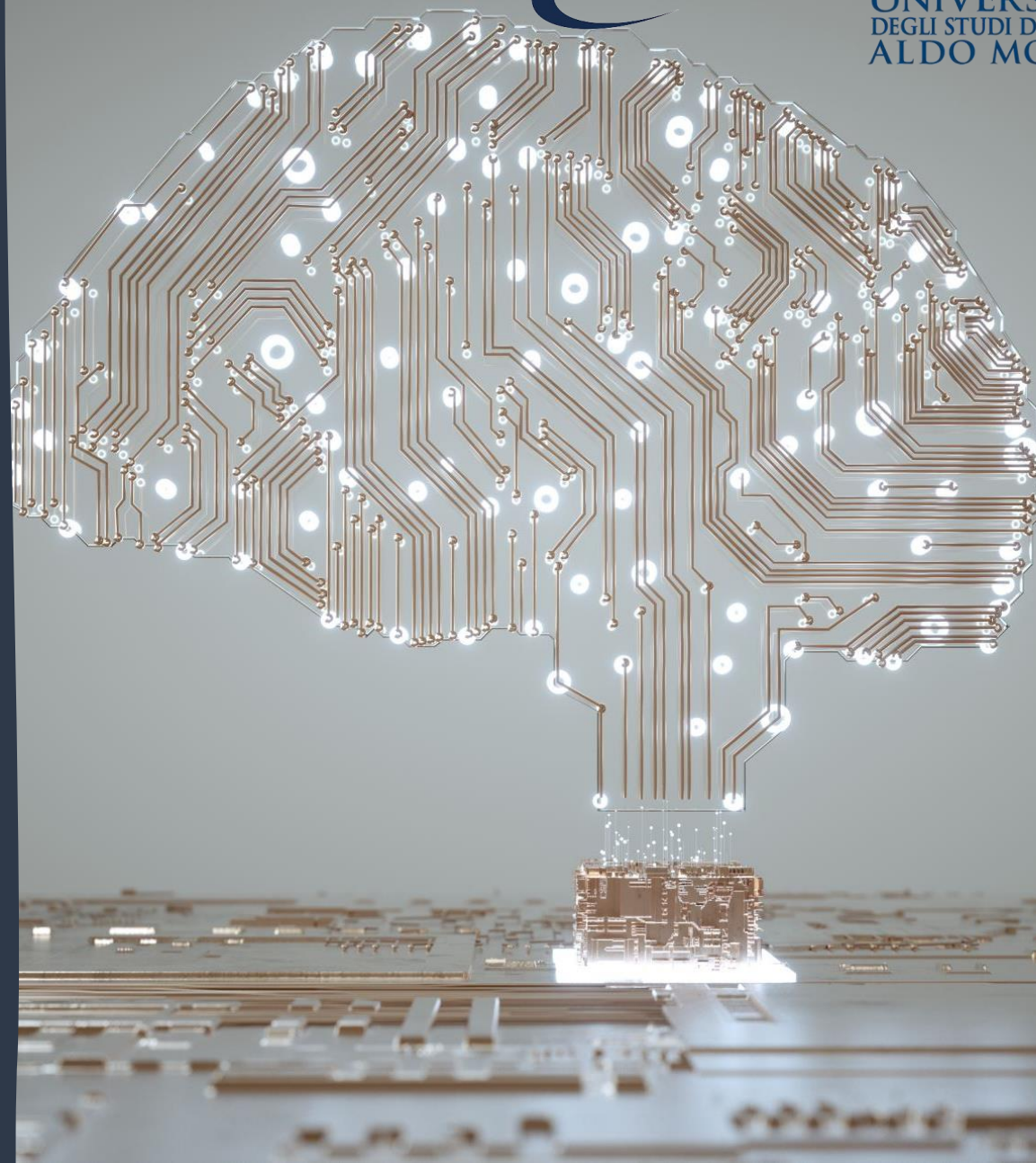


BRAIN CONNECTIVITY WITH EEG

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Outline

- EEG signals: overview
- A case of study: EEG for Parkinson's disease
- The “San Diego” dataset
- The analysis pipeline: from raw data to classifier algorithms
- The connectome analysis: complex network for brain functionality study
- The analysis results
- Conclusions and further improvements

EEG signal: Overview

The electroencephalogram (EEG) is a recording of the electrical activity of the brain from the scalp.

