A deep learning model to predict dementia from brain MRI scan

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Abstract

This project aims to predict whether a patient is at risk of Alzheimer's disease (AD) or cognitive decline based on their structural MRI scans. We construct a deep learning model to predict an individual's brain age using T1-weighted MRI to gain insight into their cognitive state based on the difference between the model's predicted age and the individual's chronological age.

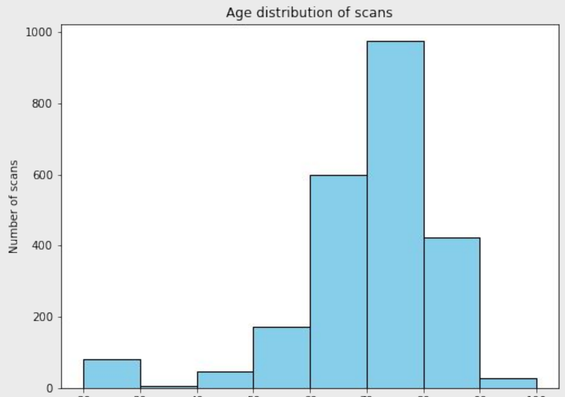
Introduction

Brain age estimation not only is useful for studying the aging process itself, but also is a useful biomarker for diseases. Deep learning methods have garnered much interest and have been extensively applied to brain age prediction. When a model trained on a healthy population is applied on possibly abnormal participants, the divergence of one's estimated age and chronological age is associated with various diseases including Alzheimer's disease, schizophrenia, and traumatic brain injury. Ideally, the trained model should accurately predict the age of healthy participants and systematically overpredict the age of participants in cognitive decline.

Dataset

- **2482** T1-weighted MRI scans from Open Access Series of Imaging Studies (OASIS-3)
- **645** scans from Berkeley Aging Cohort Study (BACS).
- For each scan, we determine the corresponding subject's age at the date of the scan and their most recent Mini-Mental State Examination (MMSE) score. From OASIS-3, we keep the first and last scans for each subject. The scans with a corresponding MMSE score less than 25 are moved into the test set as cognitive decline (AD). 10 % of the remaining scans from OASIS-3 and BACS are also moved into the test set as healthy control (HC).

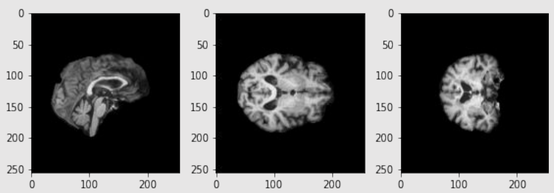
The remaining scans are used for training and validation. The scans' age distribution is shown below; most of the scans are between 60 to 90 years of age. We also do not account for the fact that some individuals have only one scan in the dataset whereas others have two.



Method

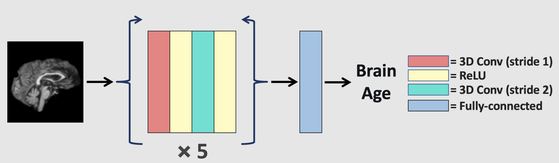
- **MRI preprocessing**:

The normalized T1-weighted MRI scans are processed by the FreeSurfer brain imaging software package.



- **Convolutional neural network:**

We use a 3D convolutional neural network (CNN) for age estimation. The inputs to the network are MRI scans, and the outputs are continuous age predictions.



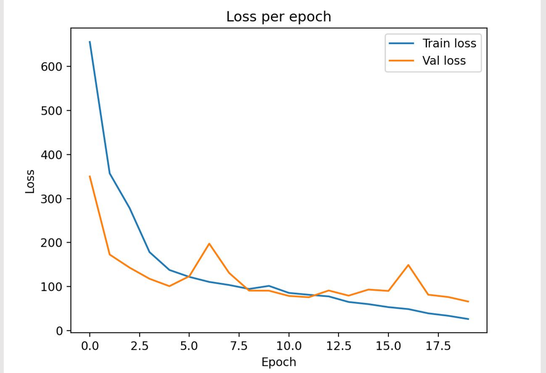
Convolution neural network architecture

We use the Adam optimizer with mean squared loss (MSE) as the loss function, and the model is evaluated using mean absolute error (MAE). The model was implemented in the PyTorch framework and trained on a NVIDIA A40 GPU.
We tried a variety of architectures, such as a variant of the above network with max pooling instead of strided convolutions. In addition, we implemented 3D versions of ResNet-10 and ResNet-18.

Results

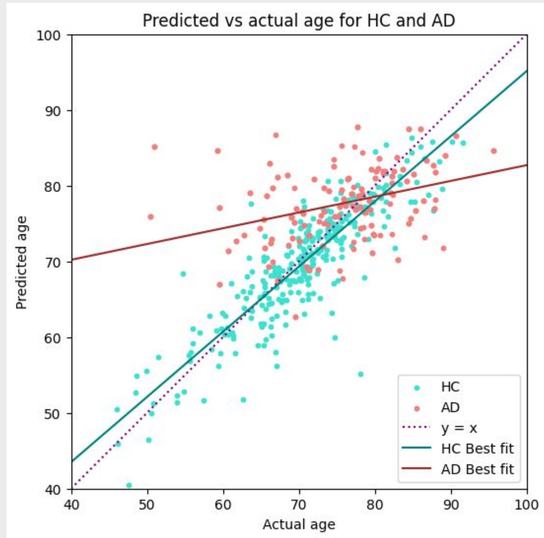
	MAE (HC)	MAE(AD)
Strided Convolutions	**2.979**	6.129
Max pooling	4.196	5.500
ResNet-10	4.818	6.980
ResNet-18	3.920	6.803

The best performing model is the **CNN with strided convolutions**. The train and validation loss curves for the model are shown below.



The best performing model gives the most accurate predictions for healthy participants and, on average, overestimates the age of participants with cognitive decline by a large margin, coinciding with our expectation that individuals with cognitive decline tend to exhibit higher brain age than chronological age.

Shown below is a scatterplot of the actual age vs. the best performing model's predictions on the test set.



Conclusion & Future Work

- By applying a CNN based architecture, we show that brain age estimation is invaluable to the prediction and diagnosis of diseases relating to cognitive decline
- Deep learning is an effective method of brain age estimation
- Next steps include accounting for the data imbalances mentioned earlier, expanding to a larger dataset, finding an independent test set and constructing a secondary classifier that predicts whether an individual is in cognitive decline given the difference in their predicted brain age and chronological age
- The causes and implications of cognitive diseases such as Alzheimer's are not yet completely understood, and will likely remain that way for the foreseeable future. Hopefully, the day will come when we can predict and treat these diseases with accuracy and with ease. Until then, brain age estimation will be relevant, and so will our work.