Machine Learning on Brain Graph

Supervisor: Dr. Ashish Khisti | Administrator / Section number: Mr. Ross Gillett / 07
Shi Hu, Jixiong Deng, Yuxi Cai
Department of Electrical and Computer Engineering, University of Toronto

Introduction

- fMRI: functional magnetic resonance imaging that reveals the activity of brain region based on blood flow [1]
- Brain graph: graphical representation of brain that shows the connectivity among regions
  - Region of brain: node
  - Connection/correlation between regions: edges
- Together: diagnosis of brain diseases [2]

Project Goal

The goal of this project is to develop a machine learning solution that can

- take fMRI data from public sources as input
- distinguish fMRI samples with ASD (Autism Spectrum Disorder) from healthy control

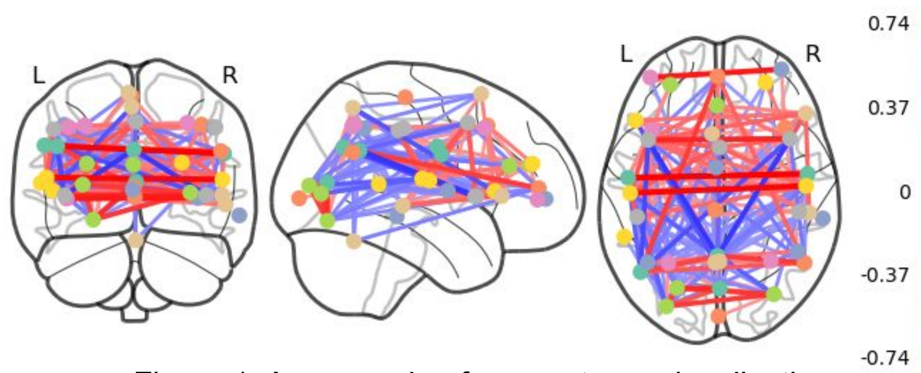

Figure 1. An example of connectome visualization

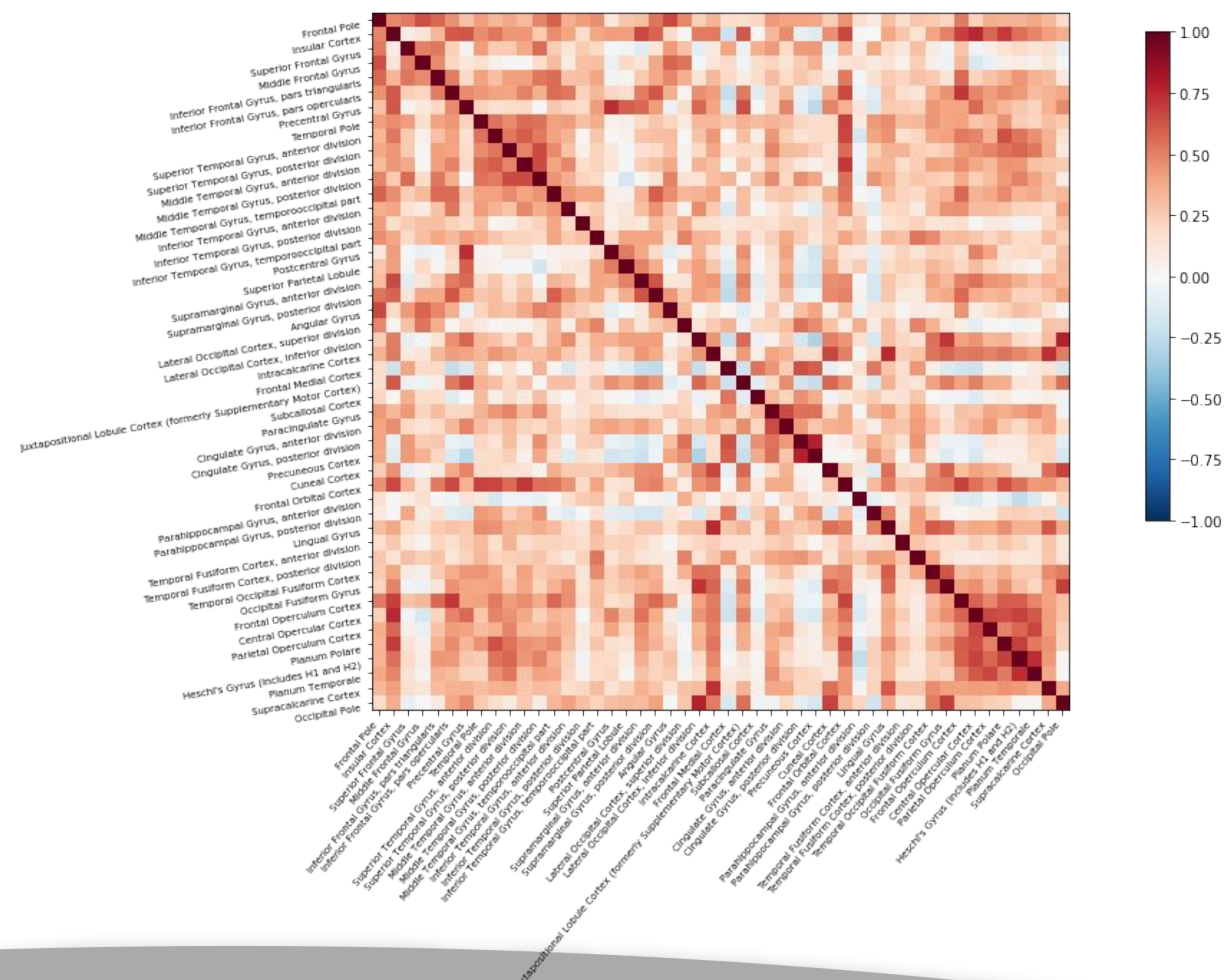
Figure 2. An example of connectivity matrix (brain graph) visualization

