A Survey of EEG Based Brain Computer Interface (BCI) and Recapitulation of Authentication Using Electroencephalogram (EEG) Signals

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Abstract: A new emerging field in the Computer Science technology is the Brain Computer Interface (BCI). This paper reviews the BCI domain and its application in the security aspect. Security breach and data sensitivity are most important these days. The paper discusses the common methods of authentication that are password, pin, biometric scans of face, palm, finger print which are easy to acquit. This paper focuses on new technology of Authentication using BCI i.e. Brain Computer Interface. It focuses on the EEG (Electroencephalogram) signals of each individual for authentication. Various activities of a person lead to unique characteristic EEG waves. This feature helps to uniquely identify an individual. The objective of this paper is to review EEG based BCI technology and recapitulation of the implementation of EEG based Authentication.

Keywords: BCI, EEG, Authentication

I. INTRODUCTION

For years humans have been fascinated to develop various interaction techniques with the machine. Controlling the computer using brain waves has been an exciting concept since decades. Brain Computer Interface has made this abstraction possible by making use of EEG signals. Electroencephalograph (EEG) is the electrophysiological monitoring technique to record electrical characteristics of human brain. It is typically non-invasive. Mainly EEG signals are signals of biomedical origin, these waves contain more information about the brain response [1]. A huge number of application systems require the authentication of users using the services in order to maintain the data security. Recently, researchers are analysing biometrics system to prevent precious data or transaction from forgery. [2]. Common conventional biometric systems like 1) DNA 2) Finger print 3) Retinal or Iris scanning 4) Voice recognition etc., fails to satisfy the characteristics mainly universality, distinctiveness, permanence, collectability, acceptability, and circumvention [3]. The EEG waves captured for an individual person are found to be unique or distinct. Thus, brain signals are more reliable and secure and have been proposed as an identification and authentication biometric [4]. This paper surveys EEG based BCI domain and recapitulates EEG based user authentication.

II. LITERATURE REVIEW

These days EEG construct identification and its application for authentication have been studied and experimented. Introductory study works have shown that an individual can be authenticated based on EEG wave signals. Sebastian Marcel et al, [5] researched the use of brain waves for authentication and found few advantages like, it is confidential and it is very difficult to acquit. Palaniappan et al. [6] showed visualizing a picture evokes recognition and memory, assuming this activity leads to unique electrical neuron signals in an individual. Danilo P. Mandic et al. [7] proposed in their work that the EEG signals were captured from individuals while exhibiting them drawings of objects chosen from Snodgrass and Vander wart picture set.
This is an apparent or prominent form of biometric authentication which will find its real time application in near future.

Survey

BCI definition

A brain–computer interface (BCI), sometimes called a direct neural interface or a brain– machine interface, is a direct communication pathway between a brain and an external device. BCIs are often aimed at assisting, augmenting or repairing human cognitive or sensory-motor functions.[8]

EEG based BCI processing model

The biggest challenge in Brain Computer Interface (BCI) is the mechanics to interact with the brain. The simplest process is to use an Electroencephalograph (EEG) device which consists of set of electrodes with a conductive gel attached to the scalp of user. The electrodes of the device read the brain wave signals. As the electrodes are connected on scalp and not directly to the brain, the signals are distorted because of the presence of skull in between.

To get the brain waves of higher resolution or quality, scientists can implant electrodes on the surface of brain or even in the gray matter of the brain. This helps in direct reception of electrical signals and also facilitates to place the electrodes at exact position of brain where the appropriate signals can be captured. But this method requires intrusive surgery to implant the electrodes which may lead to scarring of gray tissue and affect the health of person. The scarred tissue further obstructs the passing of signals.

Although the above methods differ in position of electrodes, the processing mechanism is the same. The electrodes calculate the minute differences in voltage between brain neurons. The signals captured are amplified and filtered for noise interference. Now- a- days the signals captured are interpreted in digital form by computer devices but in previous days the signals were recorded in analogous manner using patterns on sheet of paper.

