Multi-tasks Biometric System for Personal Identification

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Abstract—Recently, biometrics systems based on electroencephalogram (EEG) have received growing interest in identifying persons due to the EEG interesting characteristics. Several studies indicated that EEG is a robust biometric that can greatly improve identification rates. Biometric methods depending on multiple tasks are favorable than those based on a single task. Multi-tasks approaches can enhance personal recognition rates and also reduce the possibility of falsifying biometric data. Furthermore, biometric systems relying on cognitive tasks are harder to be reproduced. Therefore, this paper proposes a new EEG- biometric system based on multiple cognitive tasks. The method examines the electrodes placements on different sites on the scalp and selects a group of sites that influence the accuracy of the system. The results show that the proposed biometric system is capable of accurately recognizing persons. Also, the electrodes placed on frontal, temporal, and parietal sites are adequate to correctly identify persons with an identification accuracy of 100%. It has a challenging performance compared to the state of the art techniques. Thus, the proposed technique is robust and can be adopted in areas which require high security and confidentiality.

Keywords— Biometric systems, Personal identification, Security, Electroencephalogram (EEG), Machine learning

I. INTRODUCTION

Biometric is an attractive method to verify or recognize a person utilizing physiological and/or behavioral personal characteristics. Personal identification is a vital security process in many areas such as; national security, public security, e-commerce [1]. Conventional biometric approaches depend on voiceprint, face, iris, DNA, fingerprint, ID cards, keys and passwords to identify persons. Though, these methods can be forged, stolen, or copied. Moreover, apparent behaviors of individuals can be easily detected and simulated. To overcome the above insufficiencies, new biometric approaches based on neural activities such as brain signatures are currently being explored. Brain signature is a distinctive characteristic of the brain activity. It is considered as a biological feature and can be employed for personal identification [2, 3].

Electroencephalography (EEG) is a graphical method for capturing brain electrical activity from the scalp. EEG has high temporal resolution, durability and low cost compared to other techniques that measure brain such as, magneto-encephalography (MEG) and functional magnetic resonance imaging (MRI). Therefore, EEG may be considered as the most appropriate method to acquire brain activity. EEG signals can be used in medical applications such as diagnosis and rehabilitation. They can also be used for non-medical applications, such as games and entertainment, and learning and education [4]. Lately, EEG signals have attracted a lot of researchers to use them as a physiological feature for new biometric systems.

Several studies have proven that they can be successfully used as a biometric [5-7]. It has been reported in [8] that EEG waves have some exciting characteristics which make them useful in biometric systems. First, they are unique which means they have a specific neural path for each person and cannot be fabricated. Also, they cannot be captured from a dead person. Moreover, they are hard to be compelled, because, coercion of violence or blackmail lead to substantial stress on the user, and consequently stress will strongly affect the user brain activities [1]. For these reasons, biometric systems based on EEG are considered as robust techniques for personal identification in fields which need high confidentiality and high-safety requirements.

In this paper, a new biometric system for personal identification is proposed. The system is based on EEG signals acquired during multi-tasks. The novel method investigates the use of the EEG signals captured during each task, separately. Furthermore, it examines the consequence of using multi-tasks on the performance of the presented biometric system. Moreover, our method explores the effect of placing electrodes on different sites on the scalp. Finally, it selects the appropriate sites which influence the recognition rates of the biometric system.

This paper is organized as follows: section II introduces the related work; section III illustrates the EEG dataset and explains the proposed biometric system. Section V discusses the results, and VI concludes the paper.

