robot module. An RF receiver is used to receive the data that is sent by the transmitter. Now, the role of PIC microcontroller is to direct the servomotors that are connected to a robotic arm. The robotic arm functions accordingly.

Commands	Signals Extracetd
Move index finger	Attention: 20 to 45
Move middle finger	Attention: 45 to 70
Move ring finger	Attention: 70 to 95
Move pinky finger	Meditation: 20 to 45
Move thumb finger	Meditation: 45 to 70
Closing all fingers	Meditation: 70 to 95

Conclusions:

The Mindwave controlled robot gives 80 % accuracy and not 100 % accuracy.

More accuracy can be achieved when number of sensors would be increased for signal detection.

The current developed system gives 6 type of outputs.

However, less accuracy was achieved which can be improved by reducing complexity of task.

Brain–computer interface: controlling a robotic arm using facial expressions

Humaira NISAR Et. Al (year 2018)

Observations:

This paper provides information about robotic arm controlled through facial expressions using Emokey, Epoc headset and Arduino UNO. Emokey is connected to emotive control panel. EEG signals are tracked and keystrokes are identified. The data is passed to Emotiv control panel. Output is given to microcontroller which then moves the robotic arm. Given below is list of EEG signals and corresponding robotic arm response:

Signal	Movement	Keystroke	Action
Left Smirk	Make a Fist	1	Finger motors turn 180 degree.
Right Smikr	Release Fist	2	Finger motors turn 0 degree
Raise Brow	Flexion of Elbow	3	Elbow motors turn 150 degree.
Look Left/Right	Extension of Elbow	4	Elow motors turn 0 degree

Conclusion:

The system was tested on 10 people. The robotic arm was capable of making four moves (make a fist, release a fist, flexion of elbow, extension of elbow).

Accuracy obtained by system is 95 % which is very impressive.

3. STEPS INVOLVED IN BCI

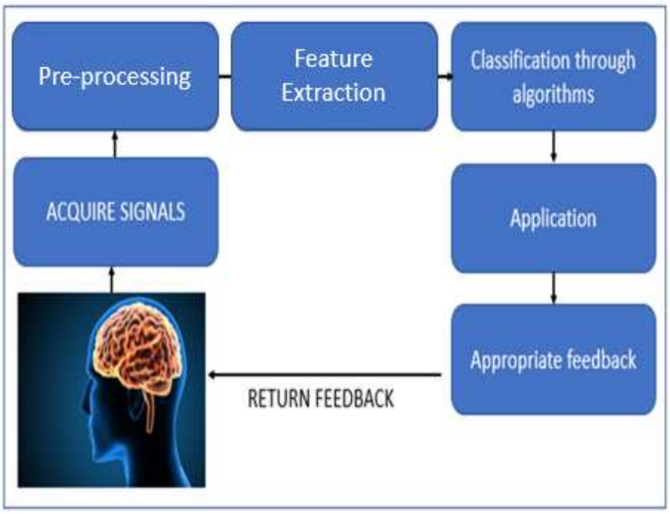

Fig.2.BCI Steps

3.1 Signal Detection

This is the method of detecting the signals that are created by neurons in the brain. These signals are raw signals. They are given as an input for pre-processing.

3.2 Signal Acquisition

After signal detection, required features are extracted during process of signal acquisition. Raw EEG signal contains various problems like sounds and noises. These noises effect the system functions. Hence, proper signal acquisition and feature extraction techniques are used to decompose signals in sub band-signals. Feature extraction process extract Time domain features and frequency domain features. Signal acquisition is used to measure brain generated oscillations. It shows voluntary neural actions that are generated by current activity of user. Mainly two techniques are used for signal acquisition:

