USING SMI TO ESTIMATE BRAIN CONNECTIVITY AND CAUSAL RELATIONSHIP BASED ON EEG DATA

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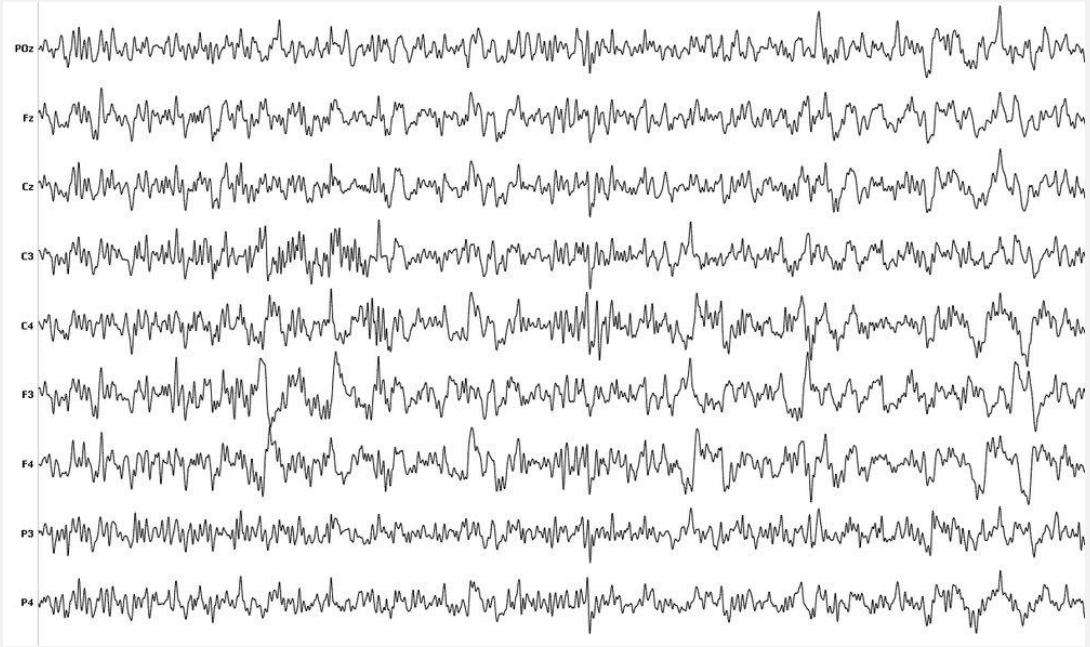
ChatGPT

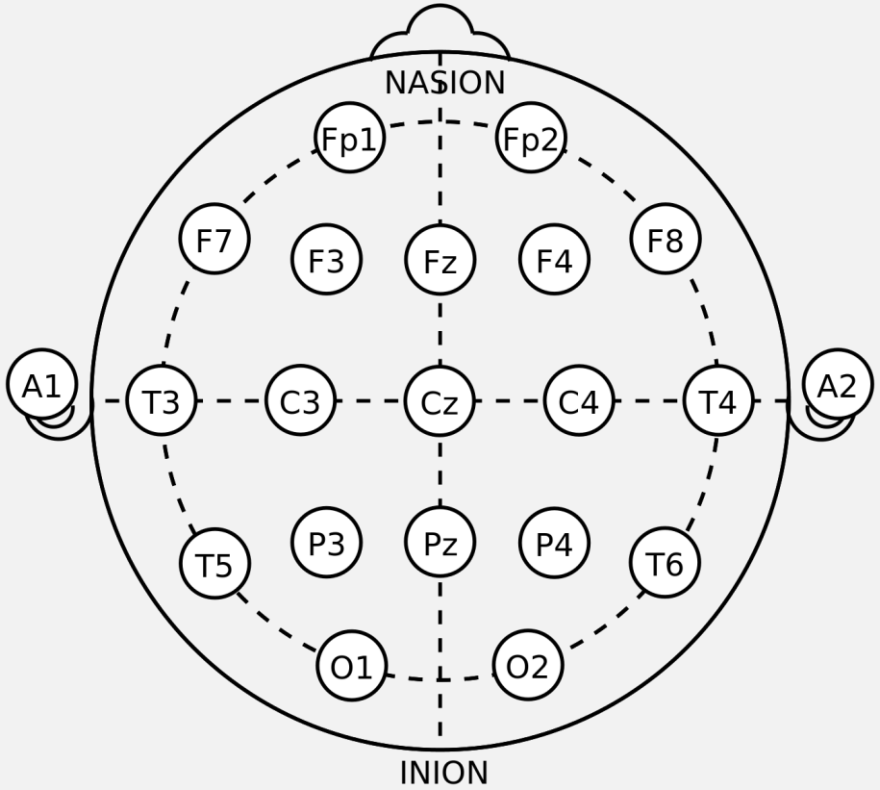
CONTENTS

INTRODUCTION

WHAT IS EEG?

- An electroencephalogram (EEG) is a test that measures electrical activity in the brain using small metal discs attached to the scalp. Brain cells communicate via electrical impulses and are active all the time, even during asleep. This activity shows up as wavy lines on an EEG recording.





WHAT IS (GRANGER) CAUSALITY

- Clive Granger introduced the method of ***Granger causality*** in the 1960s in the context of analyzing economic time series which won him the Nobel prize in Economics. Here's how it works:

A process *Y* is said to Granger cause *X* if we can predict *X* better by incorporating the past information of *Y* using linear regressive modelling.

$$x_t = \sum_{i=1}^{\infty} \hat{a}_i x_{t-i} + \hat{\varepsilon}_t,$$

$$x_t = \sum_{i=1}^{\infty} a_i x_{t-i} + \sum_{j=1}^{\infty} b_j y_{t-j} + \varepsilon_t$$

$$F_{y \to x} = \log \frac{\mathrm{var}(\hat{\varepsilon}_t)}{\mathrm{var}(\varepsilon_t)}$$

If including the past of *Y* improves the prediction of *X*, then the ratio of the error variance will be greater than 1 and the value of the log (the above statistic) will be greater than zero. If it does not improve the prediction of *X*, then the above statistic vanishes to zero.

WHAT IS SMI?

- Smoothness Index (SmI) measures how nearness of input data leads to nearness of target data.
- The formulation is as follows :

$Data = \{(\boldsymbol{x}_i, \boldsymbol{y}_i)\}_{i=1}^{m}$ $\forall i: \boldsymbol{x}_i \epsilon R^{n\times 1}, \boldsymbol{y}_i \epsilon R^{o\times 1}$ o :number of outputs

$$i^* = \underset{\forall q \neq i}{\arg\, min} \|\boldsymbol{x}_i - \boldsymbol{x}_q\| \qquad \boldsymbol{d}_{imax} = \max_{\forall q} \|\boldsymbol{y}_i - \boldsymbol{y}_q\| \qquad \boldsymbol{d}_{imin} = \min_{\forall q \neq i} \|\boldsymbol{y}_i - \boldsymbol{y}_q\|$$

$$\boldsymbol{d}_{i^*} = \|\boldsymbol{y}_i - \boldsymbol{y}_{i^*}\|$$

*$\|\cdot\|$ denotes Euclidian distance (L_2 norm) but it may be another distance definition such as L_p norm.

** It is assumed that the input and target output data are normalized at each dimension just before computing the smoothness index.

*** to avoid the effect of outliers, it is assumed that all outlier of data points are not considered in computing SmI.

WHAT IS SCHIZOPHRENIA?

- Schizophrenia is a potentially severe psychiatric condition that involves a variety of symptoms:
  - Positive : Development of a behavior or thought patterns that isn't normally present, such as hallucinations.
  - Negative : Loss of a normal function , such as lack of motivation.
  - Cognitive : Affect someone's ability to think clearly, and include deficits in attention, memory and concentration.

- Schizophrenia is considered as a disorder of brain disconnectivity, characterized by profound disruption of large-scale prefronto-temporal interactions. Another characteristic is abnormal connectivity. One consequence of abnormal connectivity in schizophrenia may be a loss of coherent functional integration that results in a disorder of association processes.

MATERIAL AND METHOD

DATASET

- The dataset consist of getting EEG records of 14 healthy people (control group) and 14 people with schizophrenia (patient group).