Final Design

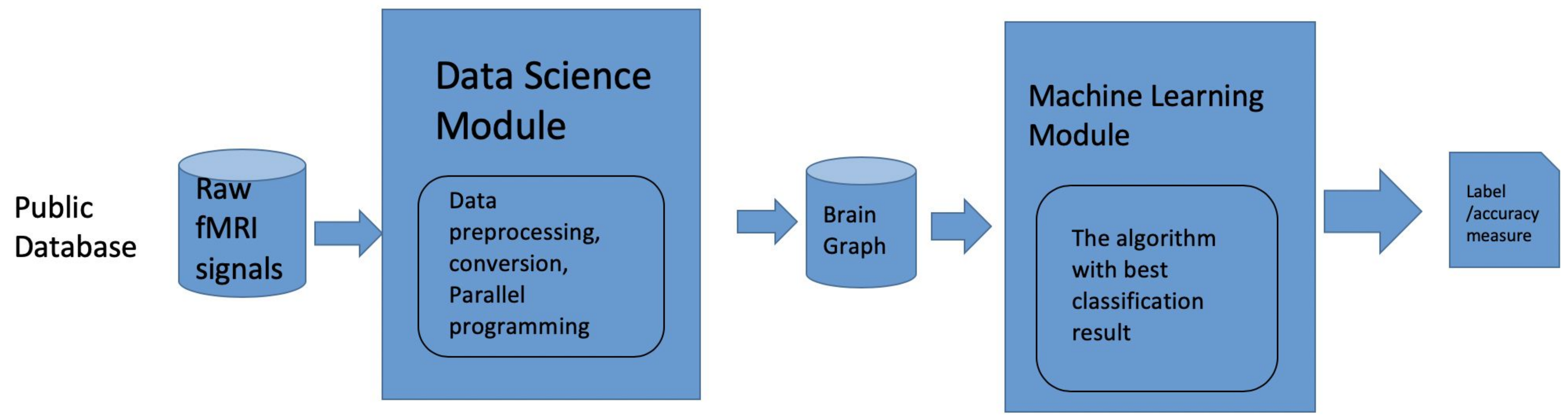

Figure 3. System block diagram

Data Science module:
collects and labels resting state fMRI from preprocessed ABIDE (Autism Brain Imaging Data Exchange) database, converts to brain graphs and stores as csv files [3]
Highlights:

- brain regions: the mask used for correlation calculation is the 48 cortical regions defined by the Harvard-Oxford parcellations [4]
- sample size: healthy control: 468, ASD patient: 403

