Recurrent Neural Network based Recognition of EEG Biographs

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Abstract--- This paper proposes an algorithm to recognize EEG biographs of individuals as a biometric verification technique. Research on brain signals has shown that each individual has a unique brain wave pattern for similar tasks. Electroencephalography signals acquired through three biometric tasks namely, relax; read and spell from twenty four subjects are used in this study. We propose an algorithm for recognition of individuals using power spectral density features and recurrent neural networks. Average recognition performance of 97.2% to 98.85% is achievable. In the proposed method spell task is found to be the most appropriate task of the three biometrics verification tasks proposed.

Keywords--- Biometric, Authentication, Signal Processing, EEG Electrodes, Power Spectral Density, Recurrent Neural Network

I. INTRODUCTION

Biometrics refers to the automatic identification or identity authentication of living people using their long-term 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.

Biometric characteristics can be divided into two main classes. Physiological and behavioral characteristics. Physiological is related to the human body characteristics, such as DNA, fingerprints eye retinas and irises, voice patterns facial patterns and hand measurements for authentication purposes. Behavioral is related and analyzing to the behavioral of a person (e.g. signature, Gait)[1]. Electroencephalography (EEG) as a biometric is relatively new compared to the other biometrics. This modality has several advantages as it is confidential, it is difficult to mimic and it is almost impossible to steal. In our previous works [2, 3, 4] experiments were conducted on a smaller dataset collected from six individuals for a three task protocol. An average recognition rate of 78.6 % was achievable from the single trial analysis. Very little research has been reported on EEG based biometrics in the literature [5-8]. In these studies the signals are acquired using visual stimuli. In this paper we propose a new algorithm for signal acquisition and an EEG biograph dataset from 24 subjects are used in the experimentation to validate the algorithms proposed.

II. METHODS

2.1 EEG Biographs

EEG is a technique that reads scalp electrical activity generated by brain structures. When brain cells or neurons are activated, the local current flows are produced. The highest influence of EEG comes from electric activity of cerebral cortex due to its surface position [9]. In this paper we propose an algorithm for biometric verification using power spectral density features of the EEG biographs and recurrent neural networks. EEG biographs are extracted for three mental tasks such as relax, reading and spell from twenty four subjects, powers spectral features of the alpha and beta waves are extracted from the raw EEG signals to train and test a neural network.

2.2 Data Collection

EEG signals are acquired from three non invasive electrodes. The electrodes are gold plated cup shape placed on the scalp. The subjects were seated conveniently in a noise free room. The subjects should perform the task mentally without any movements. The subjects are requested to perform three mental tasks and data from all the three electrodes Fp1, F4 and O2 as shown in Figure 1, were reordered for 10s during a given task and each task was repeated five times per...
session. EEG biographs for three tasks were collected from 24 subjects. Each subject attended two sessions of data collection. The sampling frequency was set at 200 Hz. The three biometric tasks are described below:

1. **Task 1 - Relax**: No mental task is performed, subjects are told to relax and try to think of nothing in particular. This task is used as a baseline measure of the EEG.
2. **Task 2 - Reading**: The subject is shown a typed card with tongue twister sentences and they were requested to read the sentence mentally without vocalizing.
3. **Task 3 - Spelling**: The subject is shown a typed card with his name and is requested to spell his name mentally without vocalization and overt movements.

![Figure 1: Electrode Placement Locations for Data Acquisition](image)

The subjects were university and volunteers aged between 15 and 26 years. During signal acquisition it was ensured that the subjects did not smoke few hours prior to data collections and all subjects were healthy and free from any medicinal drug consumption.

2.3 **Feature Extraction**

The raw EEG biographs are bandpass filtered using twelve frequency bands from the alpha and beta rhythms of 7 Hz to 42 Hz. This removes the noise due to power lines. Power spectral density features using the covariance method are used to extract the features from the band pass filtered signals. 129 features were extracted for each trial per subject per task. Each task is repeated ten times. 480 data samples for 24 subjects were obtained to train and test the neural network.

2.4 **Recurrent Neural Network Classifier**

An Elman Recurrent Neural Network (ERNN) with one single hidden layer is trained to identify the twenty four individuals based on their biographs. The input layer has 129 nodes and the output has 5 nodes representing twenty four subjects. The hidden layer nodes are experimentally chosen to be 9. 480 data samples are used in this experiment. Six neural network models are studied for the three tasks namely read, relax, and spell and with two training sets. The network is trained using the network is trained using the gradient decent learning backpropagation algorithm. Training is performed till the average error falls below 0.0001 or maximum iteration limit 1000 is reached. 70% and 80% of the dataset is used to train the network and the network is tested with 100% of the dataset.

### III. RESULTS AND DISCUSSION

The performances of the six ERNN models are recorded for twenty trails each and the average performance values are shown. Tables 1 for the three biometric tasks namely read, spell and relax. Average values for maximum, minimum, mean and standard deviation of the performance results are shown in Table 1 for the ERNN and the same is compared with the performance of a Feed forward neural network. The performance of the ERNN is appreciable with a mean identification performance of 98.85% for the spell task in comparison with the feedforward network at 92.4%. Maximum identification performances of 99% with an error tolerance of 0.05 were observed for spell and relax tasks. Standard deviation of the identification accuracy is observed to be better for the spell task at 0.48. The spell task shows better performance compared to the other two tasks. One of the causative factors could be the use of spelling the names of individuals in the experiments. 24 subject used in this study.
Recognition of EEG biographs using ERNN is proposed in this study. Biographs of twenty four individuals is acquired non invasively using three electrodes. Network models are developed using power spectral density features and one hidden neuron configuration. Experimental results validate the proposed biometric tasks and algorithms. Best performance is achieved for the spell task with a mean accuracy of 98.85% compared to the backprobagation for the spell task with a mean accuracy of 92.4%. The spell protocol proposed in this study for signal acquisition has better
recognition performance in comparison with our previous method. Future works will involve the single trail analysis of the signals and experiments with dynamic network models.

REFERENCES