Classification of Alzheimer's Disease using MRI and Related Features

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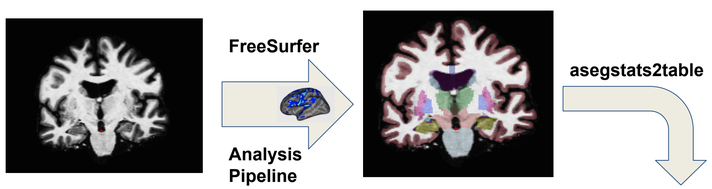
Motivation

According to a WHO survey from 2017, Alzheimer's Disease (AD) affects an estimated 47 million people worldwide[1]. Clinical diagnosis of AD is challenging especially in its early stages. With the aid of MRI processing tools and classification techniques, we are aiming at improving diagnosis efforts. Decision Tree (+Ensemble), SVM, and Deep Learning models were trained using the dataset containing various MRI and other features. Following our comparisons between various models, we determine that AdaBoost and Neural Network were able to make the best prediction of presence of AD.

Data

We used volumetric biomarkers from MRI images along with demographic and cognitive test features labeled with the ground truth values ("AD" and "Normal") as part of our training data obtained from the Alzheimer's Disease Neuroimaging Initiative [2] (ADNI). To gather volumetric data we used preprocessed ADNI MRI images and also processed raw .nii format MRI images using FreeSurfer [3]. As part of the FreeSurfer analysis pipeline overview, various image intensity normalization is performed.

MRI Processing



Measure:volume	Left-Lateral-Ventricle	Left-Thalamus-Proper	Left-Putamen	Left-Hippocampus
ADNI_429	17055	7176.8	5730.8	3767.5
Measure:volume	**Left-Lateral-Ventricle**	**Left-Thalamus-Proper**	**Left-Putamen**	**Left-Hippocampus**
ADNI_429	1219.7	691.5	330.7	5372

Figure 1: Using Freesurfer Processing as part of our pipeline to extract volumetric biomarkers. First a .nii raw format MRI file is processed with recon-all command for each subject. A subcortical segmentation of the brain then labels different volumes regions such as the right-hippocampal region. Lastly, the data is tabulated with the asegstats2table.

Features

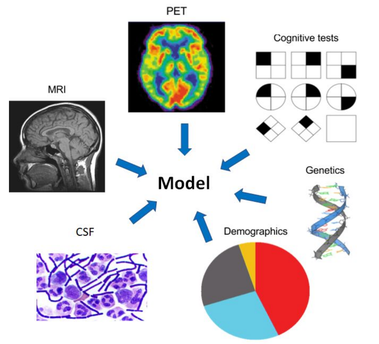


Figure 2: six categories of feature used in the model

86 features were used that can be separated into 6 categories: demographic (4), genetics (1), PET(2), MRI(82), CSF(3), and other cognitive tests(3). The majority of the features were brain volumes of different ROIs and these volumes tend to correlate with the presence of Alzheimer's Disease.

We then applied LDA or PCA to compress the number of features to 10 because our dataset provided very few samples leading to overfitting.

Models

Neural Network:
We used a classifier with 2 hidden layers, each with 3 and 2 neurons respectively; using a cross-entropy loss and logistic activation function.

$$g(z) = \frac{e^z - e^{-z}}{e^z + e^{-z}}$$

$$Loss(\hat{y}, y, W) = -y \ln \hat{y} - (1-y) \ln (1-\hat{y}) + \alpha ||W||_2^2$$

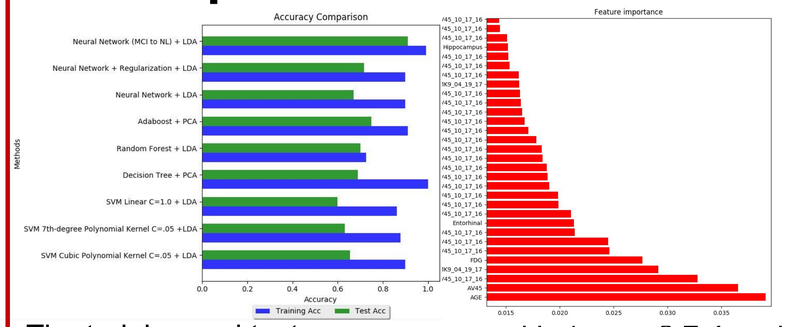
SVM:
Both linear and non-linear (polynomial kernel) classification with SVM turning regularization parameters C were used.

$$K(x, y) = (x^\mathsf{T} y + c)^d \qquad C \sum_{i=1,n} \mathcal{L}(f(x_i), y_i) + \Omega(w)$$

AdaBoost:
We used exponential loss function to update weights D of the weak learner h, which consists of T decision trees.

$$D_{t+1}(i) = \frac{D_t(i) \exp(-\alpha_t y_i h_t(x_i))}{Z_t} \qquad H(x) = \text{sign}\left(\sum_{t=1}^{T} \alpha_t h_t(x)\right)$$

Experimental Results



The training and test accuracy ranged between 0.7-1 and 0.6-0.75, respectively, with AdaBoost and Neural Nets performing better than the others. The top 5 important features were age, two MRI features, AV45 (PET), MK9 (CSF), and FDG (PET).

Discussion

We observed heavy correlation between certain PET/MRI features and AD. We were able to get some satisfactory results after applying regularization, and feature compression using LDA or PCA. We achieved high testing accuracy when separating samples into two classes: AD or Normal. But we did not achieve such high testing accuracy when we classified patients with Mild Cognitive Impairment as having AD. This could be due to the specific sample set we were using or unclear separation between Mild Cognitive Impairment (MCI) and Normal.

Future

Based on the number of data points labeled as having AD, it would be worth exploring more data containing the same biomarkers, with AD labeling. The preprocessed data from the ADNI database contains a wide variety of AD labeled subjects, but not all contain relevant biomarkers or demographic data.

References

[1] "Dementia", World Health Organization, 2017. [Online]. Available: http://www.who.int/mediacentre/factsheets/fs362/en/.
[2] "ADNI — Alzheimer's Disease Neuroimaging Initiative", Adni.loni.usc.edu, 2017. [Online]. Available: http://adni.loni.usc.edu.
[3] "FreeSurferWiki - Free Surfer Wiki", Surfer.nmr.mgh.harvard.edu, 2017. [Online]. Available: https://surfer.nmr.mgh.harvard.edu/fswiki.