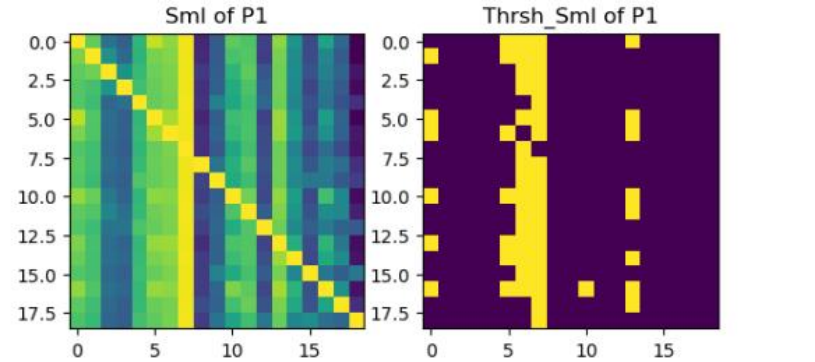
- Fifteen minutes of EEG data were recorded in all subjects during an eyes-closed resting state condition. Data were acquired with the sampling frequency of 250 Hz using the standard 10–20 EEG montage with 19 EEG channels: Fp1, Fp2, F7, F3, Fz, F4, F8, T3, C3, Cz, C4, T4, T5, P3, Pz, P4, T6, O1, O2. The reference electrode was placed at FCz.

FEATURE EXTRACTION

- As SmI is defined for a statical system and EEGs are dynamical we can't use raw EEG data for computing Smi because we should incorporate changes in time as well as changes in inputs.
- To tackle this problem we've extracted 6 statistical measures on each window of size 200 and stride of 100.
- This action turn each EEG channel into an almost (5000,6) array.
- Each feature vector consist of :
  - Average
  - Minimum
  - Maximum
  - STD
  - Medain
  - IQR

RESULTS

PATIENT GROUP



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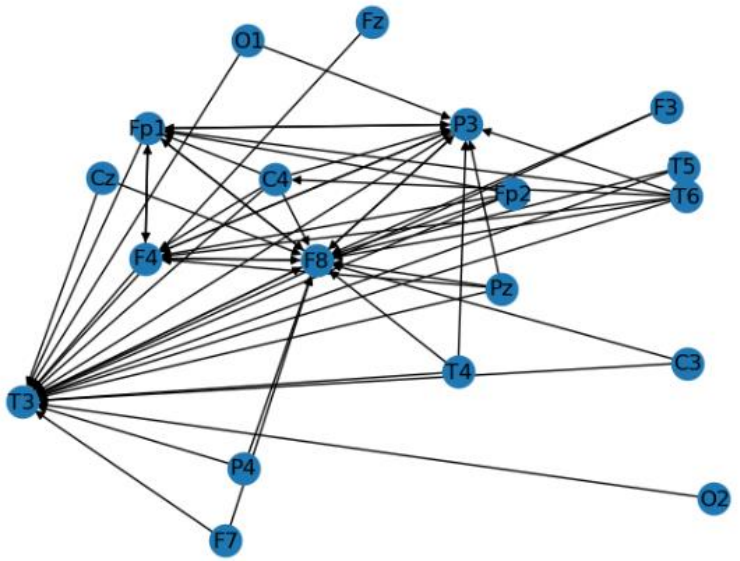

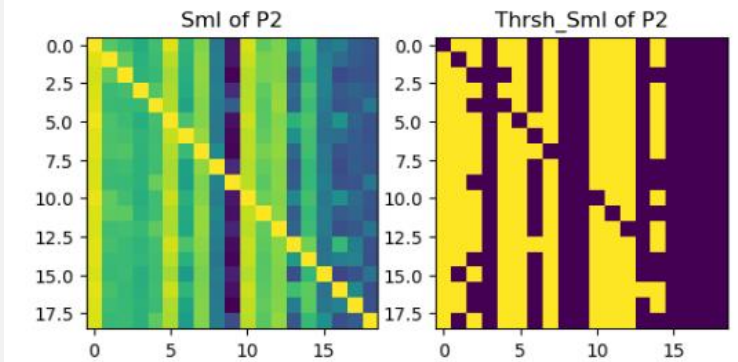

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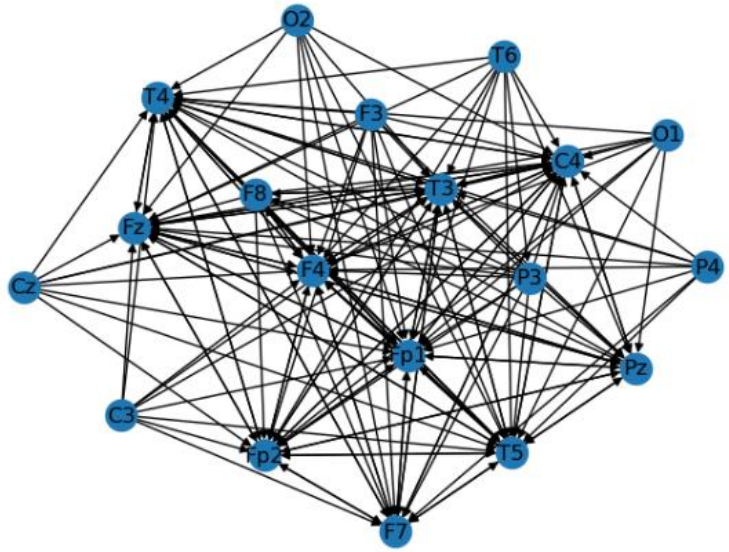

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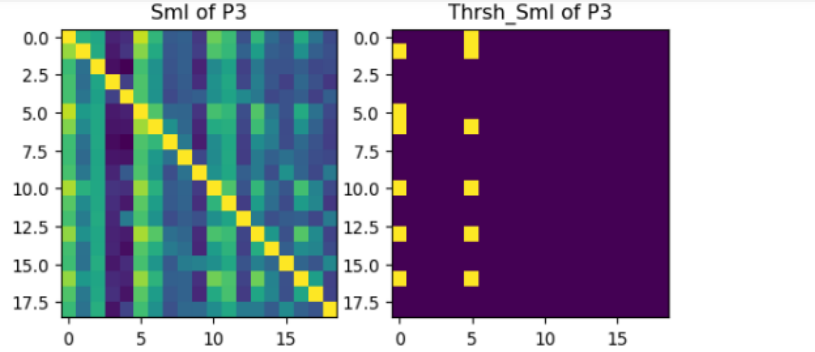

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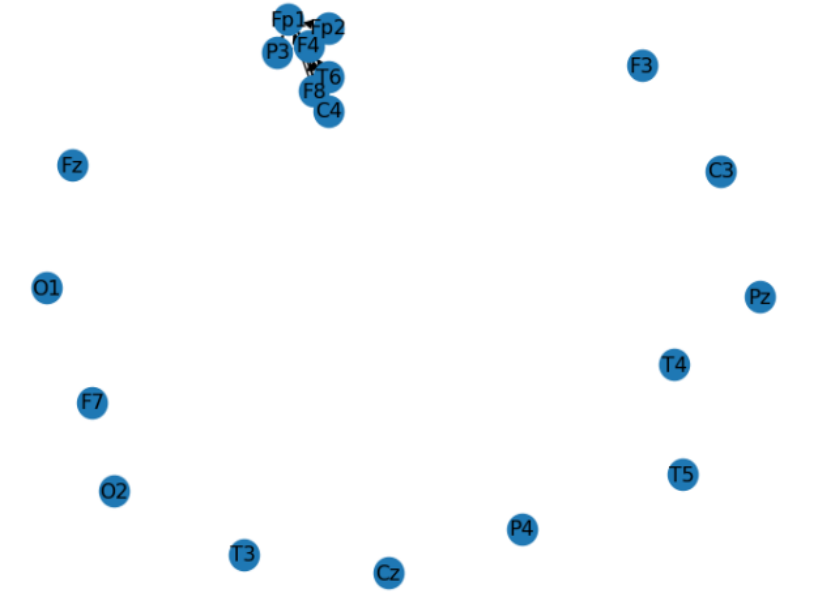

