Understanding Alzheimer disease's structural connectivity through explainable AI

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June 26, 2020

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Introduction

Problematic

- Lack of tools for understanding Alzheimer's Disease Connectivity with AI
- Need for understanding the brain connectivity of Alzheimer disease trough explainable AI
- None existing work about predicting Alzheimer's Disease over structural connectivity with deep learning Algorithms

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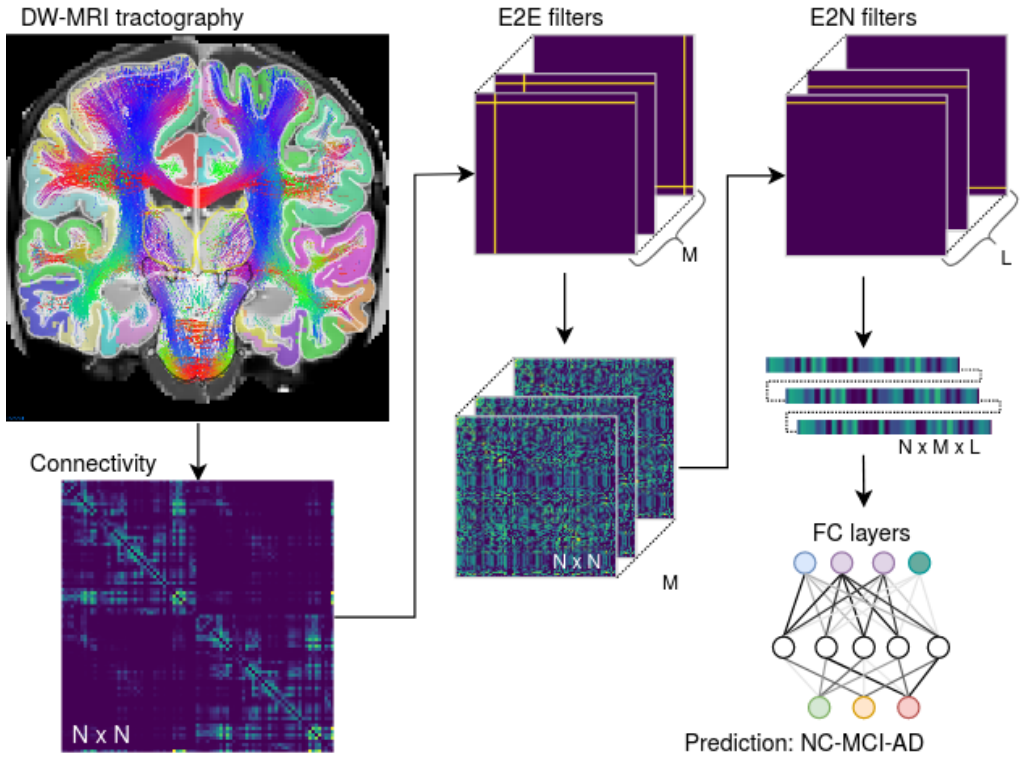
Methodology

Method

- MRI images from ADNI dataset
- Construct DW-MRI tractography
- Training adapted version of BrainNetCNN[1] : with one E2E and one E2N layers



[1] :Kawahara, Jeremy, et al. "BrainNetCNN: Convolutional neural networks for brain networks; towards predicting neurodevelopment." NeuroImage 146 (2017): 1038-1049.