II. RELATED WORK

Conventional EEG-based biometric systems proposed in the literature adopted only one kind of brain activity for person recognition. In other words, the construction of the biometric system was based on acquiring EEG signals during a single task [9]. This task may be a resting state where eyes are closed or opened, motor and motor imagery tasks (e.g., feet or hands movement), tasks with sensory inputs (e.g., visual or auditory stimuli), and cognitive tasks (e.g., reading/spelling and object Recognition) [2]. Safont et al. [10] proposed a biometric method using EEG signals acquired during resting state for 50 subjects. The authors verified their system using six classifiers, achieving an accuracy of 93.8%. Kumar and Vaish [11] introduced a method based on EEG signals captured from
six people. Different combinations of channels were tested to select the best group of channels that can provide the highest accuracies. Armstrong et al. [12] constructed a biometric technique based on EEG signals collected throughout a cognitive task. The authors used a feature extraction called N400 representing negative waves that have a peak around 400ms after the stimulus onset. Maiorana et al. [13] built a EEG-biometric system with data gathered through resting state. Then, the EEG signals are transformed into a new space using mean principal component analysis and multidimensional linear principal component analysis. Linear Discriminant Analysis (LDA) classifier was used for identifying a person. The authors of [4] proposed a novel biometric technique that collected EEG data during motor and imagery tasks. They constructed their system using each task individually. They employed wavelet packet decomposition and ANN as a feature extractor and classifier respectively. The best accuracy reached was 95% using the imagery task.

The previously discussed biometric systems rely on EEG signals collected during a single task for person recognition; though, biometric methods depending on multiple tasks have the ability to enhance the accuracy of person recognition and also raise the strain of copying biometric data. A number of multi-task methods have been proposed to improve system reliability. The CEREBRE system was introduced in [14, 15] to identify persons relying on several sensory inputs tasks. The system achieved an accuracy of 100%. In [16], the authors created a novel EEG-biometric system with data collected during rest and sensory tasks. They used Common Spatial Patterns (CSP) and (LDA) as a feature extractor and classifier, respectively. The best accuracy rate obtained was 96.97%. The authors of [3] collected EEG data from persons during resting state, sensory, motor and motor imagery tasks. They employed ensemble subspace as a classifier. The accuracy achieved was 99.98%. Kumar and Vaish [17] proposed a biometric system based on EEG dataset captured through five mental tasks. Yang et al. [18] proposed an EEG-biometric system depending on signals captured throughout motor and motor imagery tasks. The authors employed wavelet transform as feature extraction and LDA as a classifier and reached an identification rate of 99%.

III. PROPOSED METHOD

Biometric systems based on EEG data collected during resting state in which no task is given to them have a potential difficulty. These systems may suffer from the uncertainty of the thoughts or emotions that persons experience during rest, which may affect the individual in different ways, resulting in immeasurable and corrupted data. Furthermore, biometric systems that implicate sensory tasks have a greater possibility to be reproduced than those with cognitive tasks [2, 18]. As stated before, biometric methods based in multi-tasks are preferable than those that rely on a single task. Multi-tasks can improve personal recognition rates and increase the burden of replicating biometric data. For these reasons, a novel EEG-biometric system based on multiple cognitive tasks is proposed. The proposed system uses each task individually to recognize persons. Then, it combines the multi-tasks to examine if they can really enhance the recognition rates. Moreover, our method explores different electrodes placed on the scalp to observe which sites influence the recognition rates. These electrodes placements are sorted in descending order according to the identification accuracy of each site individually. Finally, a forward sequential site selection process is made to select the combinations of sites that improve identification accuracy.

The proposed biometric system consists of four steps. The first step is the preprocessing and windowing. Afterwards, is the feature extraction phase, each task is used individually to identify persons. Then, multi-tasks are fused. The next phase is the electrodes sites selection and finally is the identification phase. The steps of the proposed biometric system are shown in figure 1.

**Figure 1. Block diagram of the proposed system**

**A. Dataset Description**

The proposed EEG-biometric system uses an EEG dataset collected for 36 persons during two cognitive tasks [19]. Nineteen electrodes were placed on different sites on the scalp. These placements include frontal (Fp1, Fp2), frontal (F3, F4, Fz, F7, F8), central (C3, C4, Cz) parietal (P3, P4, Pz), occipital (O1, O2), and temporal (T3, T4, T5, T6) conferring to the International 10/20 system. Ear electrodes were used as a reference. Electrode placements on the scalp are shown in figure 2.

