Connectivity in the Human Brain Using Functional MRI Data: Classification of Sex with Graph Neural Networks

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Problem Statement

- Sie et al. (2019) found that females had stronger pairwise correlations in the Default Mode Network compared to males.
- **Our goal is to develop and train a Graph Neural Network that accurately classifies sex using resting-state BOLD signal data.**

The Dataset

- The 2018 HCP Young Adult data release contains the denoised network matrices and time series for 569 female subjects and 464 male subjects between 22 and 35 years-old.

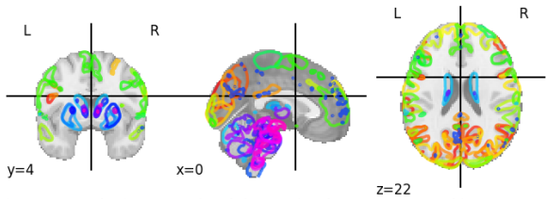


Figure 1. Voxel-wise BOLD signal time series data preprocessed into 100 regions via ICA. An illustration of the brain regions whose pairwise correlations are measure to estimate functional connectivity.

Modeling the Brain

Estimating the Network

- 427 out of 4950 pairs of brain regions showed significant differences in resting activity between males and females, suggesting the success of our classification task.

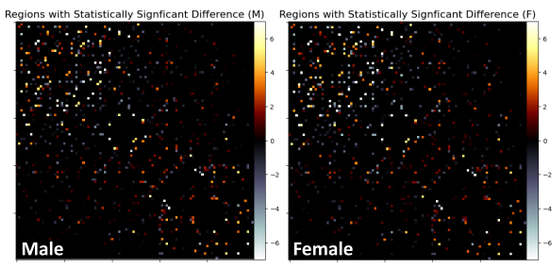


Figure 2. Pairwise correlations in Males and Females with statistically significant differences. Males (left) have lower absolute pairwise correlations than females (right), on average.

Simulating the Network

- We simulated datasets at different levels of separability using weight vectors sampled from sinusoidal waves.

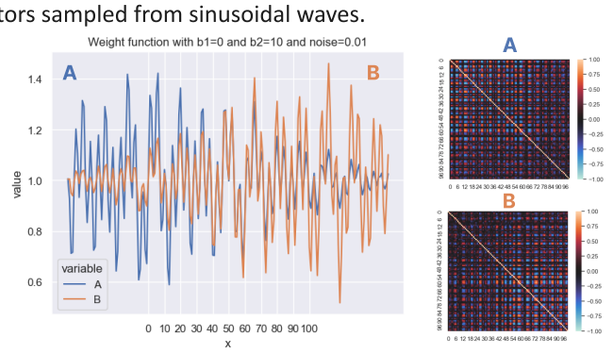
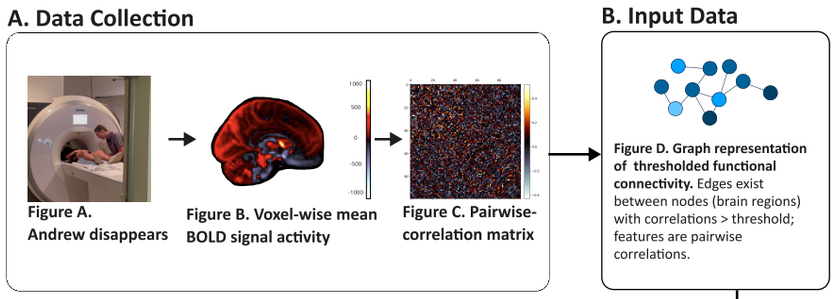


Figure 3. Simulated datasets of Subject A (blue) and Subject B (orange). Subject A (top) and Subject B (bottom) pairwise correlations were generated at increasing degrees of separability.

The Graph Neural Network (GNN)

What is a GNN?



Our GNN Architechture

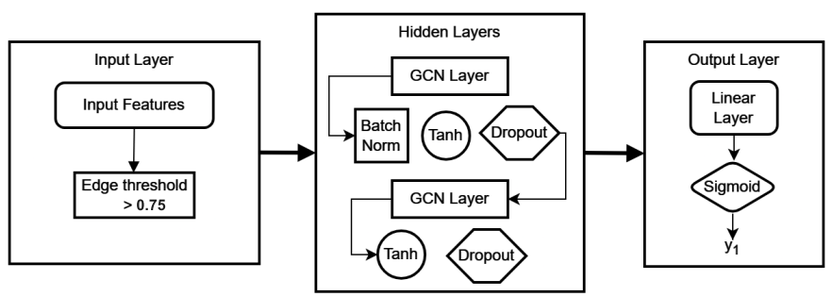


Figure 4. Binary Classifier GNN trained on thresholded Fisher-transformed correlations.

- GNN uses two GCN (Graph Convolution Network) layers that map to a lower dimension of 30; first layer uses Batch Norm (Optimization), Dropout (Regularizer), and Tanh (Activation Function); second uses only Tanh which reduces to a linear layer and finally a sigmoid (output of 0-1).
- Test and compare GNN models by pruning edges or shuffling labels; splitting data to 80:10:10 (training, validation, testing); ensemble models, change in architecture, tune hyperparameters.

WEBSITE

Graph neural networks can distinguish **sex** based on **brain activity**.

Results

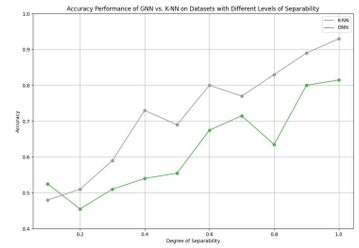


Figure 5. GNN vs. K-NN: Classification task performance on Separable (Simulated) Data. There is a positive relationship between accuracy and separability of groups for both models.

Model	Accuracy (Validation)
GNN Thresholded Edges	86.0%
K-NN [k=10]	84.86%
GNN Significant Edges	80.0%

Figure 6. GNN vs. KNN: Classification task performances on HCP Data. The GNN on thresholded edges had the highest performance at 86.00% accuracy.

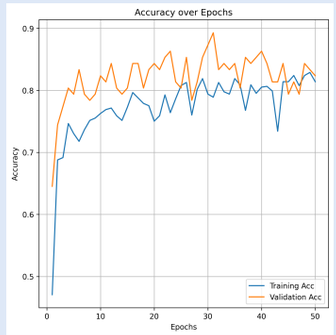


Figure 7. GNN Thresholded Edges accuracy per epoch. Monotonic increase of accuracy over epochs indicates effective classification-task performance.

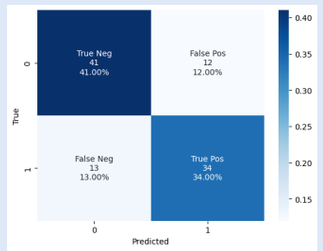
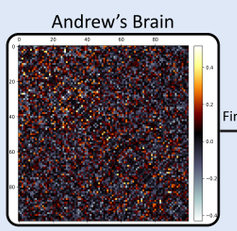


Figure 8. GNN Thresholded Edges confusion table. F1-score of 0.73. The model performed generally better at predicting males than females when given the validation dataset.



Our Graph Neural Network achieved an accuracy of **86.00% on the complex HCP data**, **outperforming** its highest accuracy when given a more **simplistic dataset** composed of increasingly separable groups.

Acknowledgements

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References

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Sie, Jia-Hong, Yin-Hua Chen, Yuo-Hsien Shiau, and Woei-Chyn Chu. *2019. "Gender and Age-Specific Differences in Resting-State Functional Connectivity of the Central Autonomic Network in Adulthood." Front Hum Neurosci 13, p. 369.*