Graph Neural Networks for fMRI Analysis

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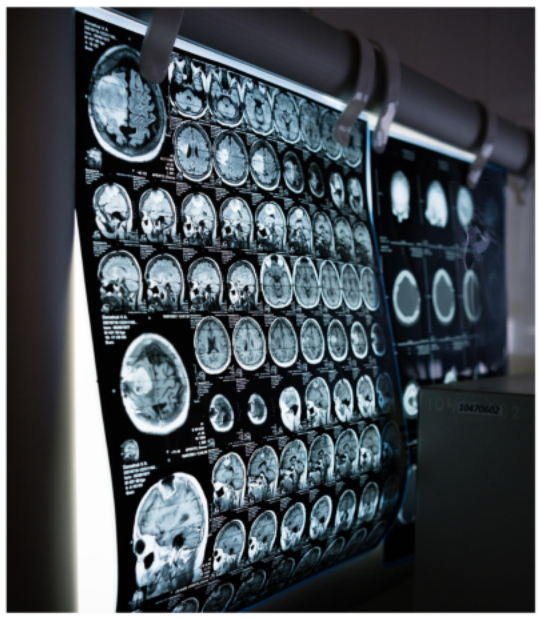
January 30th 2025, HCAIM, Utrecht, NL

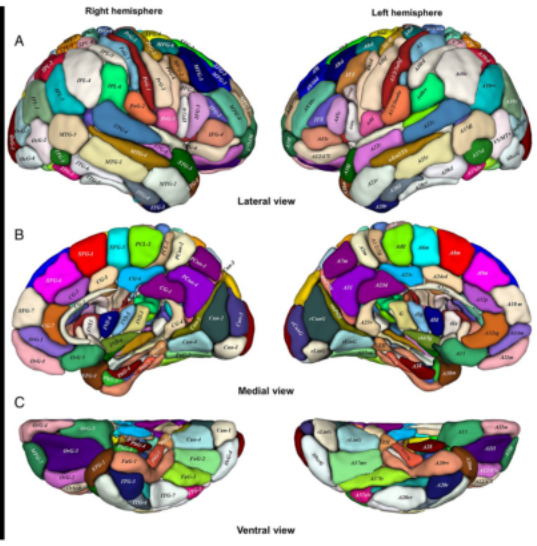
Abstract. With the help of graph neural networks we can create a tool to aid the diagnosis of neurological conditions based on the functional connectivity graph of the brain.

Introduction. Modern brain imaging techniques open an incredibly coveted window into the inner workings of the human brain. Since data from even a single high-resolution scan is too much for a human to comprehend and analyse in all details, we can turn to statistical methods and machine learning to try to make sense of the connections and mechanisms that lie within.

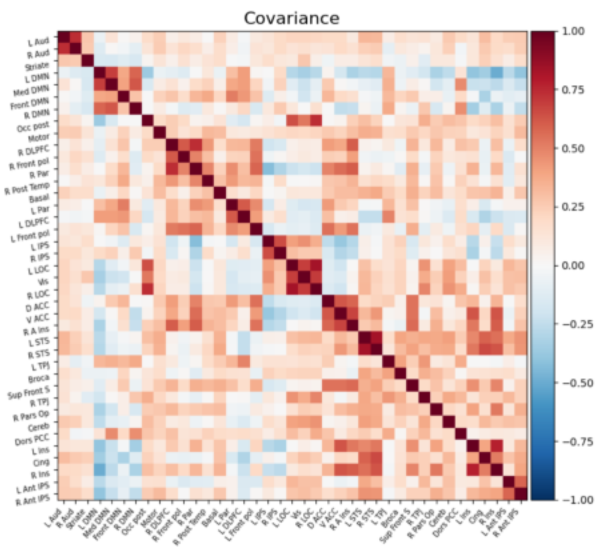
Certain psychological-neurological conditions (like ADHD, autism and severe depression) also cause a noticeable changes in how the brain functions and what neurological connections are strong. The diagnosis of these conditions is often impacted by pre-existing biases and stereotypes, meaning women and people of colour often do not get the diagnosis that would be most accurate and grant them access to helpful resources. Data quality assurance to assure the dataset is as free of bias as possible and explainability are crucial considerations.