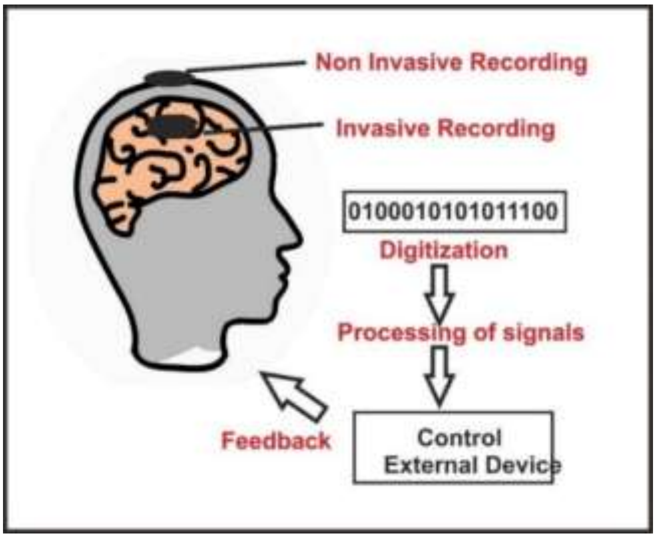

Fig.3. Types of signal acquisition

Invasive Technique:

Invasive technique of signal acquisition is a method where brain signals are recorded by implanting electrodes directly on human brain. Due to direct implantation, this technique provides high spatial and temporal resolution. The limitation of Invasive technique is that once the electrodes are implanted on the brain, they cannot be shifted on other part of the brain. Also, if body adaptations fail, medical complications may get caused. Thus, security needs to be taken care of in Invasive technique as surgery is done directly on brain.

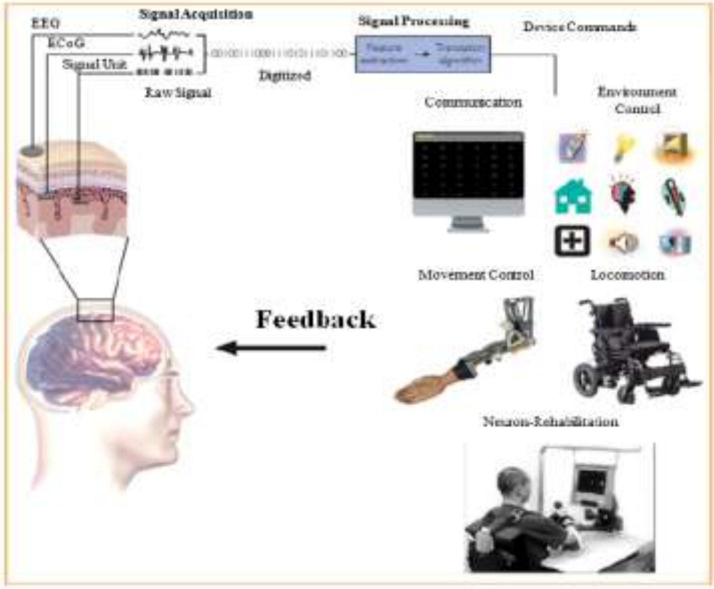

Fig.4. Invasive Brain Computer Interface [8]

Non-Invasive Technique:

Non-Invasive technique of signal acquisition is a method where brain signals are recorded by external sensors and devices. In Non-Invasive technique, medical scanning devices or sensors are present on caps or headbands. This technique avoids surgical procedures or attachment of devices permanently like Invasive techniques. However, it provides low temporal and spatial resolution as external sensors are used to sense neural activity.

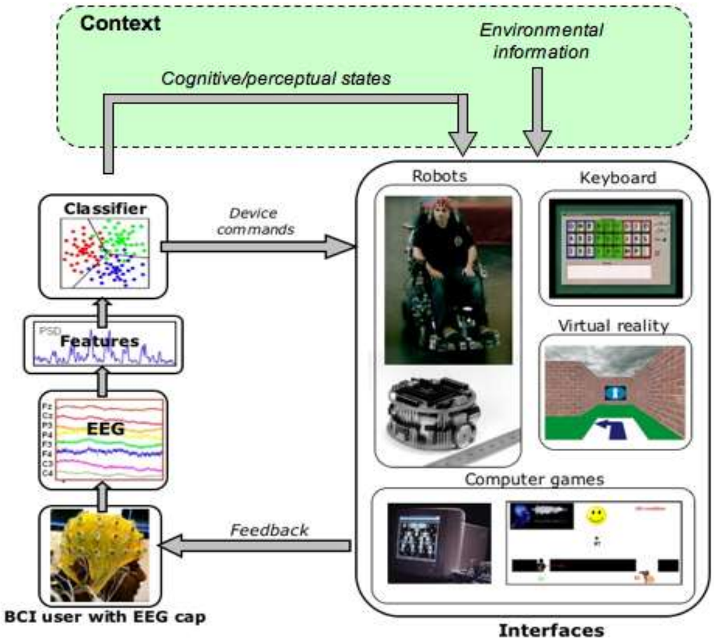

Fig.5. Non-Invasive Brain Computer Interface [9]