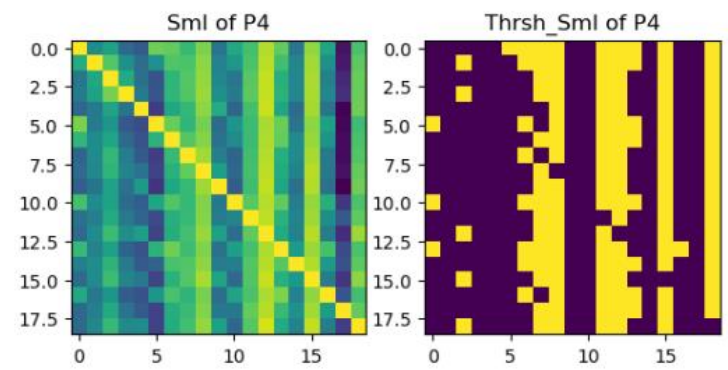

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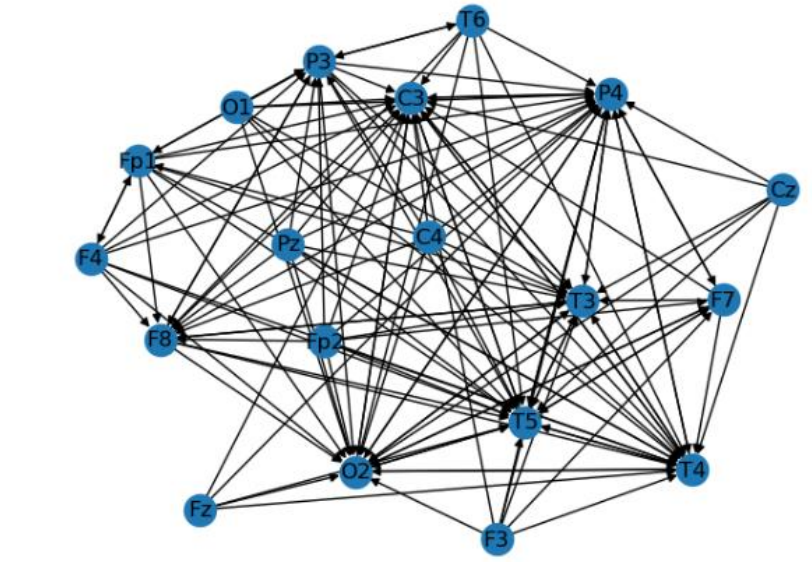

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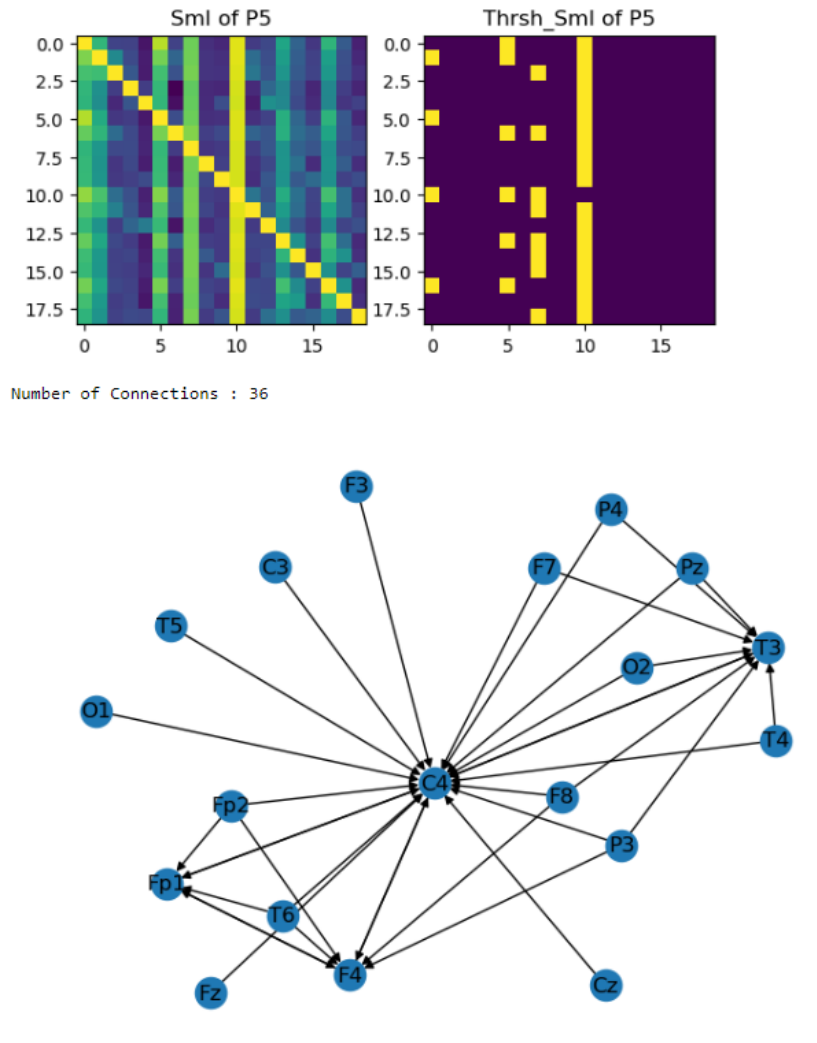