The recorded waveforms reflect the cortical electrical activity.

The advantages of the EEG

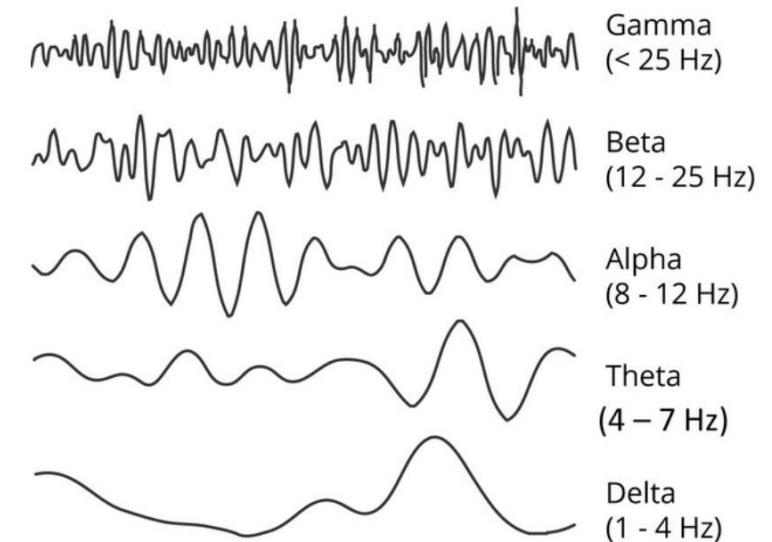
- The **temporal resolution** (millisecond scale).
- The investigations of pathologies ranging from developmental disorders to neurodegenerative disease.
- Relatively cheap neuroimaging technique, which does not require the head/ body to be fixed.

Band structure

A healthy human EEG will show certain patterns of activity which correlate with how awake a person is.

The range of frequencies one observes are between 1 to 30 Hz and amplitudes will vary between 20 to 100 μ V.

The observed frequencies are subdivided in various groups, named “band”.



CASE OF STUDY: EEG for Parkinson's disease

Parkinson's disease is a neurodegenerative disease in which neurons in the substantia nigra of the brain become damaged. These neurons are in charge of producing a substance known as dopamine, which is a chemical that acts as a messenger between neurons in the brain.

It assists the brain in sending messages to various regions of the body in order for it to work properly, particularly when it comes to body movements and speech delivery.

EEG is considered to be one of the most important PD diagnostics tool.

The “San Diego” dataset

PD					HC			
N. total	Age	State	Gender	Medication	N. total	Age	Gender	State
15	63.20±8.20	Rest	9 females 7 males	On/off	16	63.50 ±9.60	8 females 7 males	Rest

Rest

sit comfortably and relax their eyes by fixating on a cross on a screen during data collection

PD

Parkinson’s disease patients

They had mild to severe Parkinson’s disease, with an average disease duration of 4.5 to 3.5 years.

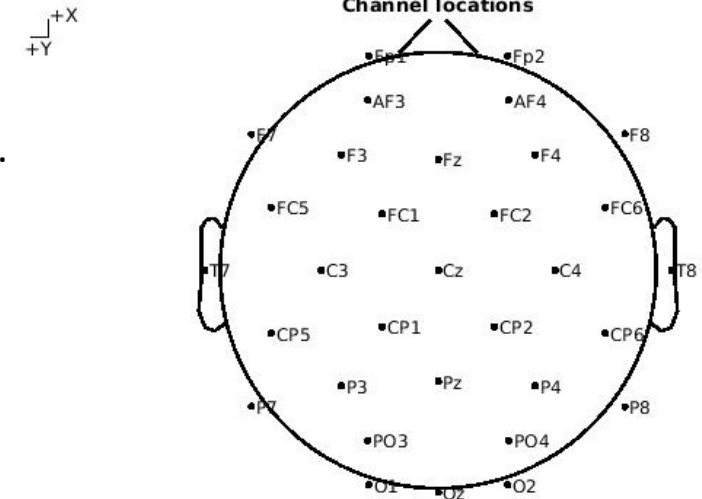
HC

Healthy control

Medication

- On medication: patients take their usual medication in the morning
- Off medication: the time between the last dose and the visit was 12h or more.

