Signal, Image and Video Processing (2023) 17:2627–2636
https://doi.org/10.1007/s11760-022-02479-7

ORIGINAL PAPER

1D-convolutional neural network approach and feature extraction methods for automatic detection of schizophrenia

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Received: 1 December 2022 / Revised: 16 December 2022 / Accepted: 29 December 2022 / Published online: 5 January 2023

Abstract
Schizophrenia is a complex psychiatric disorder characterized by delusions, hallucinations, disorganized speech, mood disturbances, and abnormal behavior. Early diagnosis of schizophrenia depends on the manifestation of the disorder, its symptoms are complex, heterogeneous and cannot be clearly separated from other neurological categories. Therefore, its early diagnosis is quite difficult. An objective, effective and simple diagnostic model and procedure are essential for diagnosing schizophrenia. Electroencephalography (EEG)-based models are a strong candidate to overcome these limits. In this study, we proposed an EEG-based solution for the diagnosis of schizophrenia using 1D-convolutional neural network deep learning approach and multitaper method. Firstly, the raw EEG signals were segmented and denoised using multiscale principal component analysis. Then, three different feature sets were extracted using leading feature extraction methods such as periodogram, welch, and multitaper. The performance of each feature extraction method was compared. Finally, classification performance of support vector machine, decision trees, k-nearest neighbors, and 1D-convolutional neural network algorithms were tested according to model evaluation criteria. The highest performance was obtained with the multitaper and 1D-convolutional neural network approach, and the highest accuracy was 98.76%. The results of the model were found to be 0.991 sensitivity, 0.984 precision, 0.983 specificity, 0.975 Matthews correlation coefficient, 0.987 f1-score, and 0.975 kappa statistic. This study presents the multitaper and 1D-convolutional neural network approach framework for the first time in the diagnosis of schizophrenia. Moreover, this study achieved satisfactorily high classification performance for the diagnosis of schizophrenia compared to methods in the relevant literature.

Keywords Signal processing · Deep learning · 1D-convolutional neural network · Feature extraction · EEG · Schizophrenia

1 Introduction

Schizophrenia (SZ) is a psychiatric disorder whose neurobiological basis is still largely unknown and defined as a functional disconnection syndrome affecting brain connections and circuits [1]. SZ refers to a life-long debilitating and serious mental illness characterized by symptoms such as hallucinations and paranoia, diminished emotions, cognitive deficits, and confused thoughts [2]. It is one of the 25 leading causes of disability and affects more than 20 million individuals globally [3]. A substantial and long-term financial burden and medication are necessary for the prognosis of SZ [4]. Moreover, compared to the general population, SZ patients are two- to three-fold increased risk of dying earlier [3]. The onset of symptoms usually begins between the ages of 14 and 30, that is, during adolescence and early adulthood. One of the best indicators of future prognosis has been found to be the interval between the onset of symptoms and diagnosis and treatment [5]. SZ symptoms are heterogeneous and associated with functional impairments and reduced quality of life. Therefore, early diagnosis of SZ is of great importance in terms of the course of the disease and it may result in a more successful treatment by increasing the life quality of patients [6].

The complexity and heterogeneity of SZ symptoms challenge an objective diagnosis that is typically based on behavioral and clinical signs. Moreover, the boundaries of SZ cannot be clearly separated from other neurological categories such as bipolar disorder [7]. For this reason, symptoms are often underdiagnosed, resulting in harmful, costly and

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