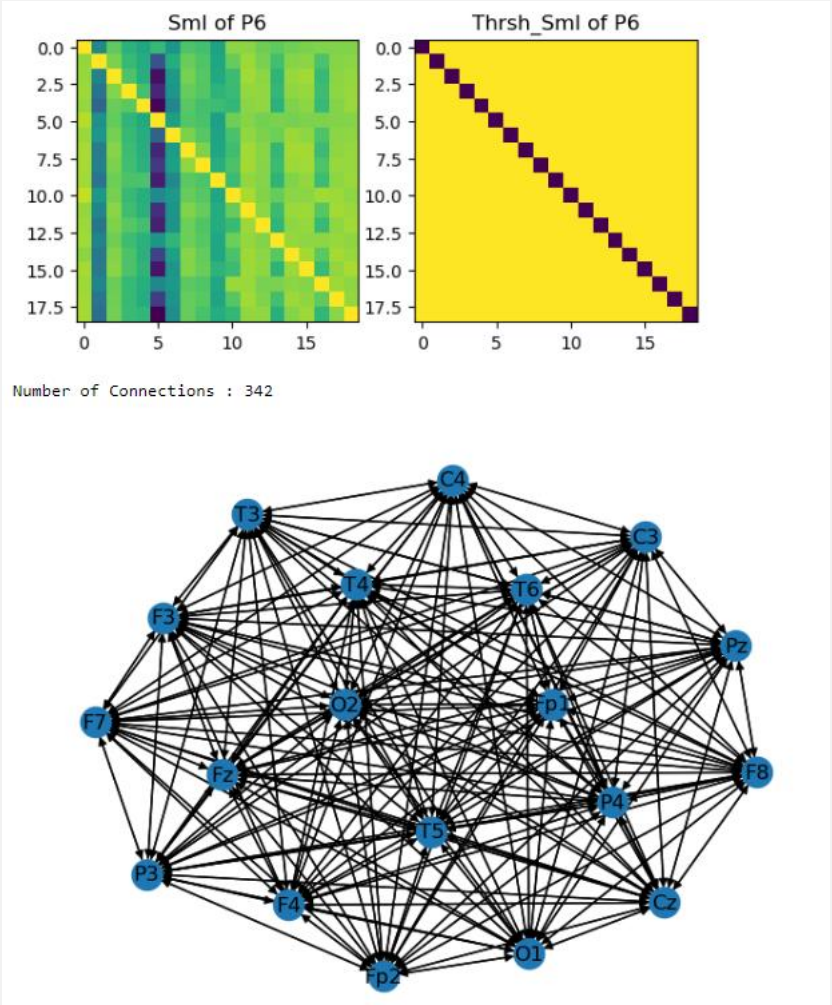

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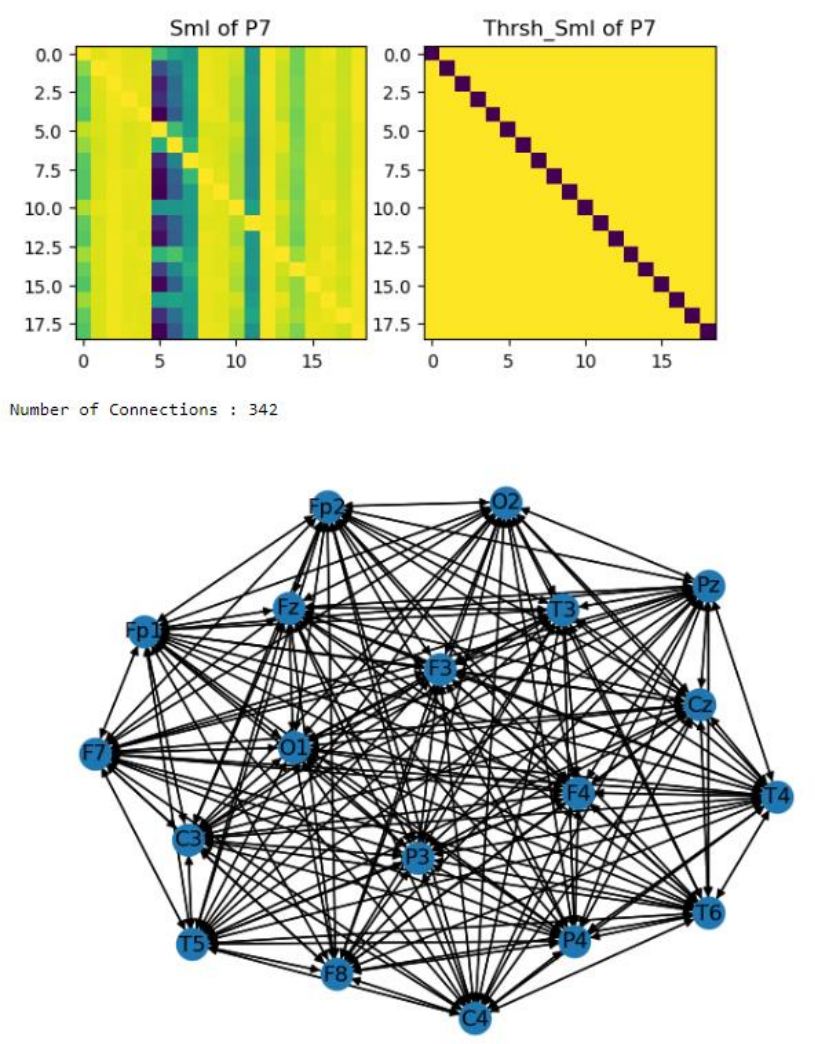

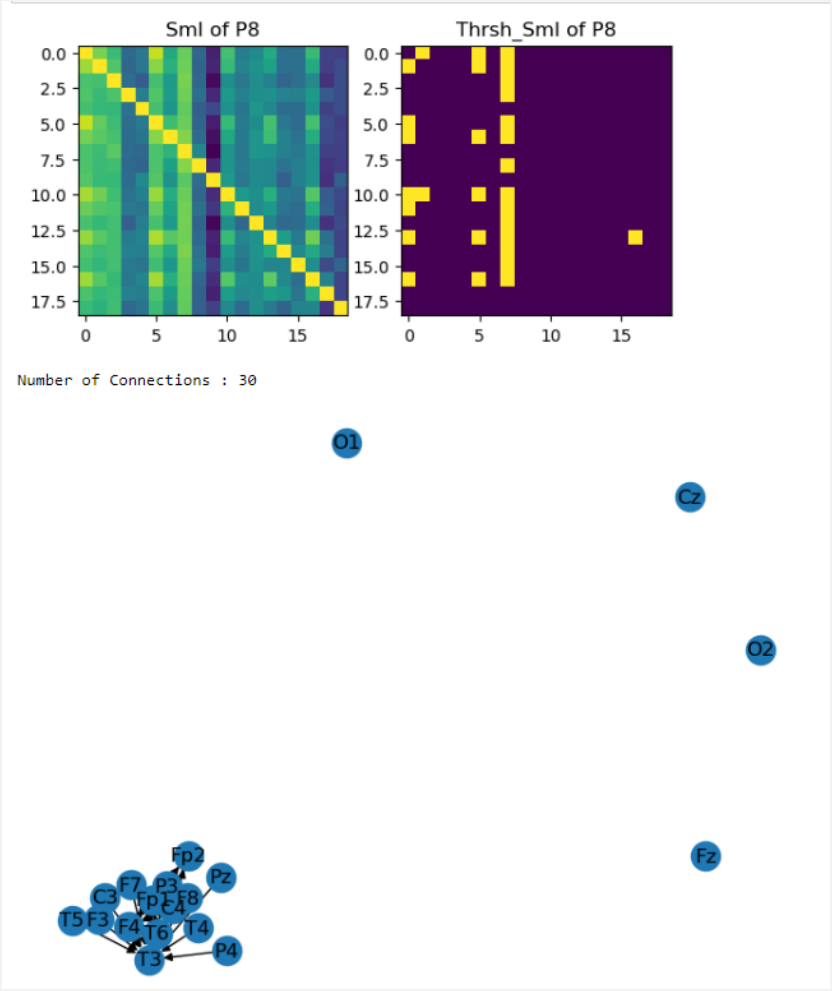

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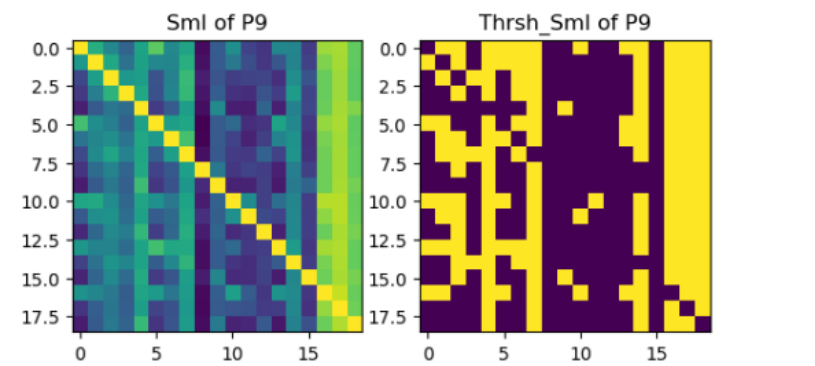

