A New Solution to the Brain State Permanency for Brain-Based Authentication Methods

Fares Yousefi
Department of Computer Science, Faculty of Engineering and Technology Liverpool John Moores University Liverpool, United Kingdom
f.yousefi@2017.ljmu.ac.uk

Hoshang Kolivand
Department of Computer Science, Faculty of Engineering and Technology Liverpool John Moores University
Liverpool, United Kingdom
h.kolivand@ljmu.ac.uk

***Abstract*— Nowadays, to access any digital device we use authentication techniques, which is a critical technology in terms of security. Present biometric authentications such as fingerprints or face recognition are the most used methods in our digitalized world, which are impressively advantageous in terms of security. However, there are still some flaws in using these methods like not being useful for physical disabilities, environment usage matters, and most importantly the possibility of replicating them with some new technologies because of their visibility. Brain signal is another human biometric that could cover the issues of other types in terms of security and visibility. There are different perspectives about the EEG authentication challenges, including ease of use, privacy, and confirmation necessities like comprehensiveness, uniqueness, collectability, and most importantly permanency which is a big challenge for EEG-based authentications specifically. In this paper, we proposed a method using the deep breath strategy to use brain signals for authentication purposes regardless of brain situation. The result shows that our proposal accomplishment can alter the entire cycle of brain-based authentication when compared with other techniques and EEGbased authentication methods according to the parameter of permanency of the technique in many different brain states.**

Keywords*— *BCI, brain-computer interface, EEG signal, biometric authentication, brain state permanency

I. INTRODUCTION

Currently, many studies and researches have been done about biometrics, such as face recognition, voice, fingerprints and iris, which broadly concentrated on the advantages of these methods. However, there are a few shortcomings and flaws in this biometrics [1].

Fingerprints and face patterns can be replicated by some specific methods and technologies [2][3][4]. On the other hand, they cannot be cancelled and the pattern is not replaceable. For instance, the human body is not able to grow a new eye or finger again. We need a biometric method safer than any of these, which could be cancellable with a higher level of security. In this case, human brainwave might meet these criteria.

Brain signals have some important advantages in comparison with other biometrics. For instance, to acquire the EEG signal, the person must be alive [5]. Some biometrics can be maintained from a human's dead body after death, which would yet legitimate for an acknowledgment after a while in the afterlife [6]. Therefore, the user has to be alive to produce EEG data. On the other hand, EEG voltage decreases drastically with distance from the brain.

Table I shows a comparison of the most commonly used biometrics and brainwave in terms of the main factors of the authentication process [7].

TABLE I. COMPARISON OF THE MOST COMMONLY USED BIOMETRICS AND BRAINWAVE BIOMETRIC

Biometric Methods	Universality	Uniqueness	Permanence	Collectability
Brainwave	High	High	High	Medium
Fingerprint	Medium	High	High	Medium
Face	High	Low	Medium	High
Iris	High	High	High	Medium

There are billions of cells in the human brain, which are called neurons. Millions of neurons exist in a cerebrum, which is assuming a significant role in controlling the human body behaviors internally and externally. The main activities of these neurons are carrying information between the human brain and body. Electrical signals are the communication way between each neuron, and this is the basis of all human thoughts, behaviors and emotions. This neuron's communication produces electrical pulses and creates a form of a wave-like pattern, which called brainwaves.

A German psychiatrist Hans Berger who invented electroencephalography (EEG–a non-invasive way of recording brain signals by placing electrodes on the scalp) discovered Alpha brainwaves back in 1924. In general, the human brain is producing five different types of brainwaves with different speed and frequency rates. According to the human's physical and mental situation, these brainwaves would change constantly.

By breaking down signals made from the cerebrum, we can comprehend mental practices of the brain. Each brain state is related to a specific signal frequency, which is for understanding the functional behavior of human brain construction. One of the important challenges for all brainwave authentication studies is brain pattern changes in different brain situations. The EEG data of any person can change in some situations like being sick, drunk, addicted to drugs, anxiety and any other situations that any human can experience in their life. Therefore, we need a method that could have the permanency of the brain pattern and stability over time, not just for a specific task or brain state but also for all the other states.