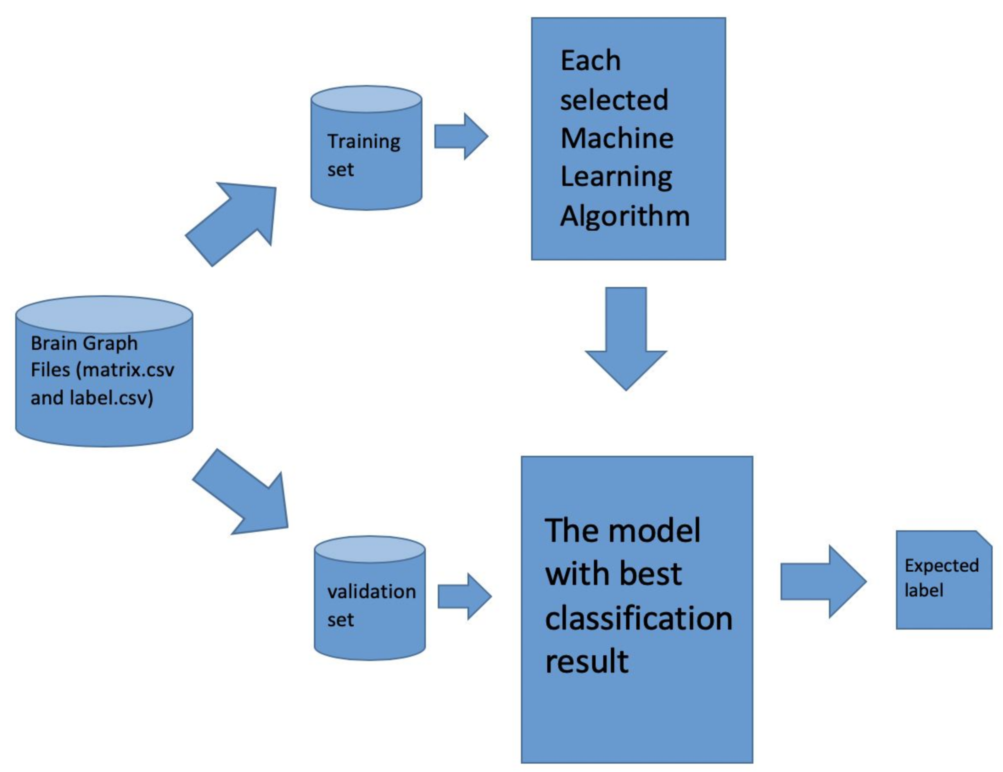

Figure 4. Detailed block diagram for the machine learning module

Machine Learning module:
Separates the incoming dataset into a training set and a validation set. Then, trains a machine learning model for every selected algorithm, based on the training set. Lastly, evaluates and selects the best model (Figure 4).
Highlights:

- The algorithms implemented are shown in Table 1

Table 1. The chosen classification model and the corresponding description for the machine learning module

Model	Description
Support Vector Machine (SVM)	A traditional algorithm proven strong as a classifier.
SVM with Gaussian kernel (RBF SVM)	Improvement on SVM with a radial basis function kernel usually resulting in smoother functions, thus improving classification.
multi-layer perceptron (MLP)	The basic version of neural network, which is proven to be very effective to do classification.
Convolutional Neural Network (CNN)	Typically used to classify images and an adjacency matrix can be viewed as a mono-channel image
DeepWalk + MLP [5]	Both DeepWalk and SDNE are graph embedded algorithm. Firstly, compute a vector representation for each vertex of a graph. Then, these vectors are fed into MLP model to do the classification work.
Structural Deep Network Embedding (SDNE) + MLP [6]	

Result and Conclusion

Based on the accuracy shown in Table 2, we chose the model based on MLP algorithm as the optimal model.

- this is expected as MLP is proven to be effective for classification. However we did expect DeepWalk and SDNE will improve the accuracy and this was the case when testing with synthetic data. But in reality, the brain graph can be noisier and more complex than the synthetic data.