**B. Data Preprocessing and Windowing**

EEG signals are preprocessed to remove noise and artifacts using three stages, they are first filtered with a band-pass filter (0.5-500Hz). Afterwards, the de-noising...
method used in [20] is employed. Finally, they are smoothed using the method proposed by [21]. Preprocessed data is then segmented using a sliding window of size 4 ms of an increment step of 1 ms.

C. Feature Extraction

In this phase, useful features capable of distinguishing between persons are extracted. For each task, four features based on power spectral density (PSD) are calculated. These features are the mean spectral power estimation in delta (δ), theta (θ), alpha (α), and beta (β) EEG frequency sub-bands. The δ sub-band includes frequencies (0.5–4 Hz), θ sub-band (4–8 Hz), α sub-band (8–13 Hz), and β sub-band (13–30 Hz). Afterwards, multitasks are fused to test if they are capable of improving the performance of the proposed biometric system.

D. Electrodes Site Selection

In this step, different electrode placements on the scalp are examined to figure out those sites that influence the biometric system’s performance. Initially, each site is used separately for personal identification. Then, these sites are ranked according to the identification accuracy in descending order. Afterwards, this ranking is adopted in a sequential forward site selection procedure to select the group of sites which achieves the highest identification rate.

E. Identification

In order to construct a biometric system, three machine learning classifiers are employed. They include linear discriminate analysis (LDA), K-nearest neighbor (KNN), and support vector machine (SVM) classifiers. Distance metric used for the KNN is Euclidian and the number of neighbors (K) is equal to 1. A linear kernel function is used for SVM. These classifiers models are first used to identify persons using each task individually. Afterwards, they are built to recognize persons based on multi-tasks. Next, they are used to select the combination of electrode placements that have the highest recognition rates. All classification models are constructed using 5 fold cross-validation. To measure the performance of the biometric system, the identification accuracy metric is calculated.

IV. RESULTS AND DISCUSSIONS

This paper aims to construct an EEG-biometric system for personal identification. Systems based on multi-tasks usually perform better than those relying on a single task. Therefore, our system depends on EEG data during multiple cognitive tasks. It also studies different electrodes placement of human scalp, to examine which sites have more influence on the performance of the biometric system. Finally, it selects the best combinations of sites which enhance the identification accuracy of the system. The results are compared with recent biometric systems based on single and multi-tasks to verify the competence of the proposed method.

A. Single Task Results

Initially, the performance of the proposed biometric system is evaluated for each task individually using each the frequencies of each sub-band and the 4 sub-bands (δ, θ, α, β). Table I shows a comparison between the identification accuracies of each task individually using the frequencies of each sub-bands separately and the 4 of them. Using the features of the 4 frequency sub-bands accomplishes better accuracies than using those of a single sub-band for both tasks as shown in Table I. Besides, it is clear from the table that task 1 has accuracies of 99.2%, 99.4, and 99.9% using LDA, SVM, KNN classifiers respectively which are higher than that of task 2.

<table>
<thead>
<tr>
<th>TABLE I IDENTIFICATION ACCURACY (%) FOR EACH TASK SEPARATELY USING FREQUENCIES OF EACH SUB-BAND AND ALL SUB-BANDS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Identification During Cognitive task 1</strong></td>
</tr>
<tr>
<td>Classifier</td>
</tr>
<tr>
<td>LDA</td>
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<td>SVM</td>
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<td>KNN</td>
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<tr>
<td><strong>Identification During Cognitive task 2</strong></td>
</tr>
<tr>
<td>Classifier</td>
</tr>
<tr>
<td>LDA</td>
</tr>
<tr>
<td>SVM</td>
</tr>
<tr>
<td>KNN</td>
</tr>
</tbody>
</table>