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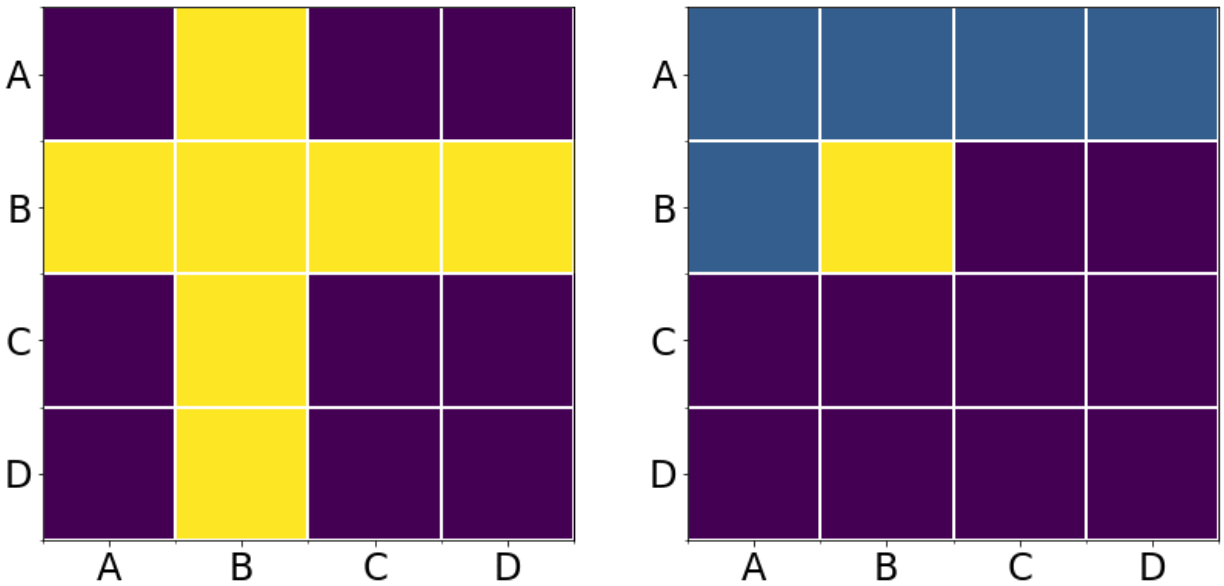
E2E and E2N filters

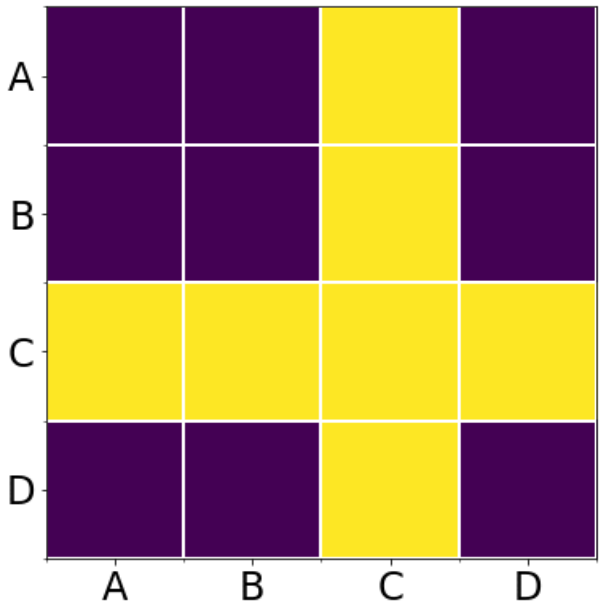
E2E filter



$$B_{i,j} = \sum_{n=1}^{M_1} \sum_{k=1}^{N} A^n_{i,k} * r_k + A^n_{k,j} * c_k$$

E2E and E2N filters

E2N filter



$$C_i = \sum_{l=1}^{M_2} \sum_{k=1}^{N} B^l_{i,k} * c'_k + B^l_{k,i} * r'_k$$

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Results

Classification Results

Prediction	Cortical volume	precision	recall	F1-score	valid. acc.	test acc.
NC - MCI	no	86%	70%	77%	79%	78%
NC - AD		95%	86%	90%	85%	91%
MCI - AD		78%	81%	80%	71%	81%
NC - MCI	yes	74%	74%	74%	77%	72%
NC - AD		91%	91%	91%	95%	91%
MCI - AD		80%	90%	85%	75%	86%

Table: Reported scores for the experiments with and without cortical volume per region

