A Survey of Biometrics Person Identification System Using EEG Brain Signal

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Abstract
Electroencephalographic (EEG) are widely used in medical and research area. In this paper discuss about EEG measurement with building basic knowledge for performing EEG recording, and it have detailed studies in analysis, feature extraction and classification of EEG signals are still lot of investigation and issues for researchers due to the diversity of the human brain signals. Biometrics refers to the automatic identification or identity authentication of living people using their enduring physical or behavioral characteristics. A biometric system provides two functions namely verification (or authentication) and identification. In verification systems a sample is directly matched against a pre-stored template, while in the identification system a closest match from all the templates is identified. Although both methods are the same, however they target distinct applications. In the verification applications the people have to cooperate with the system as they want to be accepted, while in the identification applications they are not connected with the system and generally do not prefer to be identified.

Keywords: Delta Waves; Theta Waves; Alpha Waves; Beta Waves; Gamma Waves; Mu Waves, 10-20 Electrode placement System.

1. EEG Signal and Its Characteristics

EEG measures brainwaves of different frequencies within the brain. Electrodes are placed on specific location on the scalp to detect and record the electrical impulses within the brain. The recordings are the summation of volume conductor fields produced by millions of interconnecting neurons. The EEG varies depending the location of the recording electrodes [1]. The EEG signal can be classified into six significant frequency waves as follows:

1.1. Delta Waves
Delta is the frequency range up to 4 Hz. It tends to be the highest in amplitude and the slowest waves. It is seen normally in adults in slow wave sleep. It may occur focally with subcortical lesions and in general distribution with diffuse lesions, metabolic encephalopathy hydrocephalus or deep midline lesions.

1.2. Theta waves
Theta is the frequency range from 4 Hz to 7 Hz. Theta is seen normally in young children. It may be seen in drowsiness or arousal in older children and adults; it can also be seen in meditation. Excess theta for age represents abnormal activity.

1.3. Alpha waves
Alpha is the frequency range from 8 Hz to 12 Hz. Hans Berger named the first rhythmic EEG activity he saw as the "alpha wave". This was the "posterior basic rhythm" (also called the "posterior dominant rhythm" or the "posterior alpha rhythm"), seen in the posterior regions of the head on both sides, higher in amplitude on the dominant side.

1.4. Beta waves
Beta is the frequency range from 12 Hz to about 30 Hz. It is seen usually on both sides in symmetrical distribution and is most evident frontally. Beta activity is closely linked to motor behavior and is generally attenuated during active movements. It may be absent or reduced in areas of cortical damage.

1.5. Gamma waves
Gamma is the frequency range approximately 30–100 Hz. Gamma rhythms are thought to represent binding of different populations of neurons together into a network for the purpose of carrying out a certain cognitive or motor function.[1]

1.6. Mu waves
Mu ranges from 8–13 Hz and partly overlaps with other frequencies. It reflects the synchronous firing of motor neurons in rest state. Mu suppression is thought to reflect motor mirror neuron systems, because when an action is observed,
the pattern extinguishes, possibly because of the normal neuronal system and the mirror neuron system "go out of sync", and interfere with each other [2].

2. EEG Recording Techniques

EEG measurements use recording system consisting of
a) electrodes with conductive media
b) amplifiers with filters
c) A/D converter
d) Recording device.

Electrodes read the signal from the head surface, amplifiers bring the microvolt signals into the range where they can be digitalized accurately, converter changes signals from analog to digital form, and personal computer (or other relevant device) stores and displays obtained data. Scalp recordings of neuronal activity in the brain, identified as the EEG, allow measurement of potential changes over time in basic electric circuit conducting between signal (active) electrode and reference electrode. Extra third electrode, called ground electrode, is needed for getting differential voltage by subtracting the same voltages showing at active and reference points. Minimal configuration for mono-channel EEG measurement consists of one active electrode, one (or two specially linked together) reference and one ground electrode. The multi-channel configurations can comprise up to 128 or 256 active electrodes.