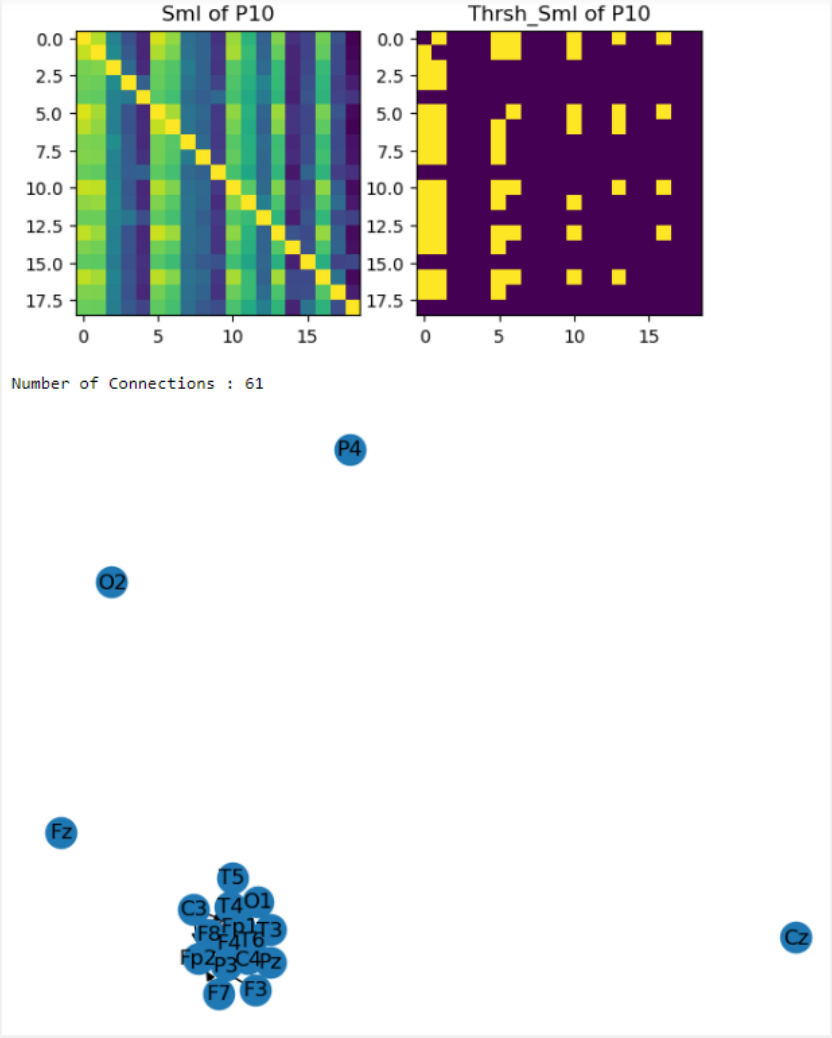

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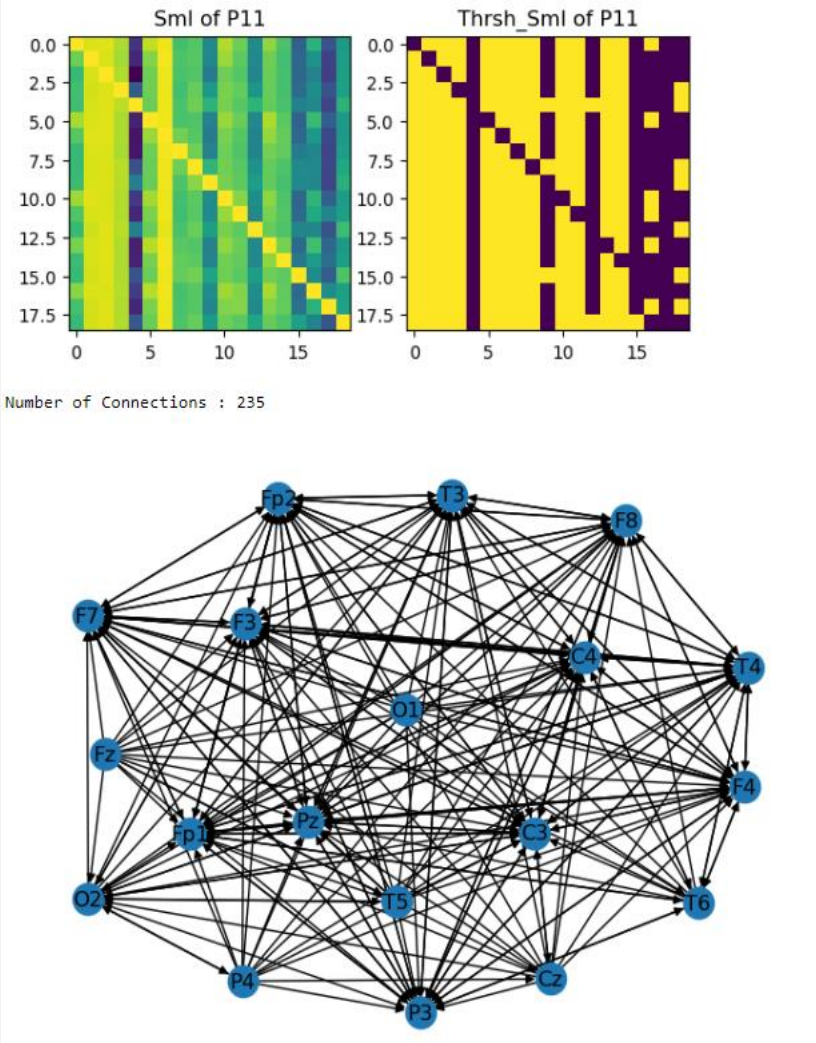

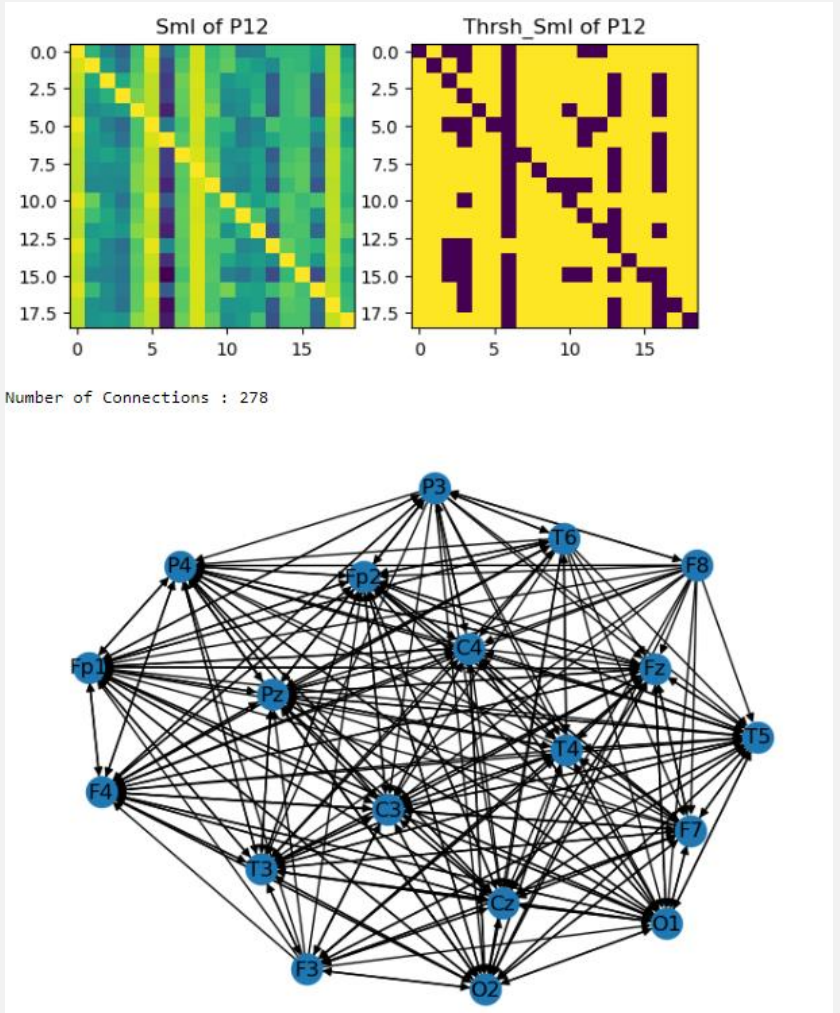

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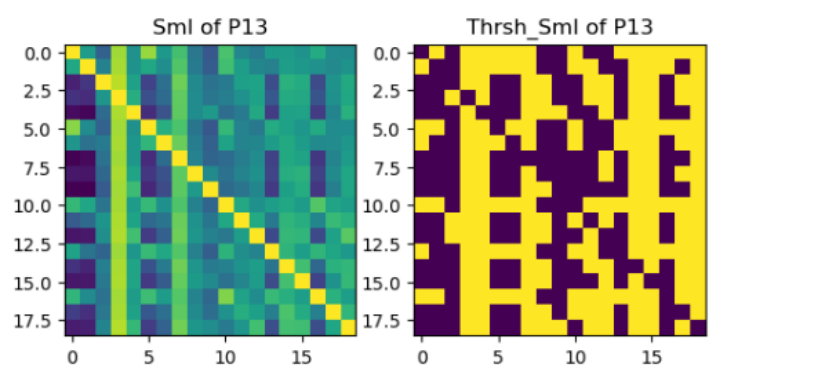

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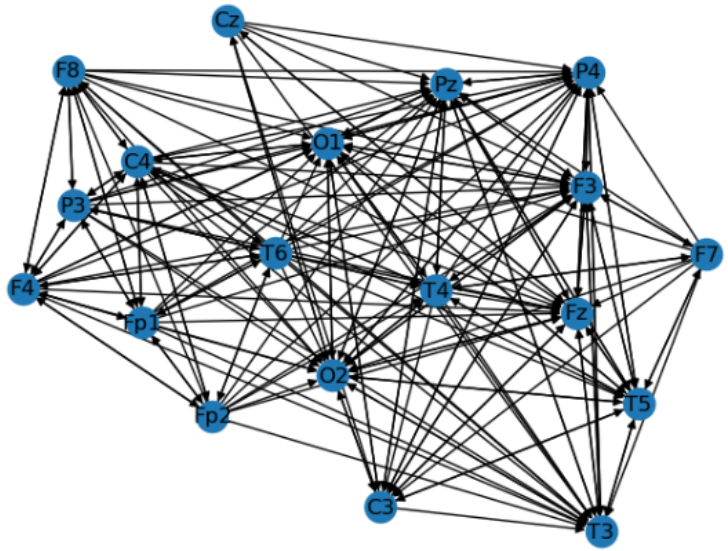