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Explainable AI

Features Visualization : Saliency Maps

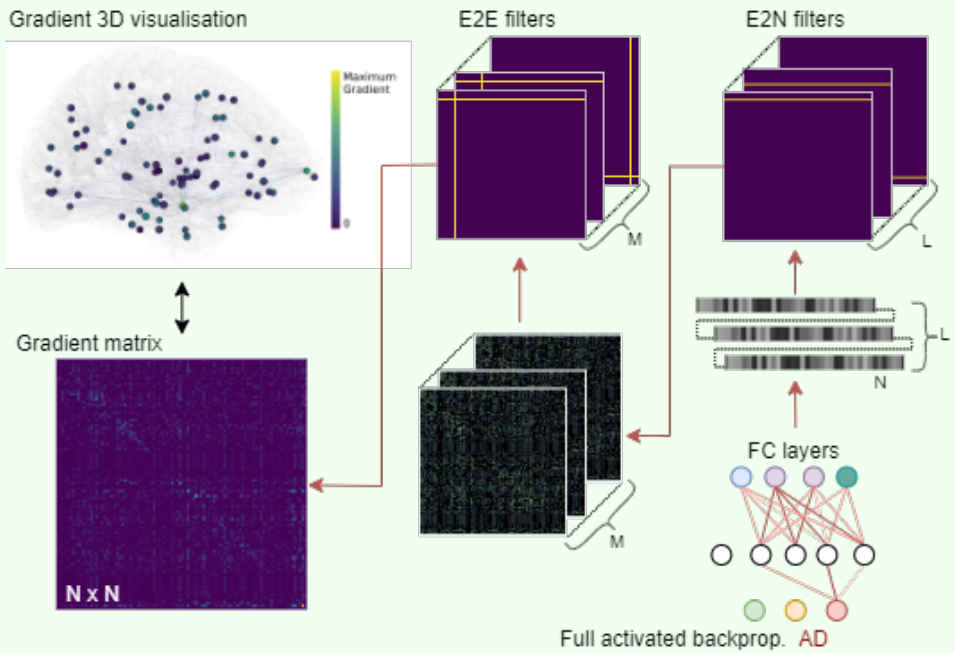

Figure: Saliency map features visualization

Explainable AI

Regions and connections ablation analysis

We evaluate the impact of changing the connectivity strength between regions of the brain on the overall performance of the model in order to determine the discriminative regions for AD

Ablation procedures

1. Node ablation : forces to zero the connections between a region *i* and every other regions
2. Node randomization : randomizes values of connectivity between a region *i* and the other regions
3. Edge ablation : forces to zero the connection between regions *i* and *j*

