Abstract of the Ph.D. Thesis

on

Some Studies on Graph Signal Processing with Application to Alzheimer's Disease Detection

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Abstract

In this thesis, we design a novel integrated Alzheimer's Disease (AD) detection model that exploits both the static and the dynamic brain connectivity based features extracted from resting-state fMRI (rs-fMRI) data to detect AD in the early stages. First, the static connectivity based AD detection model is designed wherein we propose a novel graph frequency based feature extraction method by relating the findings of two neurological experiments. The discriminating graph signal features thus extracted are then used for the classification, which is performed using a properly designed Graph-CNN (GCNN) based graph signal classifier. Performance of this proposed model is then experimentally validated using the rs-fMRI data from ADNI dataset.

Although the aforementioned model classified the normal subjects and the AD patients, with reasonable accuracy, in order to improve its classification performance further, we propose a modification to the existing GCNN architecture, which acts as a graph signal classifier. We design a novel graph wavelet based two-stage multilevel graph coarsening algorithm which is then used to perform the pooling operation in GCNN. The first stage of coarsening uses the graph wavelet based features to coarsen a given graph which is followed by an optimization based second stage, wherein at each level of coarsening, the restriction of the original graph Laplacian is preserved to obtain the reduced graph Laplacian. Efficacy of the proposed coarsening

algorithm is verified in the general context using different graph coarsening quality measures. Its effectiveness as a pooling operator in GCNN is then validated by employing it for the graph coarsening operation in the GCNN architecture. Improvement in the AD classification performance using this modified GCNN architecture attested the superiority of the modified GCNN classifier over the existing approaches for early detection of AD.

Having verified the efficacy of the proposed static connectivity based AD detection model using the rs-fMRI data, we then design a dynamic connectivity based AD detection model which is then integrated with the earlier model to improve the AD detection performance further. We propose a novel approach to characterize the dynamics of the time varying graph connectivity using the state-space representation of the graph signal, wherein the dynamic brain connectivity is modeled as a state of the system while the input graph signal serves as an observation. The dynamics of the time varying graph connectivity is characterized by the resulting state transition matrix which is then used as a dynamic connectivity based feature for AD classification purpose. After verifying the utility of this dynamic connectivity based AD detection model, we integrate it with our static connectivity based AD detection model discussed earlier using multimodal deep learning architecture. State-of-the-art classification performance of this modified AD detection model corroborated its efficacy in AD detection application.