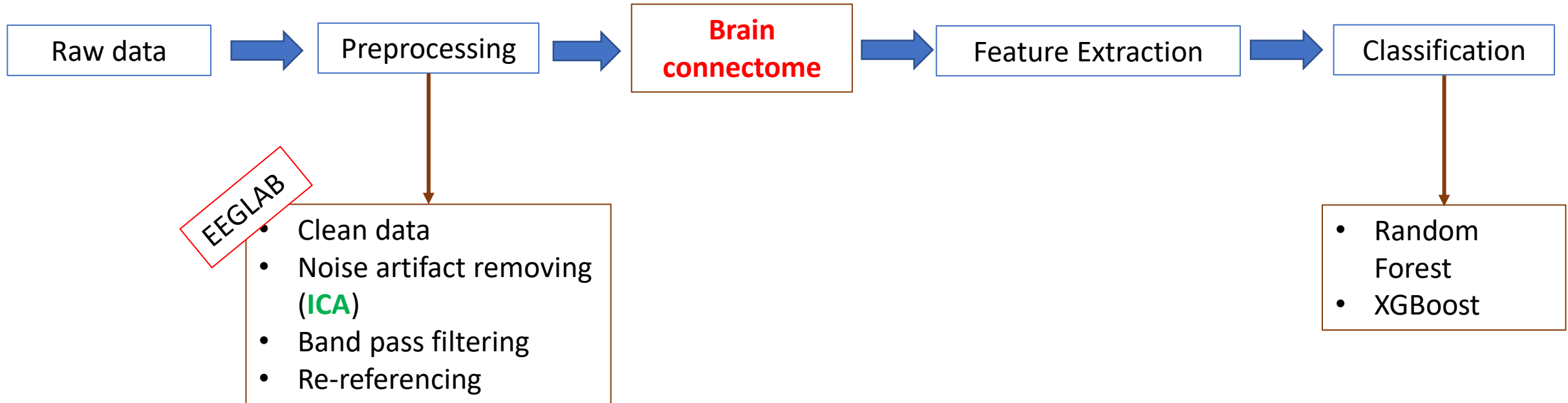
For now, we are focusing our analysis on the discrimination between HC and PD off medication.



32-ELECTRODES

[doi:10.18112/openneuro.ds002778.v1.0.5](https://doi.org/10.18112/openneuro.ds002778.v1.0.5)