In this paper, we proposed a method that improves the permanency of the brain pattern using deep breathing in different brain situations.

II. LITERATURE

A. Brain-based authentication methods

EEG data can be recorded by three different protocols: mental tasks, resting states, and tasks with an external stimulus. Selecting an appropriate protocol can affect the procedure and the accuracy of authentication directly. For example, to record the brain data for resting states or the mental tasks, there is no need to use any extra equipment but EEG devices; on the other hand, in external stimuli tasks we need some other devices to generate suitable stimulation. However, environment noise and artifacts can affect the results in simple tasks like resting states, whereas a higher "signal-to-noise ratio" (SNR) can be generated by tasks followed by external stimuli.

The most popular protocols in EEG signal acquisition are resting states [8]. The process of this protocol starts by asking the individual to sit in a quiet area and then starting the EEG recording. The alpha band is the dominant band during the resting states [9]. This protocol is popular because of its simplicity and using no extra instructions or requirements, however, the quiet environment with less mental activity can be effective in the last result.

Visual stimuli; is a group of events that are caused by external stimuli. It covers a wide stimuli range. In some of them, the individuals read unconnected texts, pseudo-words, their own names and acronyms [10]. In some experiments, it can be a group of images displayed on a screen for individuals to recognize the images in the presentation time [11], a specific geometric figure or numbers between all letterings [12], static substances versus moving substances [13]. All VEPs have a drawback, which is the need for external devices. The important advantage of VEPs is the stability of the components over time, which is very useful for the permanency condition of biometric authentications.

There is some type of events that are developed by listening to a specific tone or a part of a music. It is called acoustic stimulus. Some of these stimulus can be generated by playing various types of music for participants in which they incite various feelings and interests [14] or a provided music preference by the individual, which could act as a personal identification technique.

Mental tasks are another type that the individual should do mental activities or imagine physical body actions. It can be the body activity such as moving a hand or foot or imagine that body movement and sometimes doing both moving and imagining [15]. Studies and researches have shown that better results can be achieved by imaginary tasks in comparison to similar physical ones. Some other examples of mental tasks such as counting numbers in mind picturing the turn of a given geometric figure around a hub [16] or imagining a 2D and 3D picture as a picturizing pattern [17]. Although there is no need for any special devices in mental tasks for stimulation, to initialize the task, they still need some equipment to produce a hint for the individual.

Another type of brain state protocol is multi-tasking. In this protocol, participants would watch a video that brings different emotional states [18]. Multi-tasking protocols could be a good option to improve the classification accuracy rate, but the complexity of the tasks and the amount of time to do the process can make them be considered as a hard and timeconsuming method for authentication purposes.

Many different tasks have been presented and tested to achieve a high accuracy rate to use EEG as an authentication method. Some of the studies achieved a very high accuracy rate for their proposed method using a specific task, but the big problem in all of them is permanency and stability. Because EEG can change depending on the situation. In some positions, the brain doesn't function properly and cannot be in its normal state to create a pattern for a task. Some reasons like being sick, drunk, stress, etc.

B. Deep breath and its effects on human brain

Deep breathing is famous as a healing exercise: It is very helpful to reduce anxiety; it can help to respond the specific stressors effectively. According to the studies, deep breathing psychological effects can help humans to calm down and slowing the race of mind [19]. It can increase alpha brain waves, which present relaxation feelings and can be achievable by some tasks like meditating or daydreaming.

Although these brainwaves are generating by a healthy human brain, only one of them will rule, depending on what the person is feeling, thinking, or doing. Each person is experiencing constant stress every day that affects the brain. To make the person calm, the brain needs to get back to its baseline relaxation bringing back the brain signals to a normal state.

