Exploring the Efficacy of Machine Learning Integrating DTI Biomarkers and Classification Techniques to Facilitate Timely Detection and Precise Stratification of Discrete Stages in Alzheimer's Disease

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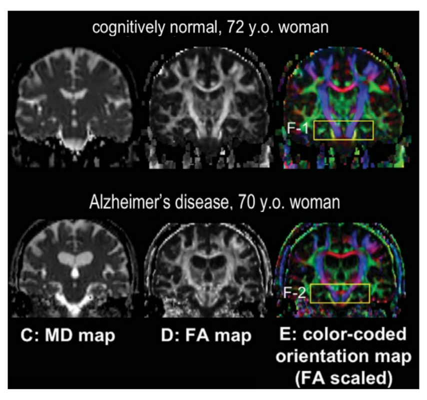
Background & Aims

Background. Alzheimer's Disease (AD) leads to a reduction in white matter volume, especially in the medial temporal and hippocampal regions[1]

- DTI is a neuroimaging technique sensitive to microscopic changes of brain tissue, making it a vital tool for detecting early changes in brain structure before the onset of severe symptoms[2]
- Early detection is of utmost importance for timely treatment and prevention of further cognitive deterioration[3]

Aims. Classify patients as having AD, Mild Cognitive Impairment (MCI), or normal cognition based on various DTI measures of ROIs and identify significant biomarkers in prediction.

- Additionally, identify which DTI measure is most significant



Methods

The Data

- ADNI3 Dataset
- Recorded FA, AxD, MD, and RD for ROIs
- Grouped participants into AD, CN, MCI, e-MCI, l-MCI, and SMC
- Created another dataset with AD, CN, and MCI
- Removed confounding variables
- Standardized data using StandardScaler
- Principal Component Analysis

ADNI Alzheimer's Disease Neuroimaging Initiative

Algorithms

- Supervised machine learning classification models best suited for this scenario
  - Random Forest, SVM, Naive Bayes, Logistic Regression, k-Nearest Neighbors, Discriminant Analysis
- Tested each algorithm on both datasets
- Used metrics of accuracy, precision, recall, and F-score to evaluate performance
- Created confusion matrices to evaluate performance for each research group

Resampling

- Imbalance of samples across research groups = biased models
- Tested both oversampling and undersampling techniques to balance
  - bSMOTE, ADASYN, ENN, etc.