Data analysis pipeline

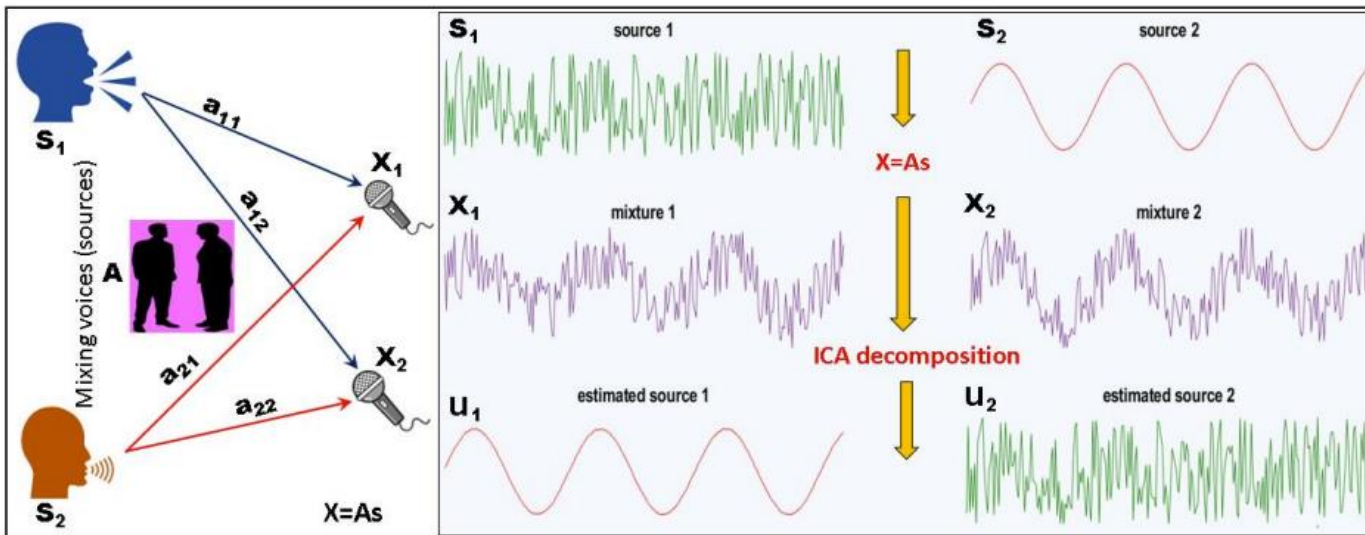


Independent component analysis (ICA)

Independent Component Analysis (ICA) is a signal processing method to separate independent sources linearly mixed in several sensors.

When recording electroencephalograms (EEG) on the scalp, ICA can separate out artifacts embedded in the data (since they are usually independent of each other).

The cocktail party problem

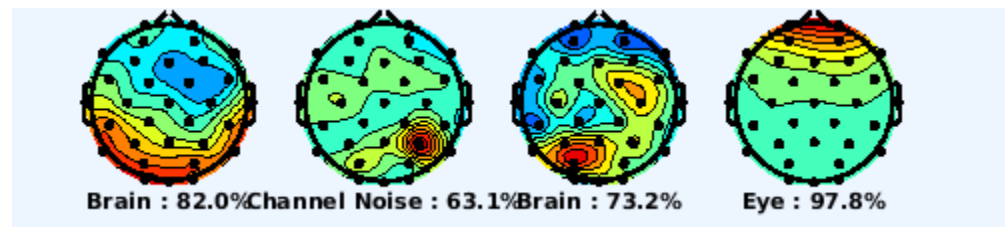


There are two people speaking simultaneously in a room. Their voices (S_1 and S_2) are recorded by two microphones placed at different locations. Their linearly mixed signals are recorded as X_1 and X_2 that can be expressed by:

$$X = As$$

ICA is aimed to estimate A and s , and obtain a de-mixing matrix W

EEG ICA EXAMPLE



Brain connectome

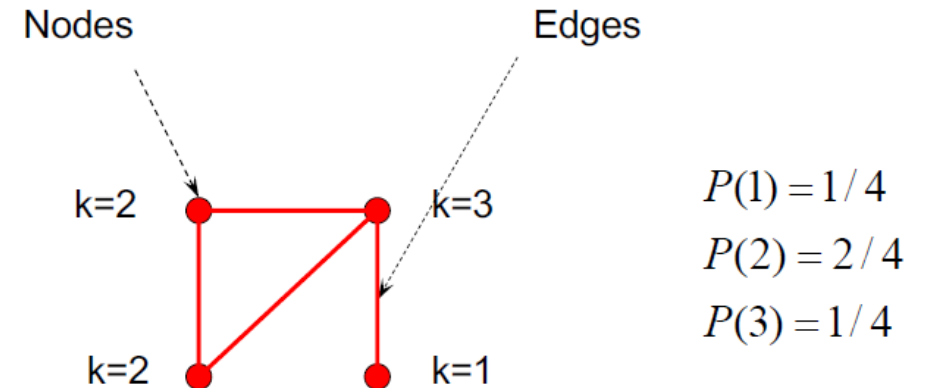
The human brain is a **complex network**.

Complex systems is a system constituted by a huge number of interacting components.

Complex Network is a geometric model (made of points and segments connecting pairs of points) to represent the relations among the components of a complex system.

Network features:

- **Degree** (k) of a node is the number of edges whom it is connected
- **Betweenness centrality** is the number of these shortest paths that pass through the vertex
- **Eigenvector centrality** is a measure of the influence of a node in a network.
- **Clustering coefficient** is a measure of the degree to which nodes in a graph tend to cluster together.
- ...
- ...
- ...