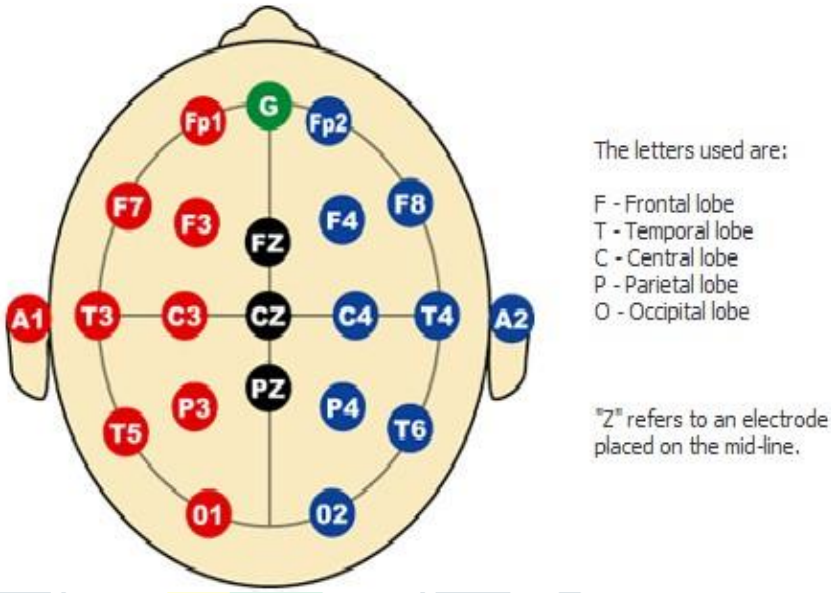

Figure. 1 Electrodes placement positions

EEG wave bands

Gamma Waves

These are the recent brain waves discovered in neuroscience. They are involved in more complex tasks along with healthy cognitive functioning. They are vital for learning, processing and memory and act as binding tool for senses to process contemporary information. Lower Gamma waves are found for people with mental disabilities. Currently, a relation between meditation and gamma activity has been found. It has frequency range between 40 and 100 Hz.

- High level: anxiety, stress
- Low level: learning issues, depression, ADHD
- Optimal level: information processing, binding of senses, cognition, learning, information processing, perception

Beta Waves

These are high frequency waves found in awake humans. They are captured during conscious states like reading, speaking, reasoning, calculating, thinking, etc. It has frequency range from 12 to 40 Hz.

- High level: high adrenaline levels, inability to be relaxed, stress o Low level: learning issues, depression, lack of attention o Optimal level: high concentration, problem solving ability, memory recall

Alpha Waves

Alpha waves are a frequency bridge between conscious mind (Beta waves) and subconscious mind (Theta waves). They help us to calm down and induce deep content and relaxation. In condition of stress a condition called “Alpha blocking” occurs which includes high Beta waves and low Alpha waves. Frequency range is from 8 to 12 Hz.

- High level: day dreaming, inability to focus o Low level: high stress level, anxiety, OCD o Optimal level: Ideal relaxation and content

Theta Waves

Theta waves are also called "suggestible waves" as these are optimal in a hypnotic state. They are found when you are asleep, daydreaming, relaxed and open mind state. It helps us to be creative, feel wholeness and more natural. Frequency range varies between 4 to 8 Hz.

- High level: hyperactivity, depression, inattentiveness o Low level: poor emotional awareness, high stress level, anxiety o Optimal level: Ideal relaxation, creativity, intuition, emotional connection

Delta Waves

Delta waves are related to "Deep" i.e. deep level of relaxation and restorative sleepiness. They are found commonly in children and are the slowest recorded waves. They are lowered as age increases. They are concerned with unconscious cardiovascular and digestive functions. Frequency ranges from 0 to 4 Hz.