3.3 PRE-PROCESSING

Raw EEG signal is processed to remove noises. On the basis of frequency range, the sub-band signals are divided as theta signal, alpha signal, delta signal, beta signal and gamma signal. After decomposition process, noise gets reduced. Rate of error is calculated after decomposition. Output of pre-processing is given to feature extraction unit.

The frequencies of the human EEG waves are:

- Delta: It has a frequency of 3 Hertz or below. Delta has highest amplitudes. It's mostly seen in children up to one year. It is also seen in stages 3 and 4 of sleep. It's mostly prominent in adults and posterior in kids.

- Theta: It has frequency ranging between 3.5 to 7.5 Hertz and is classified as a "moderate" movement. It's typically seen in children up to 13 years.

- Alpha: It ranges somewhere around 7.5 and 13 Hertz. Alpha waves are produced when eyes are getting shut and vanishes when eyes open due to alarming system

- Beta: Beta movement is "quick" action. It has a range of 14 and more prominent Hertz.

- Gamma: Gamma waves are of 31Hertz and above. It is believed that it mirrors the instrument of awareness.

3.4 FEATURE EXTRACTION

Various types of thinking activities lead to different patterns of the brain signals. BCI is system which recognizes patterns. These patterns are further classified into classes based on the features. BCI extracts particular features through signals of the brain that show similarities to a certain class and also reflect differences from rest of the classes. Various features are derived from properties of signals that have discriminative information. This information is used for distinguishing different types. Given below are all feature extraction methods that are used in BCI.

Comparing different Feature extraction methods [7]:

PCA [Principal Component analysis]

In Principle component analysis, Linear transformation is used. Uncorrelated variables are created by transforming correlated observation sets. The key features of PCA are that noise sensitivity is low. This technique can be used for data compression ensuring that no data is lost. However, the disadvantages of PCA is that Covariance matrix is very difficult to evaluate.

ICA [Independent Component Analysis]

ICA is a statistical procedure. It splits set of mixed signals into its sources without any previous information about the nature of signal. The advantages of Ica are that this method reconstruct data better than PCA in presence of noise. However, the limitations are that it is difficult to handle large amount of data signals using this method. Along with this, the method does not offer ordering of source vectors.

CSP [Common spatial pattern]

CSP projects multichannel EEG signals into a subspace, where differences between classes are highlighted and similarities are minimized. The classification is made highly effective, by creating spatial filter. This filter is used to transform the input data into output data for subsequent discrimination through optimal variance. Classifications are made effective through spatial filter. The limitation of this method is that large number of electrodes are required.

AR (Autoregressive components)

AR is a Spectrum model.AR models the EEG signal as the output random signal of a linear time invariant filter, where the input is white noise with a mean of zero and a certain variance of $\sigma2$. The motive of the AR algorithm is to produce filter coefficients, as it is assumed that various thinking activities will result in different filter coefficients. Adaptive version of AR is: MVAAR. The main advantage of AR is that frequency resolution in high for time segments that are short. However, AR is not suitable for signals that are non-stationary.

WT (Wavelet transform)

WT is a mathematical tool. It extracts data from information like audio data, videos, etc. Its extensions are CWT and DWT. Key features of WT are that it inherits multiresolution nature, provides high scalability, and provide tolerable degradation. The limitations of WT are that it takes long compression time. CWT has high computational demand and resource demand.

Given below is Survey on feature extraction methods.

Genetic Algorithm

(GA) Swati N. Moon et al. (2015)

Observations:

Demonstrated GA as optimization tool for selecting features, particularly for large data set. These features are then fed to Neural network classifier.

Conclusion:

Operating on dynamic data sets is difficult.

Classification of human emotion from EEG using discrete wavelet transform

Murugappan M et al. (2010)

Observations:

Recognized human emotions using discrete wavelet transform. Joint time frequency resolution is obtained by WT that is used for effective extraction of signals.