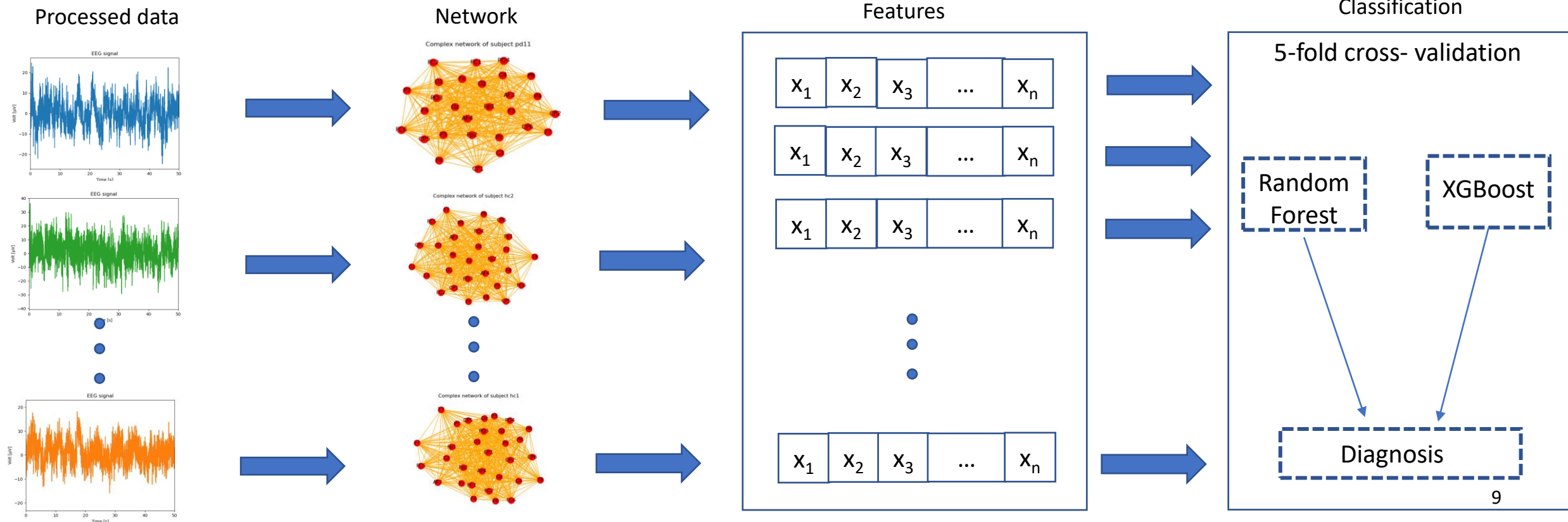
The connectome analysis: complex network for brain functionality study

The complex networks for each subject has been built by defining the nodes as the 32 EEG electrodes and the link as the **Spearman's** coefficient.

The features from the network have been extracted :

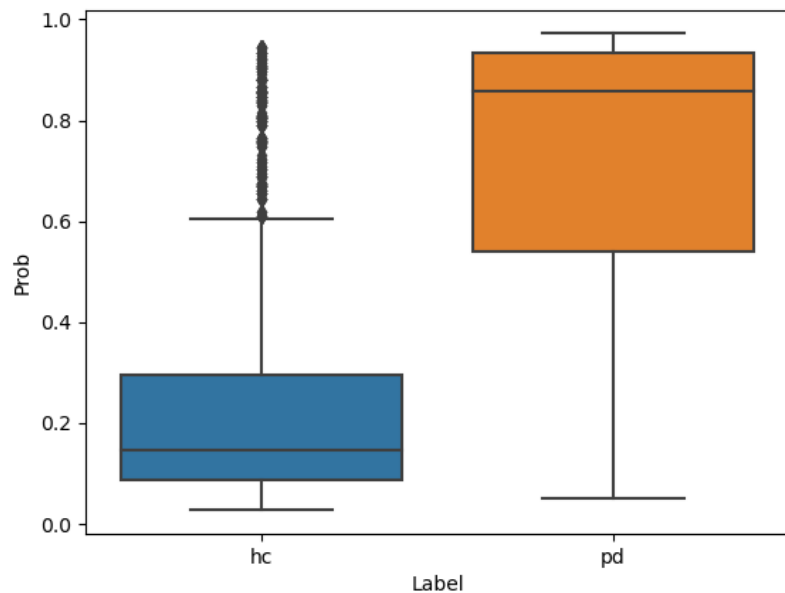
- Degree
- Betweenness centrality
- Eigenvector centrality
- Clustering coefficient

Features have been used to learn a supervised classification model within a nested cross-validation framework.