B. Multi-Tasks Results

The performance of the proposed EEG-biometric system is validated using both multi-tasks data and a single task. Figure 3 shows a comparison between the identification accuracy of the multi-tasks and each individual task. Figure 3 indicates that the biometric system based on multi-task performs better than that constructed using a single task. The identification accuracy using the multi-tasks (99.9% and 100%) is higher than that of the single task for LDA and KNN classifiers except for SVM (99.3%) which is higher than task 2 (98.3%), but slightly lower than that of task 1 (99.4%). The highest accuracy achieved is 100% using KNN classifier based on multi-tasks.
C. Electrodes Sites Selection Results

Electrodes placements on the human scalp may affect the performance of the biometric system. Therefore, in this study, we investigate the effect of each site individually on the identification accuracy. Table II shows the identification accuracy for each site using multi-tasks. It is clear from the table that the frontal site has the highest influence on the performance of the biometric system followed by temporal and parietal sites.

<table>
<thead>
<tr>
<th>Electrodes Sites</th>
<th>Identification Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frontal</td>
<td>99.4</td>
</tr>
<tr>
<td>Temporal</td>
<td>97.3</td>
</tr>
<tr>
<td>Parietal</td>
<td>96.1</td>
</tr>
<tr>
<td>Central</td>
<td>94.2</td>
</tr>
<tr>
<td>Occipital</td>
<td>93.3</td>
</tr>
</tbody>
</table>

Table II: Identification accuracies for each site on the scalp using multi-tasks.

The sequential forward site selection procedure made to select the combination of sites that improve the performance of the system ends with selecting the frontal, temporal and parietal sites. They are chosen as they have accomplished the highest accuracy of (99.4%, 97.3%, and 96.1%) using KNN, LDA, and SVM classifiers respectively. These accuracies are the same compared to the electrode placed on the whole scalp as shown in figure 4. This indicates that the 14 electrodes placed on the frontal, temporal, and parietal sites are sufficient to reach 100% accuracy using KNN instead of the 19 electrodes placed on the whole scalp. Figure 4 shows the identification accuracies of Frontal, Frontal + Temporal, and Frontal + Temporal + Parietal sites on scalp based on multi-task features using KNN, SVM, and LDA classifiers compared to the whole scalp sites.

D. Comparison With Related Recent Techniques

The results of the proposed EEG-biometric system are compared with the recent related studies. The results verify that the proposed EEG-biometric system has a competing performance compared to recent EEG-biometric systems for personal identification based on single and multi-tasks. TABLE III shows a comparison between the results of our proposed biometric system and the results of recent related studies based on single and multi-tasks.

<table>
<thead>
<tr>
<th>Paper</th>
<th>Experiment</th>
<th># Persons</th>
<th>Identification Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>戴着等 et al. [10]</td>
<td>Resting</td>
<td>50</td>
<td>93.8%</td>
</tr>
<tr>
<td>Kumar and Vaish [11]</td>
<td>Sensory task</td>
<td>6</td>
<td>91.7%</td>
</tr>
<tr>
<td>Armstrong et al. [12]</td>
<td>Cognitive task</td>
<td>45</td>
<td>97%</td>
</tr>
<tr>
<td>Maiorana et al. [13]</td>
<td>Resting</td>
<td>30</td>
<td>87.94%</td>
</tr>
<tr>
<td>Alyasseri et al. [4]</td>
<td>Motor or imagery tasks</td>
<td>18</td>
<td>95%</td>
</tr>
</tbody>
</table>

Table III: Comparison between our results and the results of recent related studies.

V. CONCLUSION

This study presented a novel biometric system for personal identification based on EEG data collected...
during multi-tasks. This system has shown that multiple cognitive tasks can increase the performance of identification compared to other types of tasks and those biometric systems based on a single task. The results indicated that the proposed system is capable of correctly identifying persons. It also showed that electrodes placed on the frontal, temporal and parietal scalp sites are enough to accurately recognize persons with an accuracy of 100%. Moreover, the performance of the proposed method indicated that it can compete with the state of the art techniques. Accordingly, the proposed biometric system is robust and can be applied for personal identification in areas which require great confidentiality and excess-safety requirements such as national security, public security, e-commerce, and military.

REFERENCES


