

OPTIMIZING EEG CHANNELS AND FEATURES FOR ENHANCED BIOMETRIC USER IDENTIFICATION

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ABSTRACT

Biomedical signals, such as Electrocardiography, Electroencephalography (EEG), and Electromyography, are reliable for user identification due to their unique and non-replicable nature. These signals are inherently associated with physiological and neurological processes, offering enhanced security in applications like defence, banking, and access control. EEG signals, in particular, capture brain activity patterns and provide high-dimensional signals of cognitive and neurological states, making them a promising tool for user identification. However, high-dimensionality and noise associated with EEG data necessitate the identification of most relevant channels and features to improve accuracy and reduce computational complexity. Thus, this study focuses on channel and feature optimization using Machine Learning (ML) techniques to enhance EEG-based user identification method. In this work, time-domain features were extracted from an open-access pre-processed RSVP-based EEG dataset, and the optimal channels and features were selected using various optimization techniques. Further, ML algorithms were employed to validate the optimized channels and features with grid search and 5-fold cross-validation. The results show that Simulated Annealing Optimization algorithm identified the most significant channels as AF4, PO3, CP1, Pz, AF3, and Oz and features as Hjorth complexity, Hjorth mobility, Teager-Kaiser energy, skewness, and line-length. The selected channels and features offer valuable insights into the brain regions associated with visual processing, attention, and cognitive load during RSVP tasks. Using the optimized channels and features, the Random Forest classifier achieved high accuracy, recall, precision and F1 score of 98.1%, 98.5%, 97.8%, and 98.1%, respectively. These findings highlight the effectiveness of optimization in enhancing reliability of EEG-based user identification.

Keywords: Biometric Identification, Electroencephalography, RSVP, Channel Optimization, Machine learning

INTRODUCTION

User identification systems are essential in modern security frameworks, enabling secure access to sensitive information and services [1] [2]. Conventional authentication methods, such as knowledge-based credentials (passwords or PINs), possession-based items (cards or tokens), and biometrics (fingerprints, facial recognition) [3], have limitations, particularly their susceptibility to spoofing. This has led to increased interest in alternative biometric identifiers like biomedical signals, which offer enhanced security due to their close ties to physiological and neurological processes. Among biomedical signals, Electroencephalography (EEG) has gained attention due to its capacity to reflect an individual's brain activity patterns, which are inherently unique [4]. EEG signals are acquired via electrodes placed on the scalp, recording electrical activity from different brain regions. The resulting signals provide a high-dimensional representation of cognitive and neurological states, offering a rich source of information for distinguishing individuals [4]. Brain activity patterns are influenced by cognitive states, mental workload, and even emotional states, making EEG a dynamic and unique signal suitable for user identification. Furthermore, EEG-based systems are non-invasive, making them suitable for practical applications requiring continuous authentication during sensitive operations [5].