2.1. Recording Electrodes

The EEG recording electrodes and their proper function are critical for acquiring appropriately high quality data for interpretation. Many types of electrodes exist, often with different characteristics. Basically there are following types of electrodes:

a. Disposable (gel-less, and pre-gelled types)
b. Reusable disc electrodes(gold, silver, stainless steel or thin)
c. Headbands and electrode cups
d. Saline-based electrodes
e. Needle electrodes

Electrode placements are labelled according adjacent brain areas: F (frontal), C (central), T (temporal), P (posterior), and O (occipital). The letters are accompanied by odd numbers at the left side of the head and with even numbers on the right side Fig.1. Left and right side is considered by convention from point of view of a subject.

As it is known from tomography different brain areas may be related to different functions of the brain. Each scalp electrode is located near certain brain centres, e.g. F7 is located near centres for rational activities, Fz near intentional and motivational centres, F8 close to sources of emotional impulses. Cortex around C3, C4, and Cz locations deals with sensory and motor functions. Locations near P3, P4, and Pz contribute to activity of perception and differentiation. Near T3 and T4 emotional processors are located, while at T5, T6 certain memory functions stand. Primary visual areas can be found bellow points O1 and O2. However, the scalp electrodes may not reflect the particular areas of cortex, as the exact location of the active sources is still open problem due to limitations caused by the non-homogeneous properties of the skull, different orientation of the cortex sources, coherences between the sources, etc[3]. High impedance can lead to distortions which can be difficult to separate from actual signal. It may allow inducing outside electric frequencies on the wires used or on the body. Impedance monitors are built in some commercially available EEG devices. In order to prevent signal distortions impedances at each electrode contact with the scalp should all be bellow 5 K Ohms, and balanced within 1 K Ohm of each other. Similar standard is required for clinical use of the EEG and for publication in most reputable journals. Practically, impedance of the whole circuit comprising two electrodes is measured, but built in impedance checks usually display results already divided by two. Control of all impedances is desirable also after finishing every single measurement.

Several different recording reference electrode placements are mentioned in the literature. Physical references can be chosen as vertex (Cz), linked-ears, linked-mastoids, ipsilateral-ear, contralateral-ear, C7 reference, bipolar references, and tip of the nose. Reference-free techniques are represented by common average reference, weighted average reference, and source derivation. Each technique has its own set of advantages and disadvantages. The choice of reference may produce topographic distortion if relatively electrically neutral area is not employed. Linking reference electrodes from two earlobes or mastoids reduces the likelihood of artificially inflating activity in one hemisphere. Nevertheless, the use of this method may drift away "effective" reference from the midline plane if the electrical resistance at each electrode differs [4]. Cz reference is advantageous when it is located in the middle among active electrodes, however for close points it makes poor resolution. Reference-free techniques do not suffer from problems associated with an actual physical reference. Referencing to linked ears and vertex (Cz) are predominant. With modern instrumentation, the choice of a ground electrode plays no significant role in the measurement [5]. Forehead (Fpz) or ear location is preferred but sometimes wrist or leg is also used. The combination of all active electrodes with reference and ground electrode compose channels. The general configuration is called montage.

2.2 International 10-20 Electrode Placement System

In order to make patient’s records comparable over time and to other patient’s records, a specific system of electrode
placement called International 10-20 system is used. The system is for 21 electrodes. The distance between the specific anatomic landmarks (nasion and inion, see Fig.1) is measured after which the electrodes are placed on the scalp using 10 and 20 % interelectrode distances. Each electrode position has a letter (to identify the underlying brain lobe) and a number or another letter to identify the hemisphere location. Odd numbers are on the left side and even on the right side. Z (for zero) refers to electrode placements at midline. The system allows the use of additional electrodes. As can be seen in Fig.1 midline (or zero) electrodes are flanked up by electrodes numbered 3 on the left and 4 on the right. The "10" and "20" refer to the fact that the actual distances between adjacent electrodes are either 10% or 20% of the total front-back or right-left distance of the skull[6] which is shown in Fig.1.

