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Distraction descriptor for brainprint authentication modelling using probability-based Incremental Fuzzy-Rough Nearest Neighbour

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Abstract

This paper aims to design distraction descriptor, elicited through the object variation, to refine the granular knowledge incrementally, using the proposed probability-based incremental update strategy in Incremental Fuzzy-Rough Nearest Neighbour (IncFRNN) technique. Most of the brainprint authentication models were tested in well-controlled environments to minimize the influence of ambient disturbance on the EEG signals. These settings significantly contradict the real-world situations. Thus, making use of the distraction is wiser than eliminating it. The proposed probability-based incremental update strategy is benchmarked with the ground truth (actual class) incremental update strategy. Besides, the proposed technique is also benchmarked with First-In-First-Out (FIFO) incremental update strategy in K-Nearest Neighbour (KNN). The experimental results have shown equivalence discriminatory performance in both high distraction and quiet conditions. This has proven that the proposed distraction descriptor is able to utilize the unique EEG response towards ambient distraction to complement person authentication modelling in uncontrolled environment. The proposed probability-based IncFRNN technique has significantly outperformed the KNN technique for both with and without defining the window size threshold. Nevertheless, its performance is slightly worse than the actual class incremental update strategy since the ground truth represents the gold standard. In overall, this study demonstrated a more practical brainprint authentication model with the proposed distraction descriptor and the probability-based incremental update strategy. However, the EEG distraction descriptor may vary due to intersession variability. Future research may focus on the intersession variability to enhance the robustness of the brainprint authentication model.

Keywords Distraction descriptor, Probability-based IncFRNN, Brainprint authentication, Object variation

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1 Introduction

Brain signals are being studied within the medical field for brain disorders such as Alzheimer, schizophrenia, spinal cord injuries, epilepsy, and stroke among the others. Furthermore, they are also applied in assistive, rehabilitative, and entertainment applications as the basis for Brain–Computer Interface (BCI) and Brain–Machine Interface (BMI). Despite widespread interest in clinical applications, the utilization of brain signals such as Electroencephalogram (EEG) is used as a biometric modality for person authentication or person identification [1–3]. EEG signal is an outstanding biometric modality with several benefits. The EEG signal would be more difficult to steal, and it would be cancellable. Numerous unique brain rhythms can trigger the EEG signals. For instance, when the stored brainprint of a client is stolen, disclosed, or lost, a different brainprint can be generated from a specific type of brain activities and responses. For example, the EEG signals can be recorded from different colour stimuli [4] or black and white stimuli [5]. Thus, a new brainprint could be used to substitute the stolen one. Furthermore, EEG is an example of biodynamic signal, demonstrating the evidence of personal aliveness. EEG is also proven to have low intra-subject and high inter-subject variability [6]. Thus, brainprint authentication research has progressed rapidly [7–9], in conjunction with the growth of portable low cost but high time resolution acquisition devices over the past few years [10]. EEG signals are usually nonlinear, nonstationary, and difficult to recreate due to the impact of several noise sources such as environmental noise and physiological noise [5, 11]. Current research normally conducted the EEG recording in a very quiet environment to minimize the disturbance [12, 13]. However, these environments are highly artificial and significantly differ from real-world situations, where people have to handle the environmental distractions. Thus, making use of the distraction is wiser than eliminating it. Human response to physiological noises is unique, but no concrete studies utilize distraction represented in EEG signals as biometric descriptors complementary to current biometric features.

A practical brainprint authentication model should always encapsulate the changes and variations of the EEG signals. Incremental learning has its capability to gradually remodel and reform the current knowledge granules incrementally for the purpose of detecting the new changes in the EEG signals. The commonly used incremental update strategies are the actual class and First-In-First-Out (FIFO) update strategies. The actual class label represents the ground truth. However, it is almost impossible to obtain the actual class label in brainprint authentication applications. In contrast, the FIFO incremental update strategy stores the new test objects and eliminates the oldest objects without considering the actual class label. It cannot ensure that only the nonrepresentative EEG signals will be eliminated, especially for the imbalanced class distribution dataset. Thus, it is crucial to modify the current incremental update strategy to implement in real-world situations. The proposed probability-based Incremental Fuzzy-Rough Nearest Neighbour (IncFRNN) is a modified version from IncFRNN [14] by introducing the probability method to overcome the use of actual class in the incremental update strategy. The proposed probability-based incremental update strategy imposes the variation of an object, object insertion, and object deletion. The main idea of the object insertion is to capture the new changes of the individual features from the EEG data due to the EEG is a nonstationary signal that fluctuates over the time.

The rest of this paper is structured as follows: Sect. 2 is a literature review on the brain responses towards environmental distractions and the existing incremental update strategies. Section 3 presents the existing IncFRNN algorithm and the proposed probability-based IncFRNN algorithm, respectively. Section 4 outlines the materials and methods, which includes the data acquisition, EEG distraction descriptor, feature selection, classification, and performance measurement and validation test. Section 5 depicts the experimental results and Section 6 provides the discussion on the findings. Section 7 draws the conclusion and suggests the direction of future work.

2 Literature review

Research on using brainprint authentication is catching attention in recent years. However, there are many challenges must be resolved before considering its application in real-life circumstances. EEG signals are susceptible to any environmental disturbance due to the weaknesses of the signals. Thus, most of the research on EEG signals recording is generally conducted in a very quiet room to minimize the disturbance. By doing this way, it is able to acquire the best quality of the EEG signals. However, one of the challenges is the EEG signals acquisition process in the current controlled environment is highly artificial and significantly differs from real-world situations. It is a critical issue but the research to address this problem is still limited [15]. Besides that, emotion is also another essential issue need to be addressed, and so far, there is lack of research to tackle this challenge. A complex psychological state known as emotion, which involves three unique components: a physiological response, a behavioural response, and a subjective experience [16]. Four critical points such as the environment and equipment setting, emotion elicitation procedure, evaluation of categories of stimuli, and evaluation of individual differences