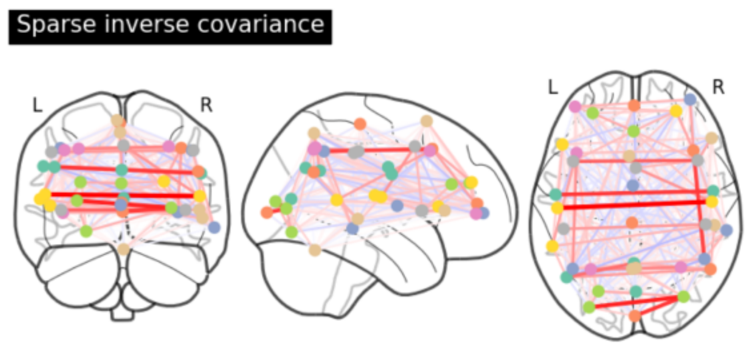


fMRI. Functional Magnetic Resonance Imaging can monitor brain activity by revealing the intensity of blood flow in sections of the brain. This increased blood flow is well correlated with more brain activity: as neurons fire more frequently in an area they require more oxygen, leading to more flow.



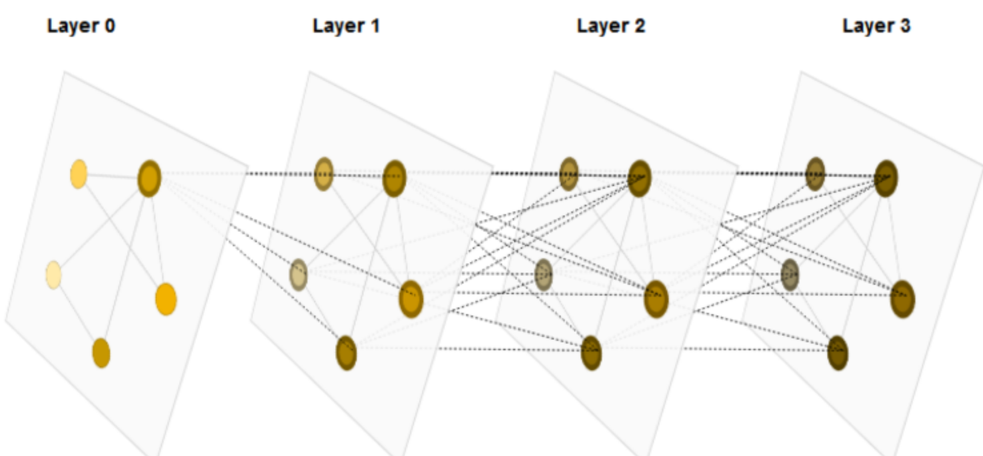
Brain Atlas. Healthcare researchers have already mapped out certain regions of the brain that are responsible for certain functions. By breaking down the brain into these ROIs (Region of Interest) it is possible to monitor their activity individually and study their connections to each other.





Connectome. Based on the covariance of the ROIs, we can estimate how strong the connection is between brain regions. These connections then form a sort of brain graph: the covariance can be thought of as an edge weight.

Graph Neural Network. GNNs work by aggregating data in a graph based on neighborhoods using message passing. Using GNNs data from the entire brain can be aggregated in a way that respects the connections and neural pathways in the brain.



Ethical concerns. Data privacy is a crucial aspect in a project like this. Involved participants share their medical data and it is unknowable what information could be extracted from a brain scan with future technology. Input data must be thoroughly vetted as to not reproduce previous bias.

Predictions. The output of the network could help by giving diagnosis predictions which could be integrated into current psychological evaluation methods. By using explainable AI techniques, mental health professionals could have more of an understanding of the neurological background of the conditions.

The HCAIM (the Human-Centred AI Master's Programme) Project is Co-Financed by the Connecting Europe Facility of the European Union Under Grant NoCEF-TC-2020-1 Digital Skills 2020-EU-IA-0068. This poster was created as part of the Blended Intensive Programme organised under the Erasmus + Programme of the European Union.

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