3. Background OF EEG Brain Signature

Several research efforts on EEG based biometrics have been reported in literature survey [6]-[10]. While justifying the use of EEG as a biometric modality using EEG signals acquired for brain interfaces from six to eight electrodes. However such signals might not be suitable for real biometric verification. Mental tasks for biometric verification have been proposed in our earlier works with minimal electrodes on a limited dataset [7]-[8]. A study by paranjape et al. (2001) suggests that EEG has biometric potential as they were able to discriminate between 40 subjects with 8 channels using autoregressive models with a correct classification rate of 82% [9]. Poulous et al. (1999) collected 1 channel of EEG from 75 subjects in one session and obtained a classification rate of 91% thus corroborating the evidence that the EEG signals carries genetically specific information and suitable for person identification[10]. Ravi and palaniappan (2005) used a total of 61 channels to record VEP EEG signals from 20 subjects. They were able to authenticate subjects with the best classification performance of 95%. Palaniappan and Mandic (2007) also using VEP were able to achieve an accuracy of 98% for 40 individuals using 61 channels [11]-[12]. Shiliang Sun (2008) used the signals from 15 electrodes of 9 subject imagining movements in a visual cue with a success rate of 94% [13].

More research on biometric identification systems are summarized here. Pouls et al. (1999a) and poulos et al. (1999b) record EEG signals from 1 channel of 4 subject resting with eyes closed[12]-[14]. They applied parametric processing and computational geometry and achieved 84% and 91% respectively. Some researchers have also used EEG as an authentication tool. Riera et al. (2008) collected data from 51 subject and 36 intruders. The EEG were recorded from 2 channels while subjects were sitting with eyes closed for 1 minute. They obtained a true acceptance rate of 96.6% and false acceptance rate of 3.4% [15]. Hema et al. (2008) recorded EEG signals authentication rate of 97% [16]. Jiang Feng Hu (2009) were able to achieve accuracy ranging from 75% to 80% for subject authentication and 75% to 78.3% for identification using 6 channels [17]. Hema C.R. et al. (2010) EEG signals of 50 subjects is acquired non invasively using three. Best performance is achieved for the spell task with a mean accuracy of 95% using burg algorithm for RNN model [18]. Hema C.R. (2008) Electroencephalography signals recorded during four biometric tasks, such as relax, read, spell and math activity were acquired from twenty five healthy subjects. The proposed algorithm for recognition of individuals uses power spectral density and neural networks. The performance of the existing algorithm was found to be 95% for spell task using single channel data. The performances of the proposed algorithm are appreciable with an accuracy of 98% for the spell task and 95% for the read task. Comparisons are also made using single channel and two channel data. Experimental results show that two channel acquisition process yields better recognition rates [19]. Elakkiya et al. (2018) EEG signals are generated while the subjects perform three different tasks, namely relax, read and spell are acquired from twenty four subjects. We propose an algorithm for recognition of individuals using signal power and backpropagation neural networks. Second methods spell task is more suitable for biometric authentication or verification. The Elman neural network with an average accuracy of 85%-93%. Twenty four subjects were used in this study. The usage of brain signatures as a possible for biometric verification technique [20]. Elakkiya (2018) Electroencephalography signals recorded during four biometric tasks, such as relax, read, spell and math activity were acquired from twenty five healthy subjects. We propose an algorithm for recognition of individuals using power spectral density using Recurrent Neural Network and Feed forward Neural Network. The performance of the Recurrent Neural Network is appreciable with an accuracy of 98% for the spell task and 95% for the read task [21]-[33].

4. Conclusion

EEG based biometric authentication system using brain signature, which is a part of a biometric security system. A biometric system is used in two different modes they are authentication and identification. Identity authentication occurs when the user claimed to be already enrolled in the system; in this case the biometric data obtained from the user are compared to the user data already stored in the database. Identification occurs when the user biometric data is matched against all the records in the database as the user can be anywhere in the database or he/she actually does not have to be there at all. The biometric recognition or biometrics refers to the automatic authentication of a person based on his/her physiological (e.g., fingerprint, iris) or behavioral (e.g., signature) characteristics or traits. Biometric techniques can potentially prevent unauthorized access to ATMs, cellular phones, laptops, and computer networks. The biometric security systems have been proved to be accurate and very effective in various applications. The biometric features can be easily acquired and measured for the processing only in the presence of a person. Hence these systems are proved highly confidential.

References

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