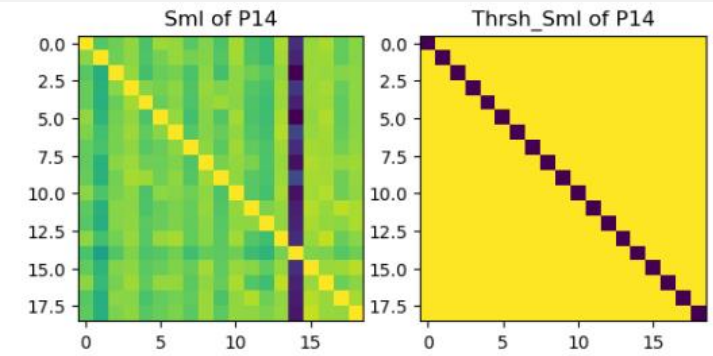

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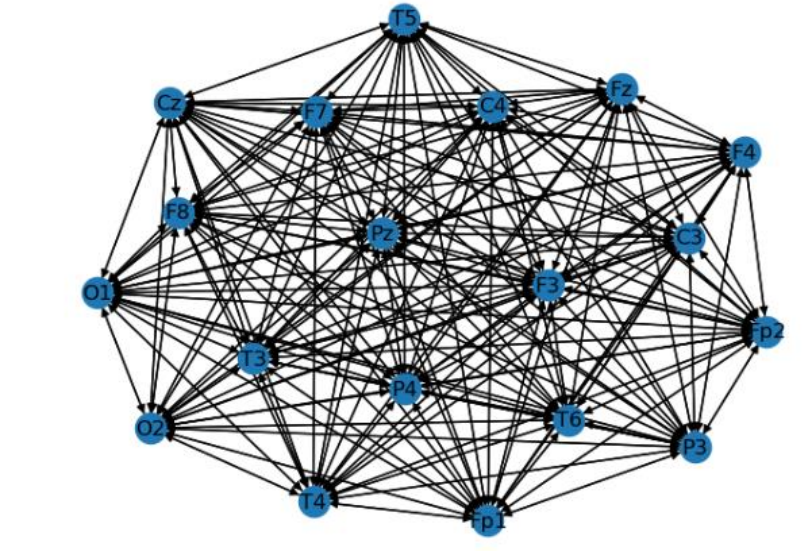

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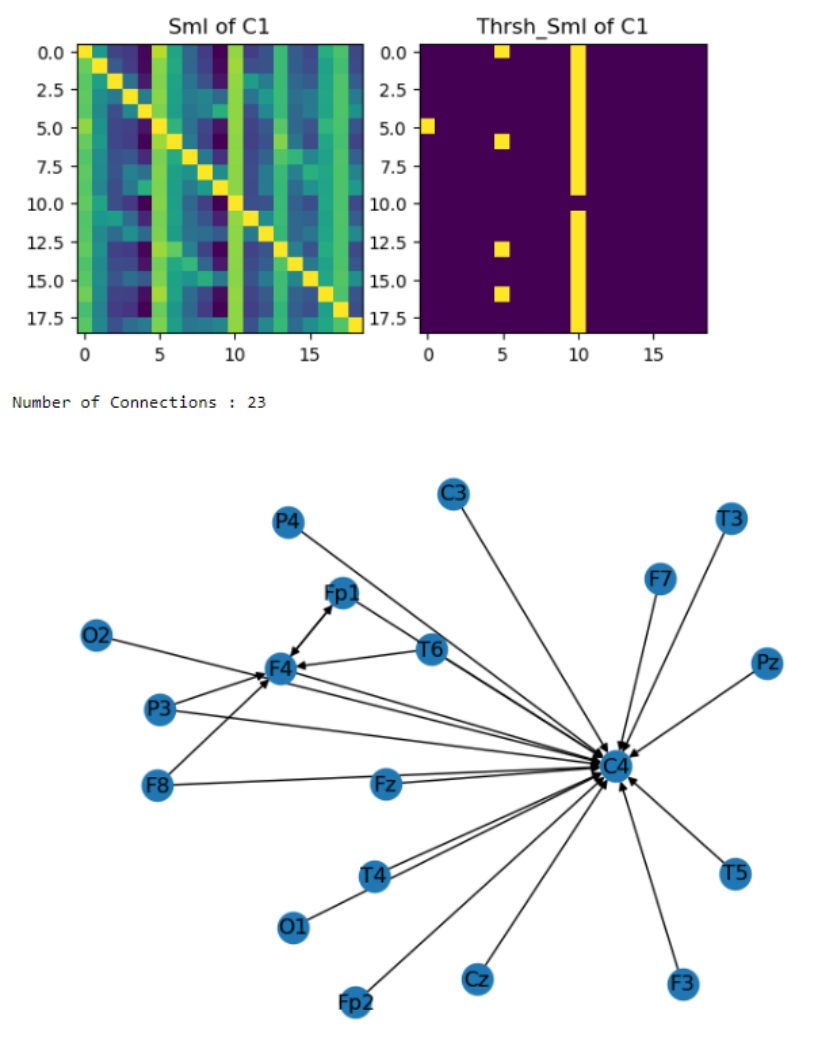

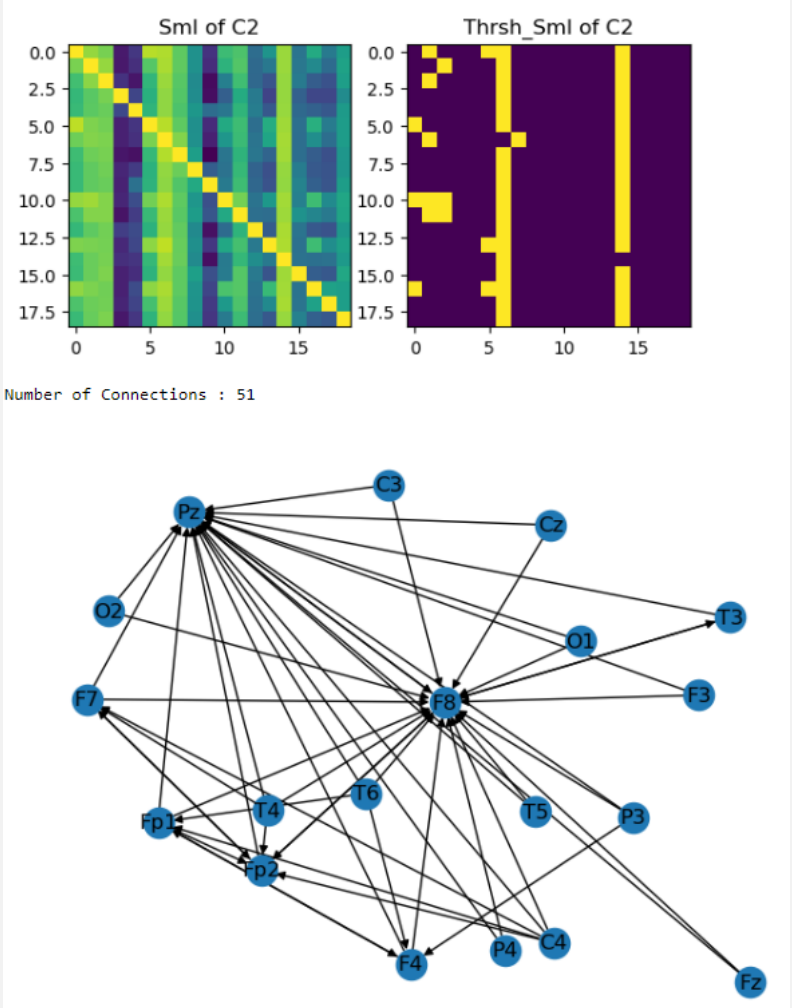

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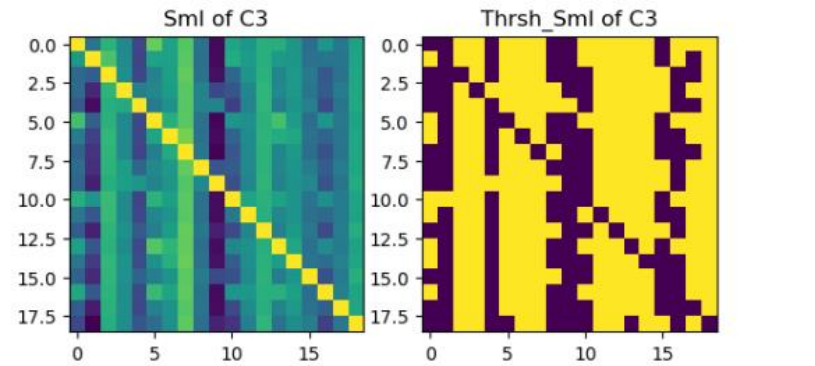