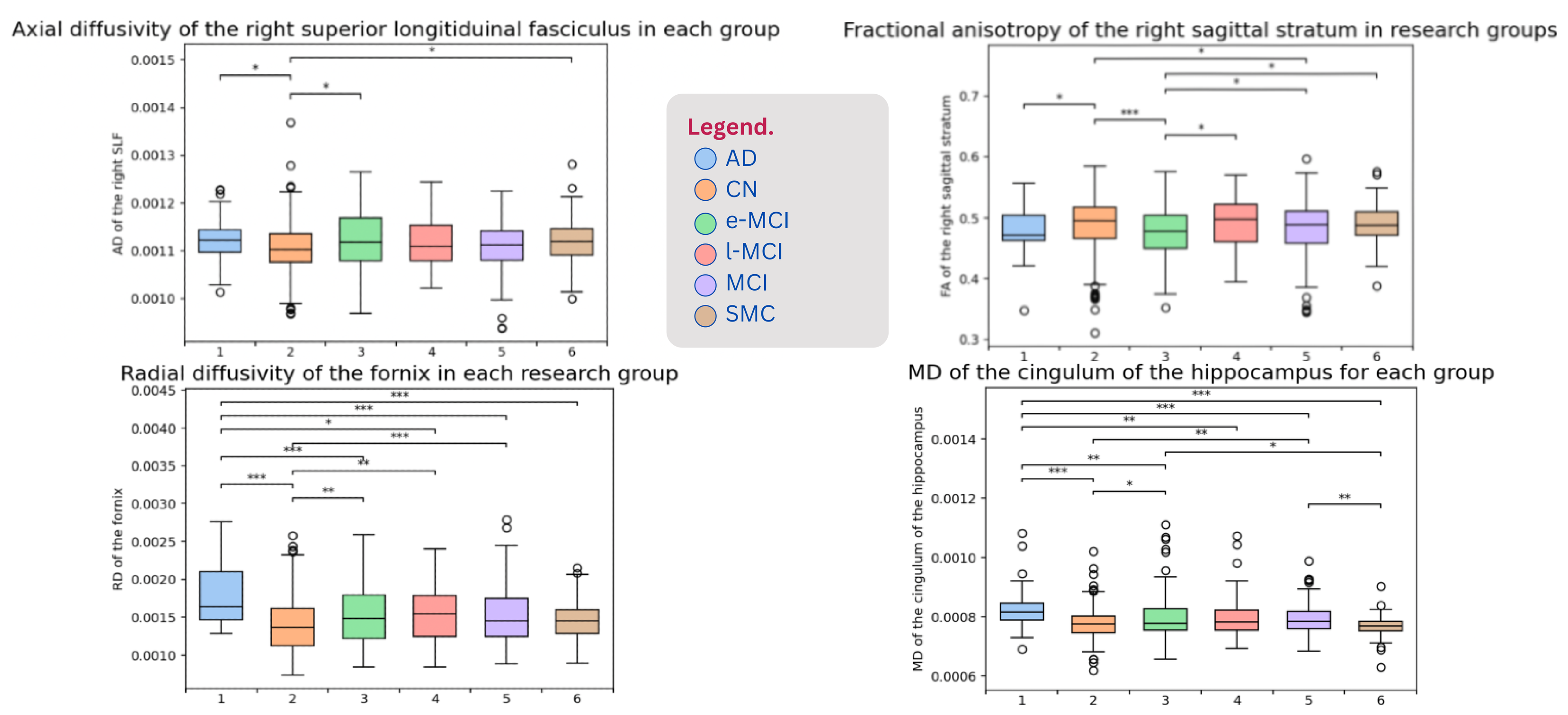
Results

Fig. 1. The top 9 features of the Random Forest Classification algorith, sorted by brain structure, DTI measure, and importance.

Brain Structure	DTI Measure	Importance
Hippocampal cingulum - left (CGH-L)	MD	0.02235
Body of corpus callosum (BCC)	AD	0.0164
Hippocampal cingulum - left (CGH-L)	RD	0.01556
Fornix/stria terminalis (FXST)	MD	0.01384
Fornix (FX)	RD	0.01233
Corticospinal tract - right (CST-R)	FA	0.01217
Fornix (FX)	FA	0.01135
Sagittal stratum - right (SS-R)	FA	0.00993
Superior fronto-occipital fasciculus - left	AD	0.00845

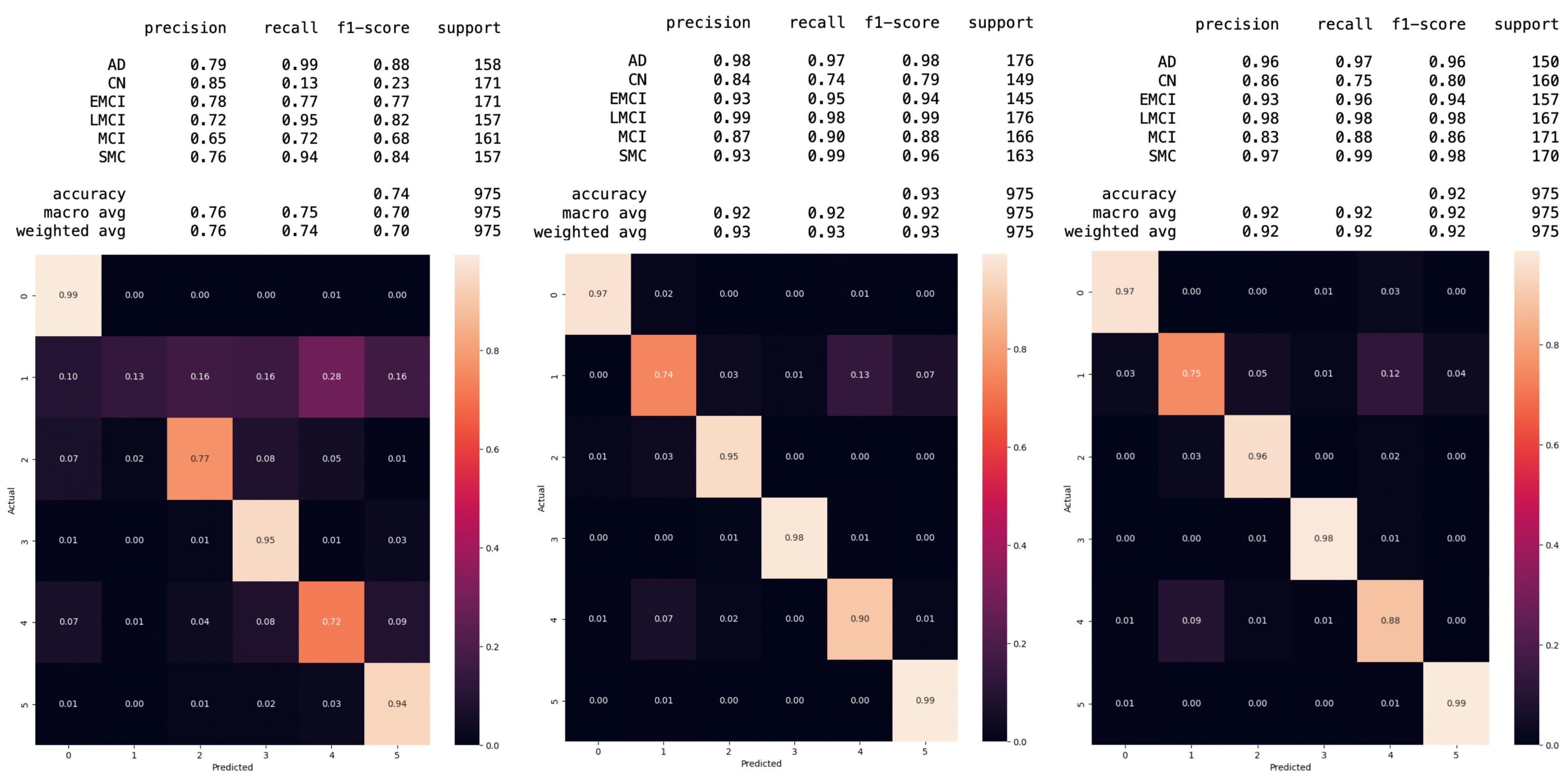
* Higher importance numbers correlate to higher significance