- High level: severe ADHD, brain injuries, inability to think and learn o Low level: poor sleep, inability to rejuvenate body, revitalize brain o Optimal level: restorative REM sleep, healthy immune system

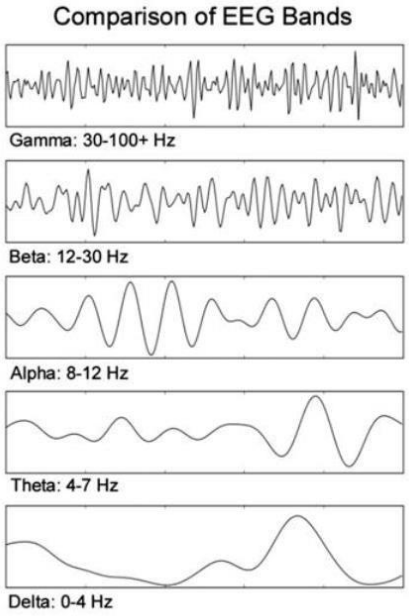

Figure. 2 EEG wave bands

The EEG brain waves for various activities performed by human beings are acquired and processed for BCI applications in following manner:

I. Signal amplification and digitizing

The signals acquired are of low amplitude or strength which need to be amplified first for further usage. The signals are amplified and the unnecessary electrical noise signals are reduced. Further they are converted into digitized forms and sent to computer for processing.

II. Feature extraction

The feature extraction phase fetches the signal features from the digitized information and quantifies it according to the user's motive characteristics. It is then transformed into compact categorized form for output processing.

III. Feature Classification

The features extracted from above phase are classified based on their frequency band. Based on frequency bands the inference is drawn regarding the user intention or condition. After recognizing the activity, the appropriate command is provided to the computer or machine.

IV. Feedback or Output

The machine processes the commands by applying the algorithm and produces the desired output. This output acts as the feedback mechanism for the user based on the EEG waves captured and the concerned BCI application.

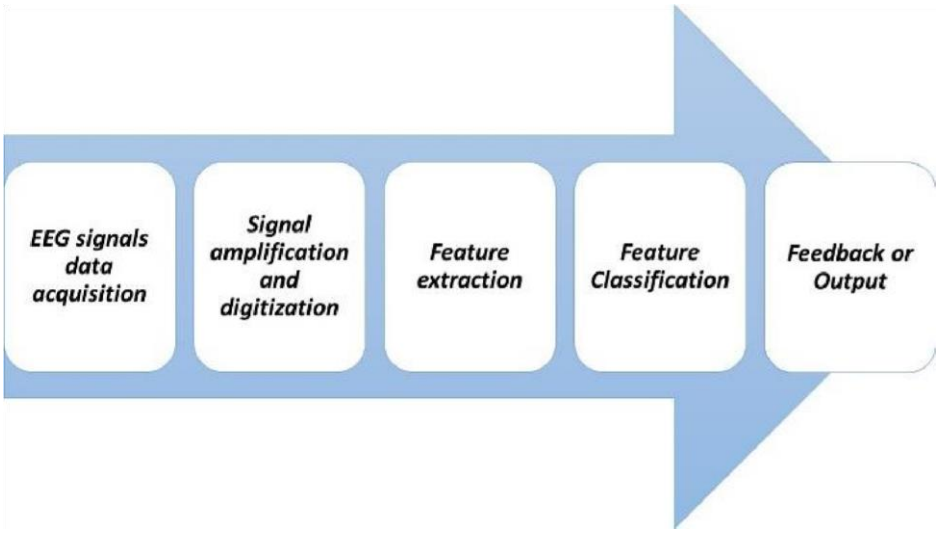

Figure. 3 Block diagram of EEG signals processing

Current authentication methods

Data security is an issue of great concern these days. Authentication is required to enable organizations to keep their networks secure by allowing only authenticated users (or processes) to access its protected resources, which may include computer systems, networks, databases, websites and other applications or services. Some of the common authentication techniques used are –

- Password authentication
- Pin authentication
- 2 factor authentications
- Biometric authentication

These authentication methods can be acquitted and compromised in one or the other way. To reduce the attacks in security breach the research has been directed to brain waves-based authentication.