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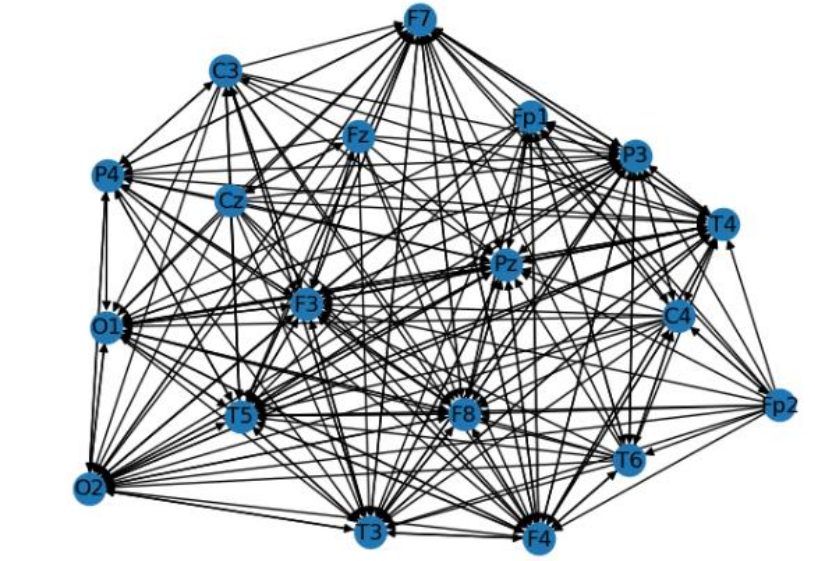

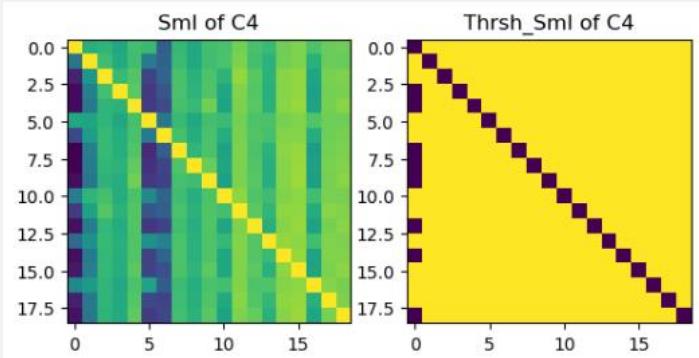

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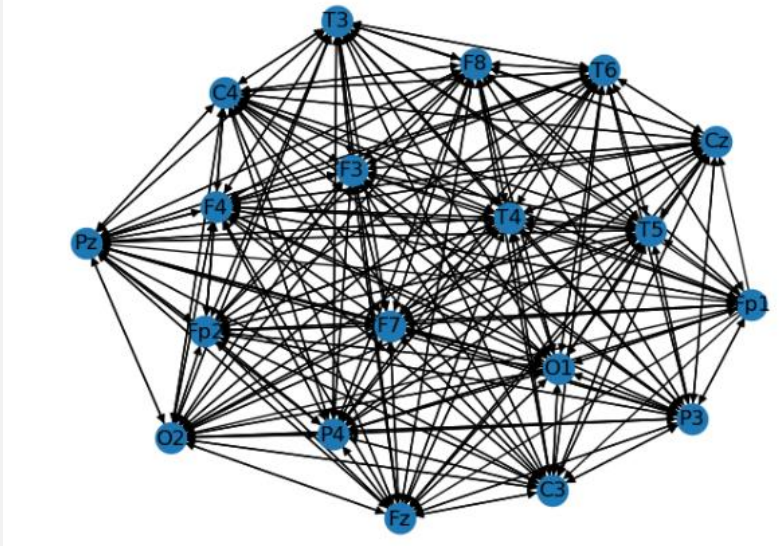

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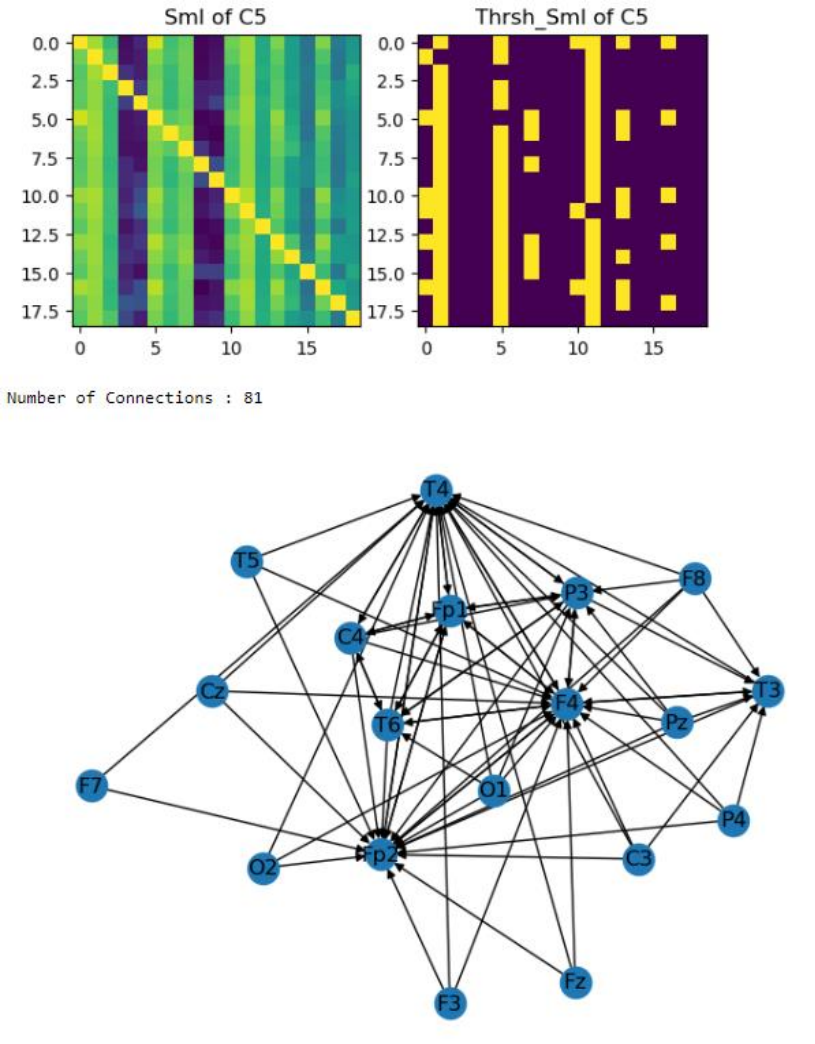