Fig. 2. While some DTI measures show significant differences between groups (RD, MD), others are relatively consistent (AD, FA).



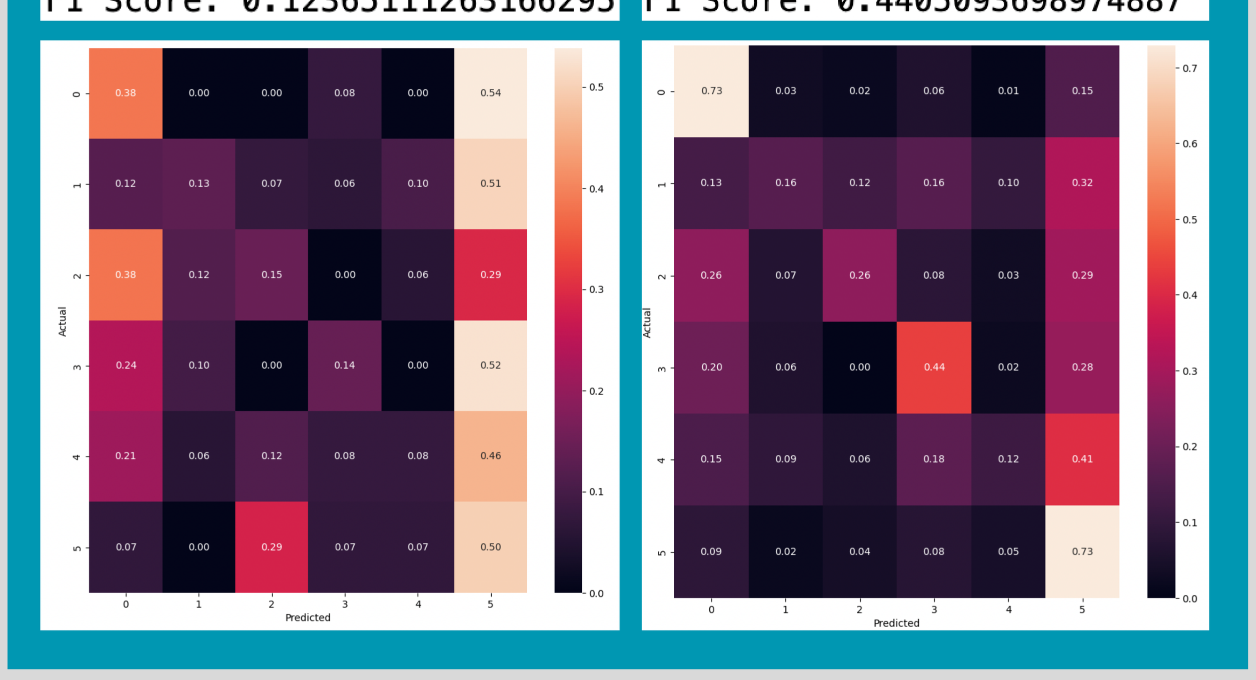
- When examining different algorithms, it's important to consider a variety of metrics
  - While some models have a high overall accuracy score, that may be because they are biased towards a certain group