Table 2. Performance of each model

Algorithm	Training Loss	Training Accuracy	Validation Loss	Validation Accuracy
basic SVM	0.592192	97%	0.626772	92%
RBF SVM	0.620976	100%	0.689268	92%
MLP	0.656901	99%	0.677377	97%
CNN	0.69032	54%	0.693904	51%
DeepWalk + MLP	0.346648	99%	0.797786	50%
SDNE + MLP	0.394087	99%	0.878836	49%

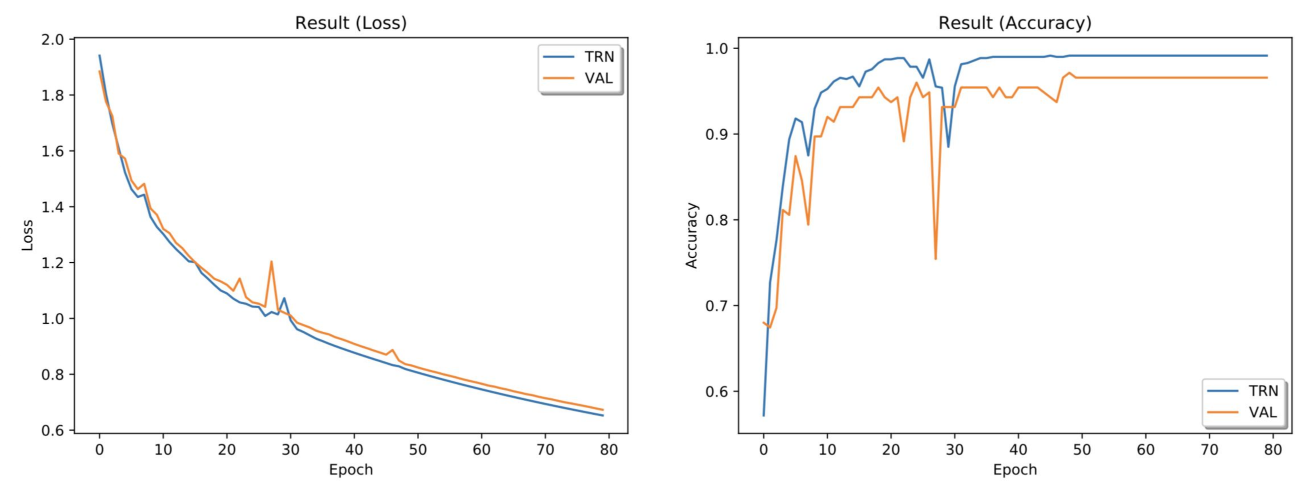

Figure 5. Learning curves of MLP

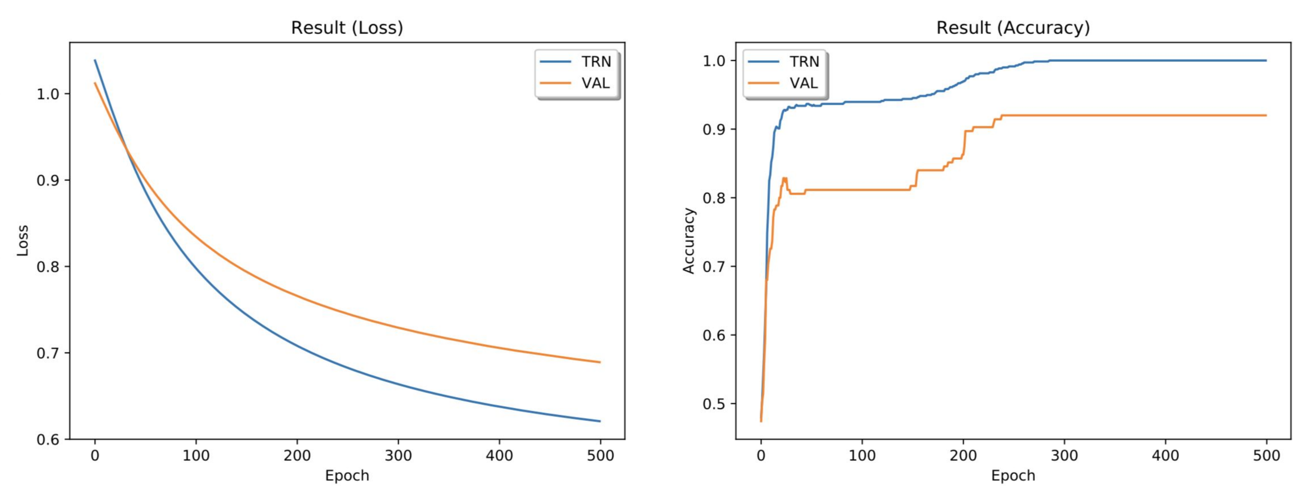

Figure 6. Learning curves of SVM + Gaussian kernel

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