Conclusion:

Modified energy features give better classification of emotions than conventional. Absolute Logarithmic Resourcing Energy Efficiency has property of giving max average classification rate as compared to conventional features. Hence, extracted features are successfully calculated regardless of age, color of subject. Also, it shows relationship with audio visual content between EEG detected and emotional state that is experienced by the particular user.

3.5 Classification

Classification is used to analyze and interpret user intentions through results produced by feature extraction step.

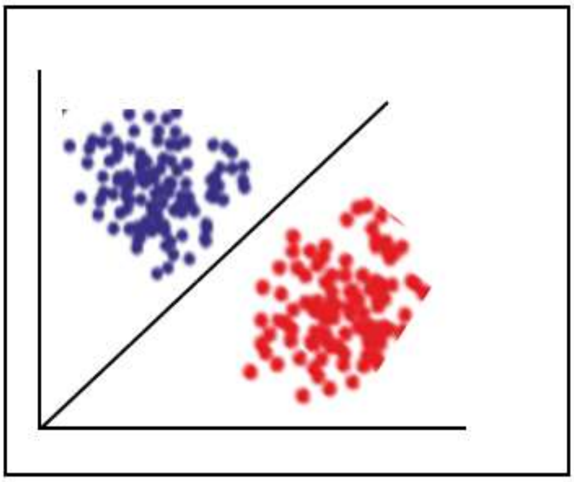

Fig.6. Classification

Given below are the classification methods required for BCI applications. Different Classification techniques are as follows:

1. **Bayesian analysis**: It is used to produce non-linear decision boundaries.

2. **LDA**: Its simple classifier having acceptable accuracy and has low computational requirement.

3. **SVM**: It's a binary method or multiclass method that is used for maximization of distance between the hyperplanes and nearest training samples.

4. **A-NN**: ANNs are used widely for pattern recognition as they are able of learning from training data. Once trained, the ANNs can easily recognize a set of training data-related patterns.

5. **K-NNC**: k-NNC use metric distances between the test feature and their neighbours.

Regression

It employees the features that are extracted from EEG signals as independent variables and are used to predict user intentions. However, these regression algorithms are less popular than classification algorithms. In most BCI systems, classification is used instead of regression. It's the final execution of device. The device will function in accordance to thoughts of the user that have been interpreted by BCI system. The feedback can be positive or negative according to functionality of system.

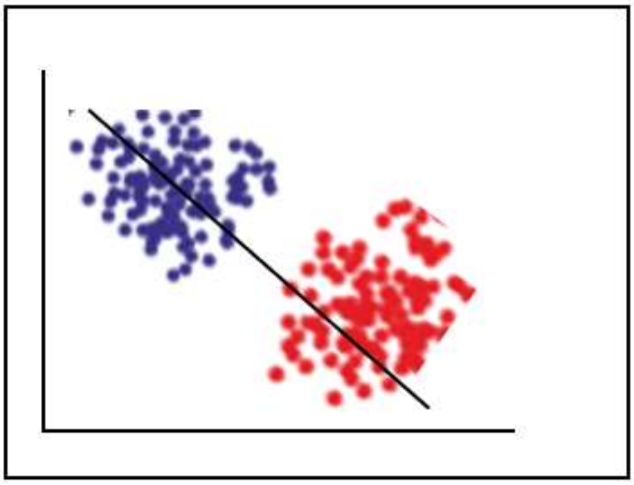

Fig.7. Regression

4. CONCLUSION

This paper reviews the Brain computer interface and its applications in field of science and technology. The various areas where BCI is applied are Medical, Neuromarketing and advertisement, Security and advertising, Smart environment, gaming, etc. This paper gives description about different techniques that ae involved in extracting and manipulating brain signals into actions. The techniques involve signal acquisition, feature extraction, manipulation of signals and finally getting the robotic device into action.

Various researchers have used various devices, techniques, software's and equipment's to get robotic devices work as per user requirements. However, more advancements and study need to be done in order to get better results from devices. Thus, there are still many obstacles for researchers in field of BCI. BCIs are still slow and error-prone. More research is required to reach expected accuracy. In order to use BCI systems on a daily basis, it needs to be more reliable, simple to use, maintainable and adaptable in real environment.

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