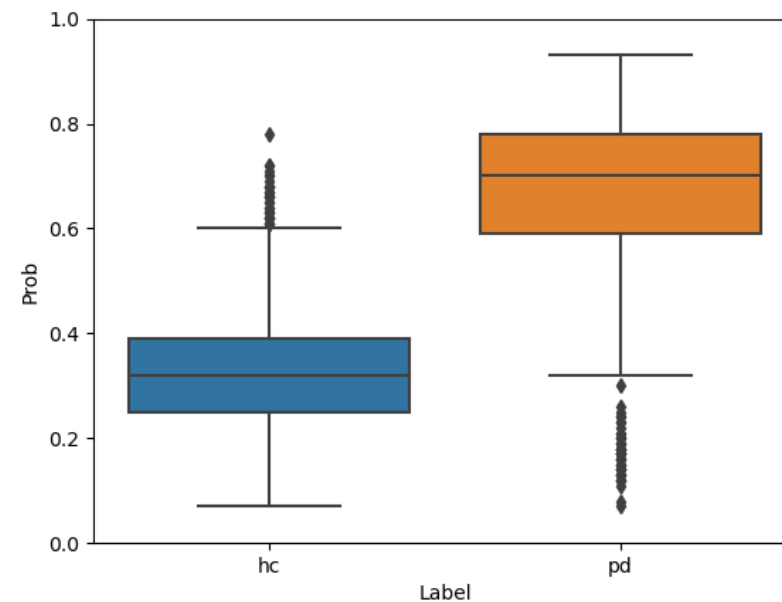


The analysis results

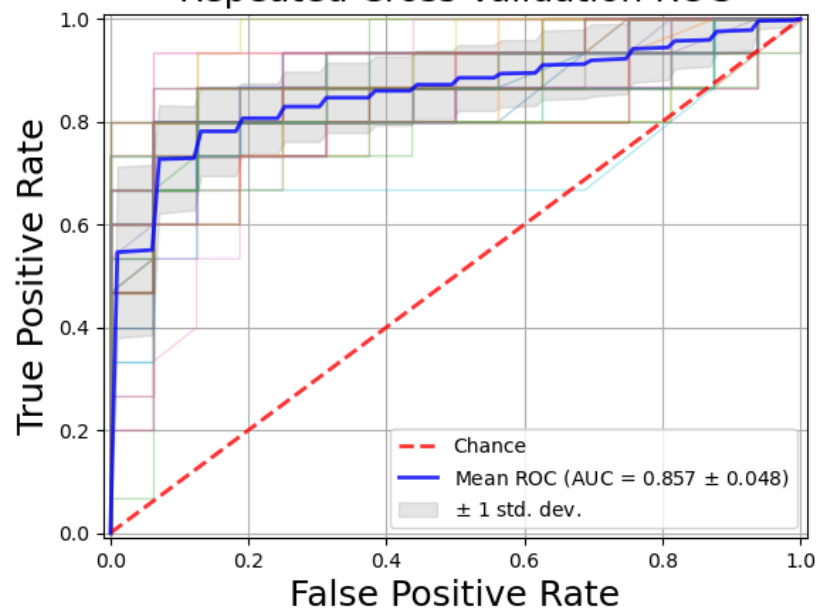
XGBoost



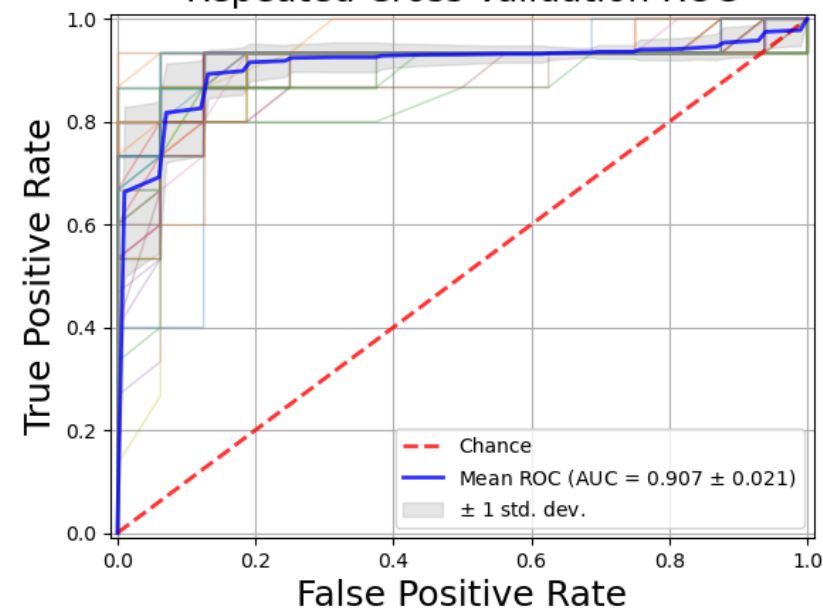
Random Forest



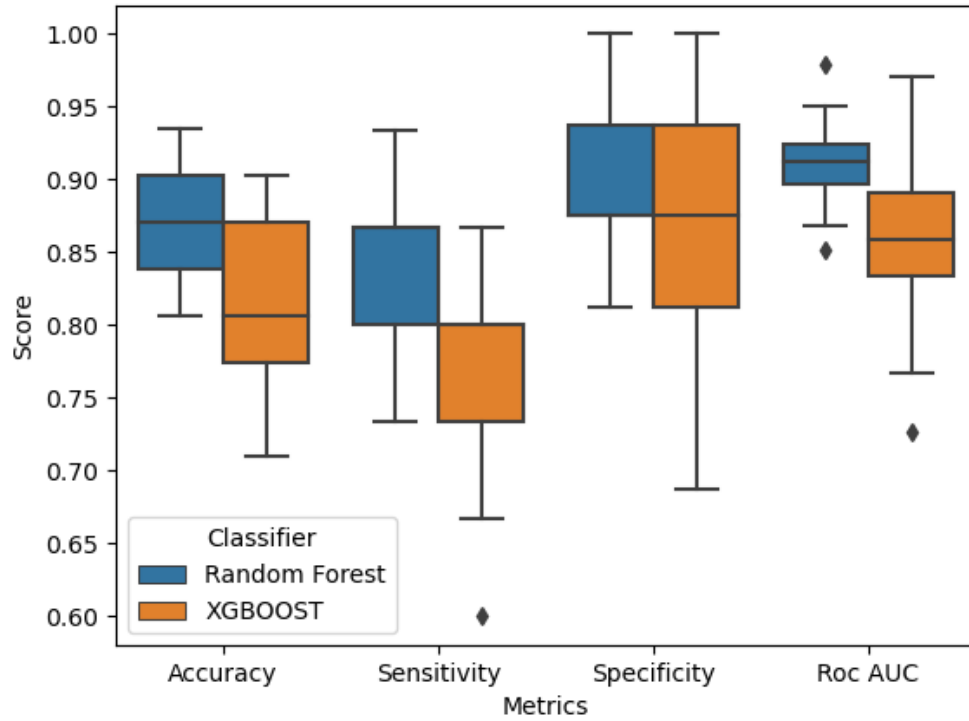
Repeated Cross-Validation ROC



Repeated Cross-Validation ROC



The analysis results



	XGBoost	Random Forest
Accuracy	0.821±0.047	0.875±0.031
Sensitivity	0.761±0.058	0.844±0.047
Specificity	0.877±0.067	0.904±0.040
AUC ROC	0.860±0.048	0.911±0.021

Conclusions

- EEG signals allows a deep investigation of the brain functionality.
- The connectome analysis have been implemented as a tool to study and map the human brain.
- Random forest and XGBOOST have been applied as classification algorithm, giving promising results.

Further improvements

- A bigger dataset is needed.
- A comparison between on/off medication should be performed.
- Feature importance and XAI algorithm will be implemented to deep investigate the brain functionality and to map the brain regions which are interested by the Parkinson's disease.



Thank you for
your attention!