Fig. 3. Each confusion matrix and classification report represents the three best-performing models k-Nearest Neighbors, Gradient Boosting, and Random Forest) from left to right.



Before and After Resampling (bSMOTE)

Accuracy: 0.1525974025974026	Accuracy: 0.403076923076923O5
F1 Score: 0.12365111263166295	F1 Score: 0.4405093698974887



Discussion

Analyzing results. Using a Gradient Boosting Algorithm with SMOTE + ENN produces best average accuracy score

- However, accuracy for predicting CN is extremely low --> bSMOTE is preferred
- AD first damages the entorhinal cortex, aligns with our findings of significant ROIs in prediction[4]

Fig. 4. Alterations in normal behavior of axons are exhibited by lower FA and higher MD values.[5]

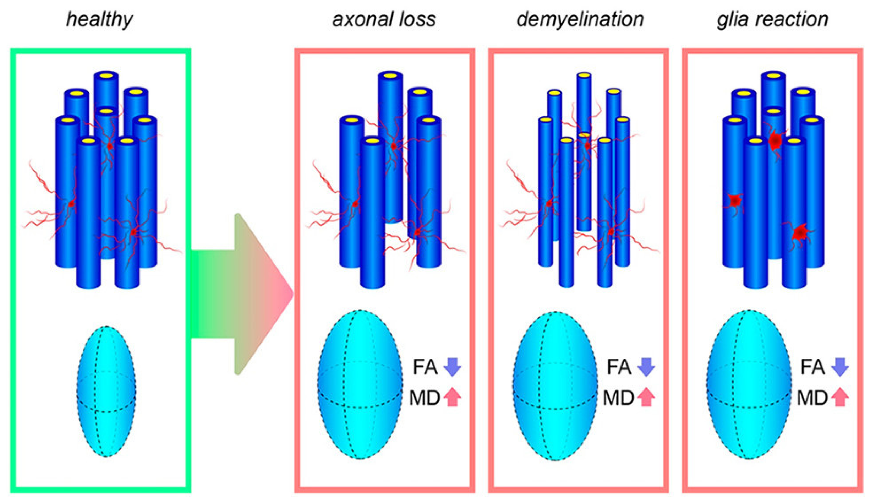
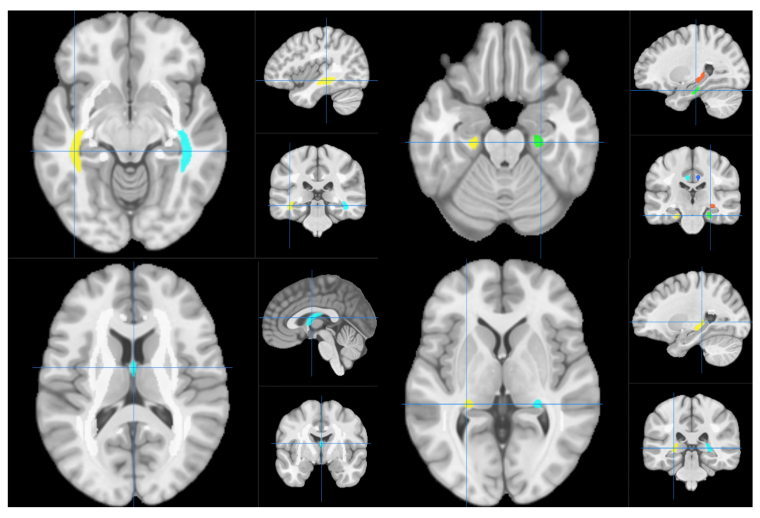


Fig. 5. Significant ROIs, from left to right and top to bottom, are as follows: sagittal stratum, cingulum of the hippocampus, fornix stria terminalis, fornix



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