Classification of Alzheimer's Disease Stages using Weighted Brain Connectivity based Graph Convolutional Neural Network

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***Abstract*—Alzheimer's disease (AD) is a progressive neurodegenerative disorder that manifests in distinct stages, including cognitively normal (CN), mild cognitive impairment (MCI), and severe AD. An early and precise classification of these stages is critical for effective treatment and patient care. While neuroimaging and machine learning have advanced AD diagnosis, significant challenges remain, such as data variability, the need for large datasets, and the intricate nature of brain connectivity. This study addresses these challenges by introducing a Weighted Graph Convolutional Neural Network (W-GCNN) that utilizes weighted structural brain networks derived from diffusion MRI. Unlike traditional unweighted brain networks, the weighted brain network captures the varying connection strengths between brain regions, offering a more nuanced representation of brain connectivity. The proposed W-GCNN architecture employs advanced techniques like graph convolution and sort pooling to classify individuals into CN, MCI, and AD stages. Using a dataset from the Alzheimer's Disease Neuroimaging Initiative (ADNI) that includes 116 CN, 130 MCI, and 112 AD subjects, the proposed W-GCNN model achieves an accuracy of 91% in distinguishing among the three categories. This approach not only enhances the accuracy of stage classification but also provides a robust framework for the early diagnosis of AD, supporting the development of personalized treatment plans. The results highlight the potential of weighted GCNNs in automated AD classification, offering clinicians a more reliable tool for patient management and improved treatment outcomes.**

Keywords- Alzheimer's disease, mild cognitive impairment, weighted structural brain network, weighted graph convolutional neural network

I. Introduction

Alzheimer's disease (AD) is a chronic, irreversible neurodegenerative condition and the primary cause of dementia, predominantly affecting older adults. It is characterized by a gradual decline in cognitive functions, including memory, reasoning, and the ability to perform everyday tasks [1].

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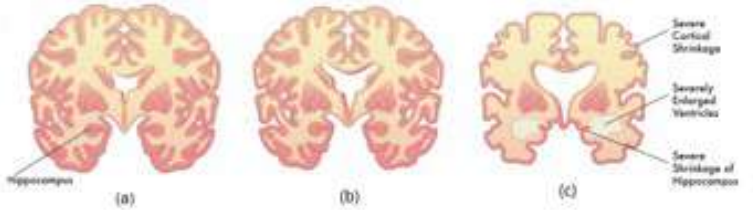

Fig. 1: Coronal slices of healthy and stages of Alzheimer's brain (a) CN (b) MCI (c) AD (https://altoida.com/)

AD progresses through several stages (Fig. 1) from cognitive normal (CN), beginning with mild cognitive impairment (MCI), advancing to moderate, and finally severe AD, where individuals lose the ability to carry out basic bodily functions [2]. Globally, AD poses a significant and growing public health challenge. As per the World Health Organization's report, around 55 million people globally are currently living with AD, a figure expected to rise to 100 million by 2050 [3]. According to the Lanka Alzheimer's Foundation (https://alzlanka.org/), nearly 150,000 people in Sri Lanka are affected by dementia, with projections indicating this number will increase to approximately half a million by 2050.

Detecting AD at an early stage is crucial, as it allows patients to receive treatments that can slow the progression, alleviate symptoms, and enhance their quality of life. AD diagnosis relies on clinical assessments and cognitive testing, while key biomarkers such as beta-amyloid plaques [4], tau protein tangles [5], and biomarkers based on neuroimaging [6] are increasingly used to enhance early detection and monitor disease progression. Despite ongoing efforts to develop simpler and more affordable tests, no existing method has proven sufficiently accurate and reliable across all stages of AD diagnosis. The majority of research on biomarkers in sporadic Alzheimer's disease has been conducted through cross-