C. Alpha waves for brain-based authentication According to the connection of alpha waves and relaxation brain states, increasing alpha waves activity could help the person to stay relaxed and reduces stress and anxiety. Scientists discovered that enhancing alpha waves might improve creativeness by an average of 7.4%. They also claimed solid proof that individuals with despondency have weakened alpha activities. It means that a low mood would be treated by improving alpha brain patterns potentially. According to the studies, alpha waves could be a better option to test brain signals for authentication purposes. Because in the majority of times and all different situations of human life no matter how active or low mood the brain is, we can improve the Alpha waves by doing deep breathing. It could guaranty the stability of the brain state in all different situations and make the process of recording, processing, and classification of the produced EEG easier and more accurate.

III. METHODOLOGY

The proposed method has been done in four stages; First, recording the EEG signals from participants; Second, preprocessing the raw data, filtering, and normalization. Third, extracting the features from the clean data. The final stage, selecting the specific features according to the purpose of this study and classification.

A. Signal Acquisition

To acquiring the signals, a 14 channels Emotiv Epoc BCI device [30] and a computer to record and store the data, was used. The data recorded, digitize and got ready for analysis. In this study, the data acquired in three different session-days. The first session-day was in the morning, the second sessionday in the afternoon, and the last one in the evening. Each session was about 30 min per participant per session-day. The deep breathing study was examined in fifteen healthy individuals at the age rate of 25-45. First, each participant has been asked to sit on a chair and close their eyes and breathe normally and EEG data were recorded for 2 minutes. After the normal breathing, participants have been asked to do the deep

breathing task in three section of inhale, breathe holding and exhale for about five to six breaths per minute. It starts with three seconds for inhalation and following that two seconds breathe holding and finally three seconds for exhalation. According to the studies, the range of four to six minutes may be an appropriate time for individuals to accumulate alpha brainwave successfully.

B. Pre-Processing

To clear the data, a band-pass filter in the range of 0.5 Hz and 50 Hz was applied using a Finite Impulse Response (FIR) technique [20]. High-pass filter is one of the best ways to remove large amplitude and the slow drifts in the data. The range of 0.5 Hz makes the data ready for Independent Component Analysis (ICA) analysis technique, which is very sensitive to low band-pass frequencies.

After filtering the data and clearing it from artifacts and noises, the ICA algorithm applied to the data to do a blind source separation of the process of signal mixing [22].

C. Feture Extraction

According to the aim of this project and analysing the relaxation state brainwave types produced by deep breathing, our main focus was on Alpha and Beta waves. Therefore, the power spectral density (PSD) method, which extracts the frequency characteristics of signals was used. PSD presents a consistent and effective way to extract the characteristics of spectral patterns with high discriminate accuracy for motor imagery EEGs [23] [24]. In this method, the PSD computed based on Welch Periodgram up on the frequency distributions; in this process, a 50% overlap section was used between a 400 points window. After visually inspecting the entire data for all subjects, three features were extracted from the alpha and beta bands of PSD. This was done by recognizing and selecting the highest PSD peak values in each band separately.

D. Classification

For the classification of the appropriately selected features, two classifiers were used; Support Vector Machine (SVM), and Neural Network(NN) which are the most commonly used in classifying EEG signals [25].

SVM and Neural Network can both express the information to a higher dimensional space to allocate a choice limit. SVMs could be equivalent to a superficial neural network architecture [26]. On the other hand, for a large amount of data, a NN will overtake an SVM. The two classes of calculations can surmise non-linear decision capacities, with various methodologies.

IV. Results and Discussion

EEG data were recorded from 15 participants who have been asked to do deep breathing in three sections of inhale, breathe holding and exhale for about five to six breaths per minute; three seconds, two seconds and, three seconds respectively. Classification of EEG data with three labels, inhalation, holding the air and, exhalation was done using SVM and NN classifiers.

A successful recall percentage achieved for each 3 parts of the deep breathing. The EEG data used in this task recalled different parts of deep breathing over the 14 channels per participant successfully. The three domains extracted data features were fed to the classifiers separately. The results showed that inhalation and exhalation are harder to recall but breat-holding got a higher successful recall (92%, 90% for SVM and NN classifiers respectively) than the other two with (78%, 76% for inhalation and, 75%, 76% for exhalation).