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Node ablation

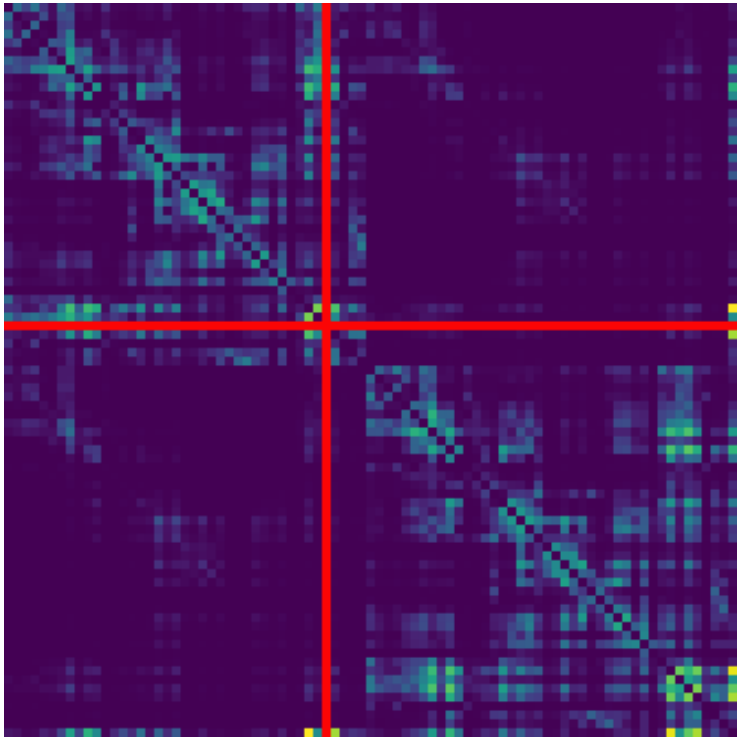

Figure: connections between a region *i* and other regions forced to zeros

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Node randomization

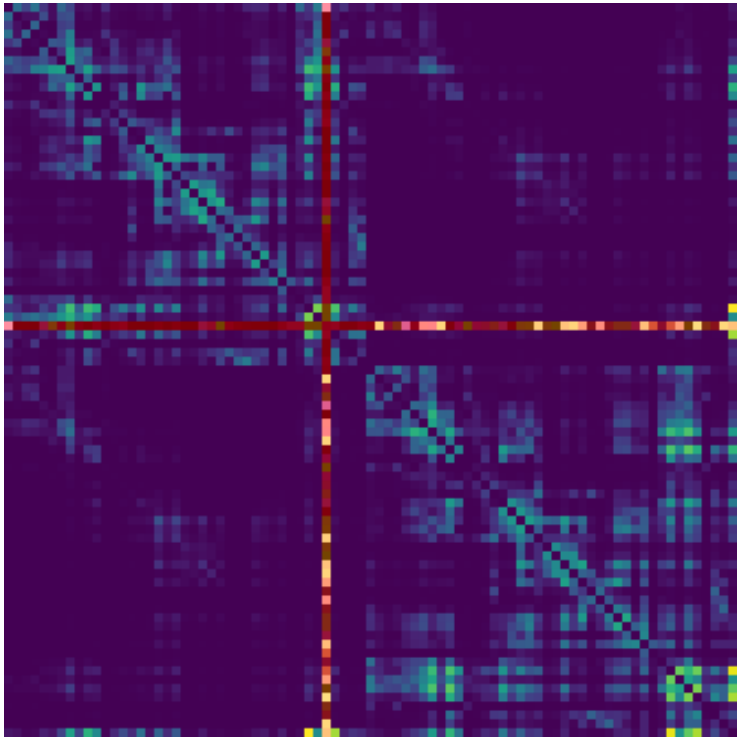

Figure: connectivity randomization between a region *i* and other regions

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Edge ablation

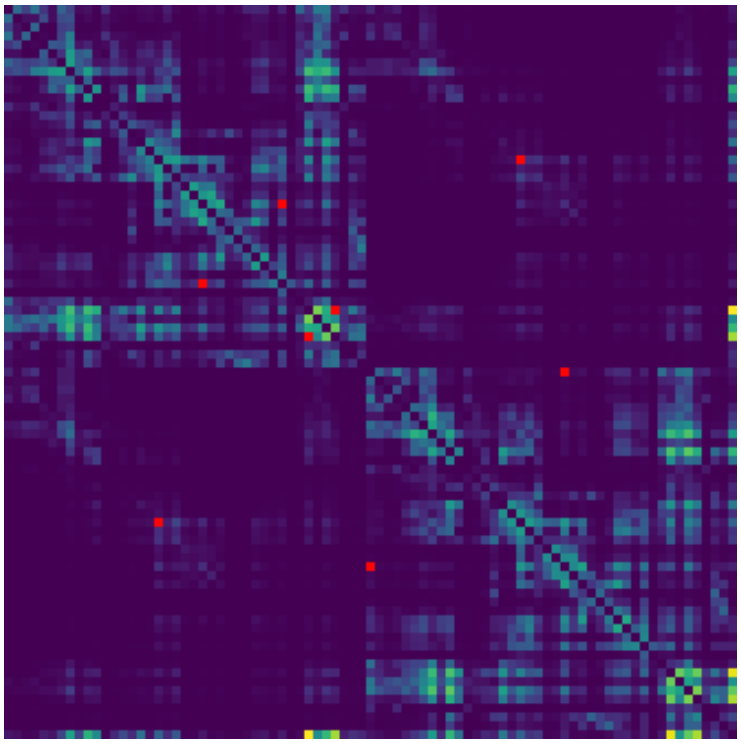

Figure: connection between a region *i* and *j* forced to zero

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Experiments

Analysis

1. **No single region** and its **connections** are responsible for AD prediction but **combined** several **effect** of multiple cortical regions
2. The **amplitude** of the **retropropagated** gradient underlines which regions correlate with the neural net prediction
3. **Entorhinal** is the most intense difference between AD and NC along with **hippocampus** for MCI and NC
4. The reported regions are **correlated** with the ones from Alzheimer literature

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Future works & perspectives

Future works

- Creating larger datasets as disease progression can be assessed as a continuum in time
- Incorporating anatomical priors for the structural connectome reconstruction
- Adding information from relevant brain features like fractional anisotropy (FA), mean diffusivity (MD), other MRI contrasts
- Application of advance geometric or graph CNN over the connectome

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Acknowledgments