Early Detection and Explainable Analysis of Alzheimer's Disease Using Resting-State fMRI and Convolutional Neural Networks

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Abstract: Alzheimer's disease (AD) is an incurable neurodegenerative disorder that progressively damages the brain, leading to memory loss and cognitive decline. Early detection of AD is essential, as it can help delay or slow the progression of the disease. However, finding reliable and automated diagnostic methods remains a significant challenge. Resting-state functional MRI (rs-fMRI) is a non-invasive imaging technique that captures brain activity in a resting state, providing insights into the brain's functional connectivity. In this study, we utilized data from the ADNI database, including rs-fMRI and T1-weighted MRI scans of 100 AD subjects and 100 normal controls (NC). Following comprehensive preprocessing, functional brain networks were constructed using Regions of Interest (ROIs) from the Harvard-Oxford atlas as nodes, with Pearson correlation coefficients between the time series of different brain regions forming the edges, resulting in 164 x 164 connectivity matrices for each subject. We propose a CNN architecture designed to classify individuals as NC or AD patients by extracting high-quality features from the brain's functional connectivity networks derived from rs-fMRI scans. The proposed model was validated using a 5-fold cross-validation approach, achieving an average classification accuracy of 98.5%, demonstrating high reliability and robustness. Beyond its high accuracy, the CNN model also emphasizes explainability by identifying the most critical brain regions and connections for distinguishing between NC and AD cases using the Grad-CAM technique. This explainable deep learning approach not only enhances diagnostic accuracy but also improves the interpretability of results, enabling the identification of key biomarkers and brain regions associated with AD. The findings suggest that this method could be a powerful tool for early AD detection, offering insights for targeted interventions and understanding the disease's mechanisms.

Keywords: Alzheimer's disease, Convolutional Neural Network, Explainable deep learning, Functional Brain Network, rs-fMRI.

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