TABLE II. Performance of the breath-holding recalled vs not recalled by SVM & NN classifiers

Classifier	Precision	Recall	F-Score	Accuracy
SVM	0.95	0.89	0.85	0.92
NN	0.95	0.88	0.86	0.90

The results showed, Deep breathing definitely promotes mental health, may induce relaxation and can bring the brain state back to normal. This could also be very helpful for any kind of brain pattern that would be used as a brain-based authentication. According to the studies, deep breathing can be a very effective way to change the structure of the brain and bring it back to a normal state. The main act for each type of meditation is doing deep breathing. Scientists discovered that the brain is so oxygen reliant and it uses approximately 20% of the oxygen that the body needs to function. Besides, oxygen deficiency could cause humans to feel fuzzy, out-of-focus and distracted. Consequently, deep breathing has a big impact on the human brainwaves to get back to a normal state. Brain patterns can change in some specific situations that anyone can experience in life including sickness, anxiety, stress, fear, sadness, and many others that can influence the human's brain. Therefore, the brain cannot produce the needed signals to create a pattern. This study shows that deep breathing could be a new solution for the problem of permanency in any brainbased biometric authentication.

V. Conclusion

An experiential study was presented, which investigated deep breathings as a brain state for authentication purposes based on human EEG data. A 14 channel BCI device was used in this study to record the brain waves of 15 participants, while they were asked to take deep breaths in three steps each time. Our results show that deep breathing can make the brain improve the alpha and beta waves no matter which situation the person is experiencing which could be the best option to have a stable brain pattern that could be predicted with high accuracy for the authentication process. Therefore, we used the different parts of deep breathing as an authentication brain pattern and we were able to successfully achieve an average accuracy of 92% and 90% using SVM and NN classifiers respectively to recall the breath-holding part of the deep breathing. This work may give the premise to future work investigating if brain signals can be used to predict the unique brain pattern from long-term memory in all different situations of human life.

References

[1] F. Yousefi, H. Kolivand, "Brain Signals as a New Biometric Authentication Method Using Brain-Computer Interface". In: Lee N. (eds) Encyclopedia of Computer Graphics and Games. Springer, Cham, 2019, DOI: https://doi.org/10.1007/978-3-319-08234-9_370-1

[2] K. Cao and A. K. Jain. 2016. Hacking Mobile Phones Using 2D Printed Fingerprints. Technical Report MSU-CSE-16-2. Michigan State University.

[3] E. Marasco and A. Ross. 2014. A survey on anti-spoofing schemes for fingerprint recognition systems. ACM Computing Surveys 47, 2 (Sept. 2014), 1–36.

[4] Chaos Computer Club (CCC). 2014. Fingerprint Biometrics hacked again. https://www.ccc.de/en/updates/2014/ursel.

[5] E. F. M. Wijdicks. 1995. Determing brain death in adults. Neurology 45 (May 1995), 1003–1011.

[6] M. Trokielewicz, A. Czajka, and P. Maciejewicz. 2016. Post-mortem human iris recognition. In Proceedings of the 2016 International Conference on Biometrics (ICB'16). 1–6.

[7] A. K. Jain, A. Ross, and S. Prabhakar. 2004. An introduction to biometric recognition. IEEE Transactions on Circuits Systems and Video Technology 14, 1 (2004), 4–20.

[8] Di, Y. , An, X. , He, F. , Liu, S. , Ke, Y. , Ming, D. , 2019. Robustness analysis of identifica- tion using resting-state EEG signals. IEEE Access 7 (c), 42113–42122 .

[9] Barry, R.J. , Clarke, A.R. , Johnstone, S.J. , Magee, C.A . , Rushby, J.A . , 2007. Eeg differences between eyes-closed and eyes-open resting conditions. Clin. Neurophysiol. 118 (12), 2765–2773 .

