GeoHSAF: Geometric Hippocampus Shape Analysis Framework for Longitudinal Alzheimer's Disease Classification

Mubarak Olaoluwa*[1], Heni Loukil[2], Arafet Sbei[3], and Hassen Drira[1]

[1]Images, Modélisation, Apprentissage, Géométrie et Statistique – Laboratoire des sciences de l'ingénieur, de l'informatique et de l'imagerie – France
[2]National Institute of Applied Science and Technology (INSAT), Tunis 1080 – Tunisia
[3]MData One, Les Berges du Lac, Tunis 1053 – Tunisia

Abstract

Alzheimer's disease (AD) is the most common form of dementia and a progressive, irreversible brain disorder that affects millions worldwide. The majority of existing research on AD classification relies on cross-sectional brain magnetic resonance imaging studies, which consider information from a single time point and fail to account for the progressive nature of AD. Longitudinal analysis, however, is crucial for capturing AD evolution and enabling more accurate diagnosis. To address this gap, we propose GeoHSAF, a novel hippocampus-based geometric learning framework for longitudinal AD classification. To the best of our knowledge, GeoHSAF is the first hippocampus-based geometric learning framework for AD classification in longitudinal datasets.

The proposed GeoHSAF includes various components, one of which is a shape interpolation module that addresses the problem of missing or inconsistent hippocampal shapes across subjects by predicting intermediate shapes to ensure temporal continuity. We evaluate the effectiveness of GeoHSAF on three public longitudinal AD database: The Alzheimer's Disease Neuroimaging Initiative (ADNI), the Open Access Series of Imaging Studies (OASIS), and The Australian Imaging, Biomarker and Lifestyle (AIBL), and benchmark its performance against existing approaches. GeoHSAF achieves new state-of-the-art results on binary classification tasks (AD versus Normal controls (NC)), while also demonstrating strong performance on more challenging triple-class classification tasks (AD versus NC versus Mild Cognitive Impairments (MCI)).

Furthermore, we demonstrate the contribution of other components of the proposed GeoHSAF (shape space modeling, tangent space configuration, and dimensionality reduction) through ablation studies and assess the interpolation module both quantitatively and qualitatively to validate its fidelity. Our proposed method is fully reproducible, and all codes are publicly released at: https://github.com/ayodejimb/GeoHSAF

Keywords: Longitudinal Alzheimer's Disease, Hippocampus, Shape Analysis, Shape Interpolation, Deep Learning

*Speaker