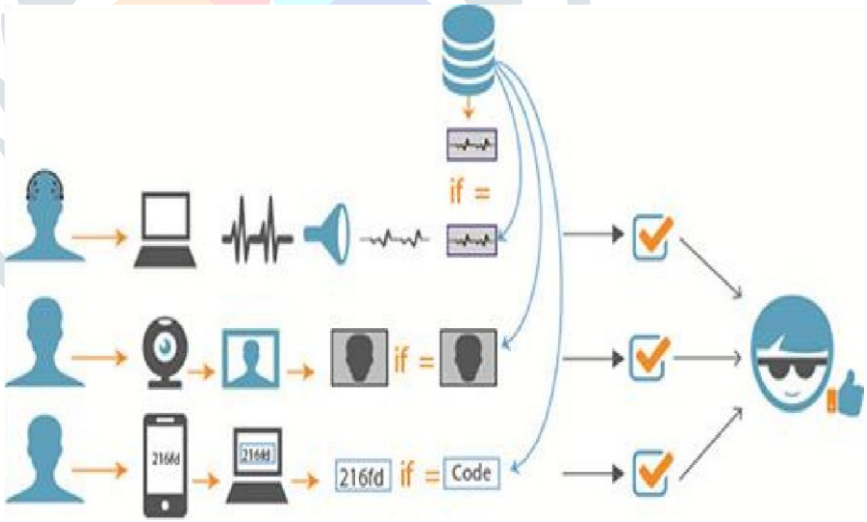

Figure. 4 [9] Current authentication methods

EEG based BCI authentication model

To implement an intelligent biometric authentication, we require a device which records electrical signals of brain which is Electroencephalogram (EEG). It is made of three terms 'Electro' which means the electrical activity, 'encephalo' which means a brain, and 'graph' which means the picture. Since everyone has a unique EEG waves pattern, this feature is a key to a new reliable authentication technique.

Signals acquired from the headset are collected, pre-processed which includes amplification, reducing noise, and digitizing. The features of brain waves bands are extracted and classified. The classified features are modelled into a compact model in case of user registration phase. This model is stored in local or remote database. Every time the user logins the data acquisition, pre-processing, feature extraction and classification takes place. The model stored in the database is compared with the user EEG features and if matched the user will be authenticated as shown in the figure. 5 below.

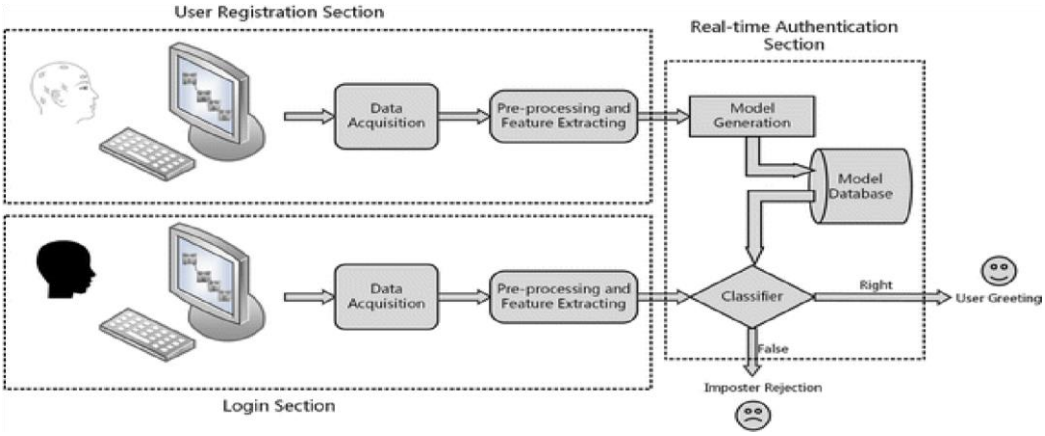

Figure. 5 [10] Flow chart of EEG based authentication system

This method of authentication can be the highest level of security known till date, as the EEG features can't be acquitted. This form of security can be used in information sensitive areas like Defence, Government administration, etc.

Shashank N, Mrs. Rashmi C R [11] showed the successful use of EEG brain signals in user identification and authentication. They showed picture data to the subjects and asked them to count the objects. The EEG signals dataset captured was filtered using Parks-McClellan FIR filter. Feature extraction was done using multi-wavelet transformation. Classification of features was based on KNN method.

Conclusion

EEG based BCI is a new emerging foremost technology these days which will be soon implemented in various application domains in every day life. The feature extraction and classification are an important phase in BCI using EEG. These processes lead to unique data models which are universal. The unique EEG data modelling lead to implementation of authentication using EEG based BCI which is in great need to replace the conventional authentication techniques which are weak in nature.

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