[10] Ruiz-blondet, M. , Khalifian, N. , Armstrong, B.C. , Jin, Z. , Kurtz, K.J. , Laszlo, S. , 2014. Brainprint: identifying unique features of neural activity with machine learning. In: Proc. 36th Annual Conf. of the Cognitive Science Society, pp. 827–832 .

[11] Zuquete, A. , Quintela, B. , Silva Cunha, J.P. , 2010. Biometric authentication using brain responses to visual stimuli. In: International Conference on Bio-inspired Sys- tems and Signal Processing, pp. 103–112 .

[12] Das, R. , Piciucco, E. , Maiorana, E. , Campisi, P. , 2016. Visually evoked potentials for EEG biometrie recognition. In: 2016 1st International Workshop on Sensing, Pro- cessing and Learning for Intelligent Machines, SPLINE 2016 –Proceedings .

[13] Zhang, F. , Mao, Z. , Huang, Y. , Lin, X. , Ding, G. , 2018. Deep learning models for eeg-based rapid serial visual presentation event classification. J. Inf. Hiding Mul- timed. Signal Process. 9 (1), 177– 187 .

[14] Kaur, B. , Singh, D. , Roy, P.P. , 2017. A novel framework of EEGbased user identi- fication by analyzing music-listening behavior. Multimed. Tools Appl. 76 (24), 25581–25602 .

[15] Alyasseri, Z.A .A . , Khader, A .T. , Al-Betar, M.A . , Papa, J.P. , ahmad Alomari, O. , 2018. Eeg-based person authentication using multiobjective flower pollination algo- rithm. In: 2018 IEEE Congress on Evolutionary Computation (CEC). IEEE, pp. 1–8 .

[16] Kumari, P. , Vaish, A. , 2016. Feature-level fusion of mental task's brain signal for an efficient identification system. Neural Comput. Appl. 27 (3), 659–669 .

[17] Yousefi, F., Kolivand, H. and Baker, T., 2020. SaS-BCI: a new strategy to predict image memorability and use mental imagery as a brain-based biometric authentication. Neural Computing and Applications, pp.115.

[18] Chen, J.X., Mao, Z.J., Yao, W.X. and Huang, Y.F., 2019. EEG-based biometric identification with convolutional neural network. Multimedia Tools and Applications, pp.1-21.

[19] Komori, T., 2018. Extreme prolongation of expiration breathing: Effects on electroencephalogram and autonomic nervous function. Mental illness.

[20] Walia, R. and Ghosh, S., 2018. Design of active noise control system using hybrid functional link artificial neural network and finite impulse response filters. Neural Computing and Applications, pp.1-10.

[21] Sharma, R., Pachori, R.B. and Upadhyay, A., 2017. Automatic sleep stages classification based on iterative filtering of electroencephalogram signals. Neural Computing and Applications, 28(10), pp.2959-2978.

[22] A. Hyvärinen, and E. Oja, "Independent component analysis: algorithms and applications." Neural networks, 2000, pp.411-430.

[23] N. Brodu, F. Lotte, and A. L´ecuyer, "Exploring two novel features for EEG-based brain-computer interfaces:Multifractal cumulants and predictive complexity," Neurocomputing, vol. 79, pp. 87–94, 2012.

[24] L. Duan, H. Zhong, J. Miao, Z. Yang, W. Ma, and X. Zhang, "A Voting Optimized Strategy Based on ELM for Improving Classification of Motor Imagery BCI Data," Cognitive Computation, vol. 6, no. 3, pp. 477–483, 2014.

[25] M. V. Martin, V. Cho, and G. Aversano, "Detection of subconscious face recognition using consumer-grade braincomputer interfaces," ACM Trans. Appl. Percept., vol. 14, no. 1, pp. 7:1–7:20, Aug. 2016.

[26] USNFIS: Uniform Stable Neuro Fuzzy Inference System,
Neurocomputing, Vol. 262, pp. 57-66, 2017.