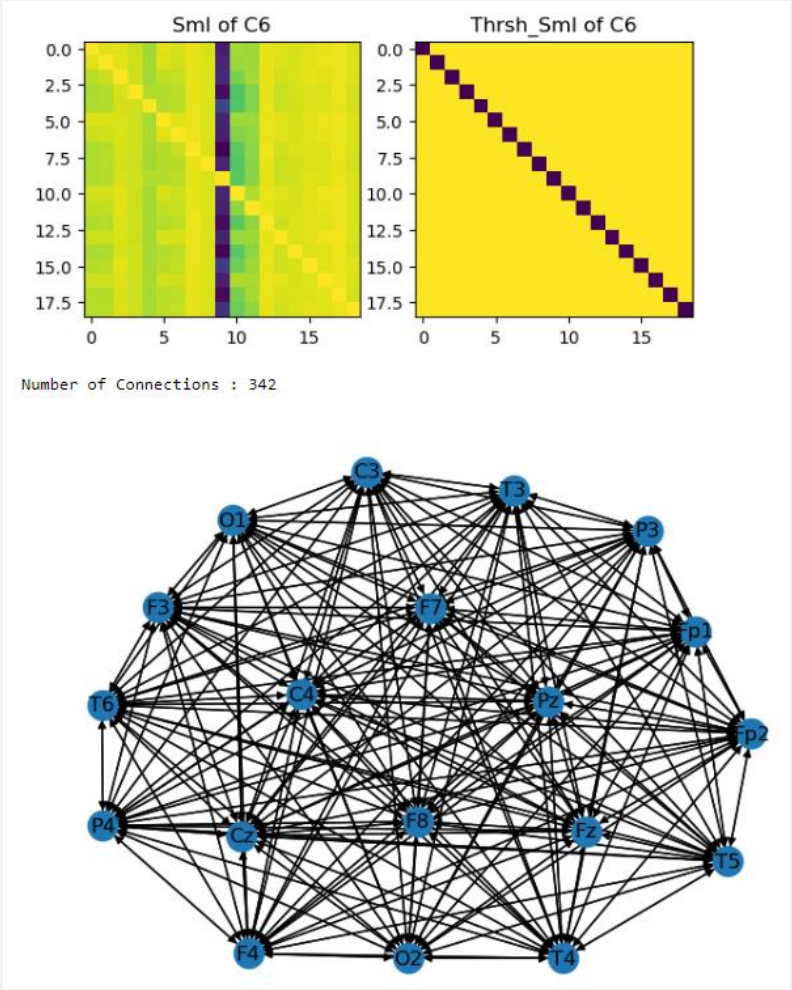

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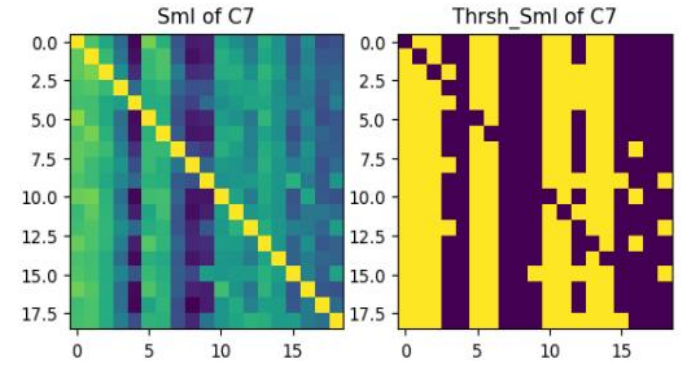

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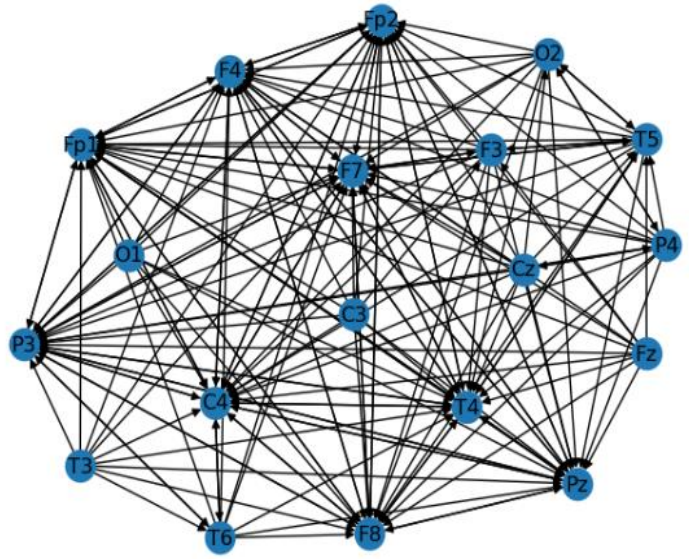

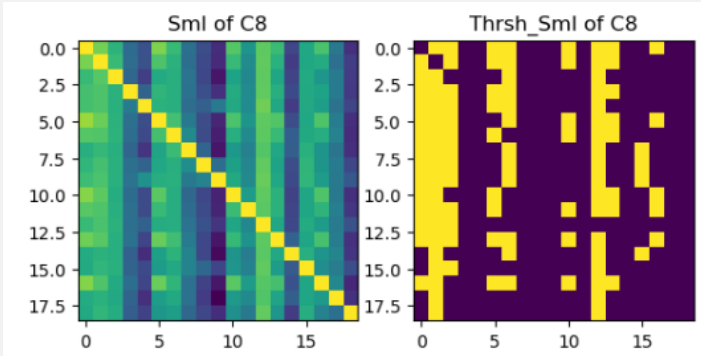

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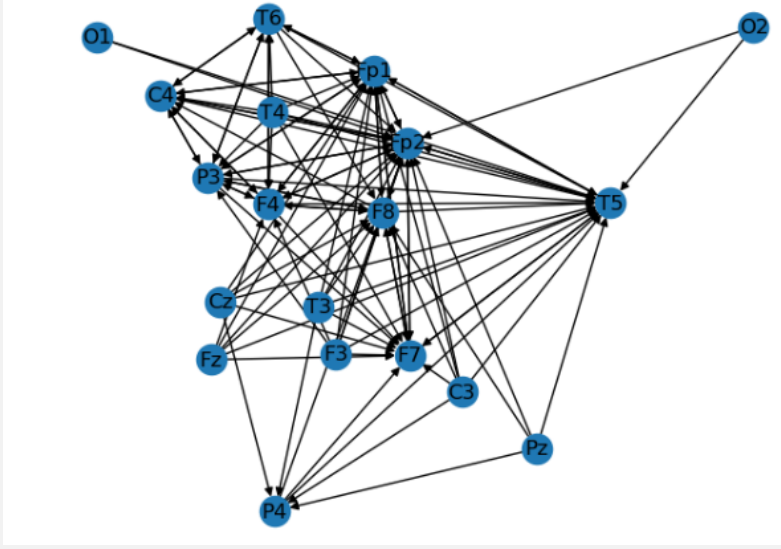

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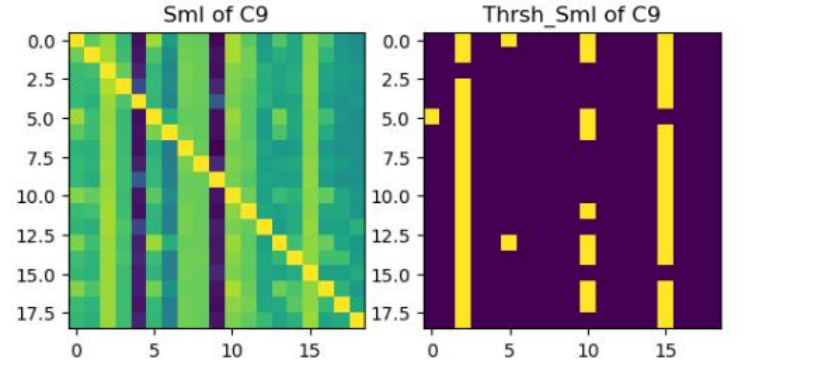

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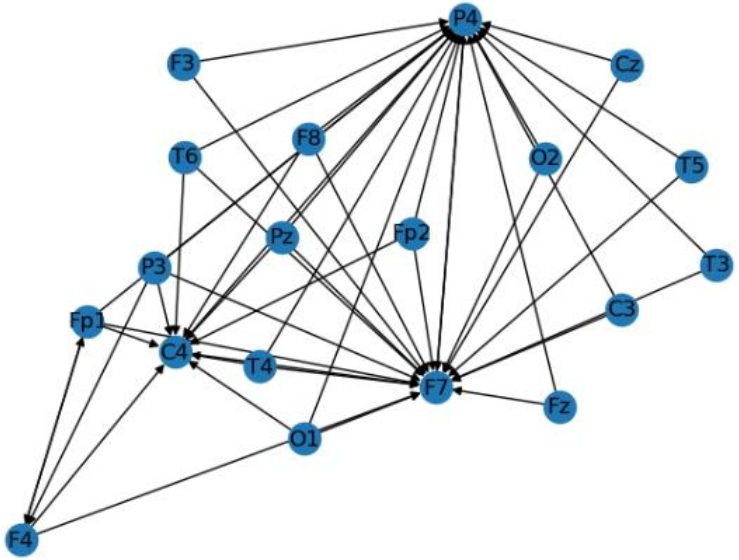

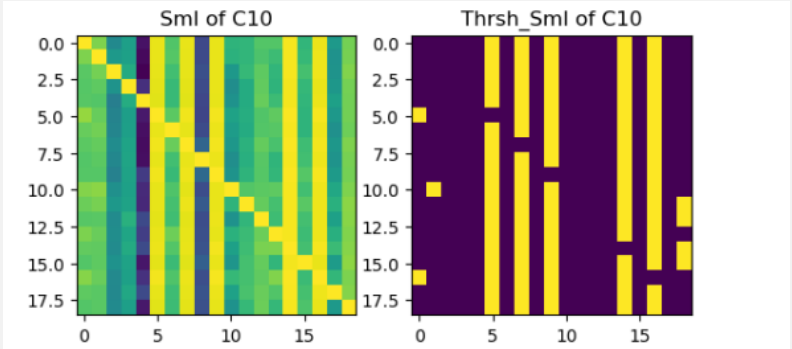

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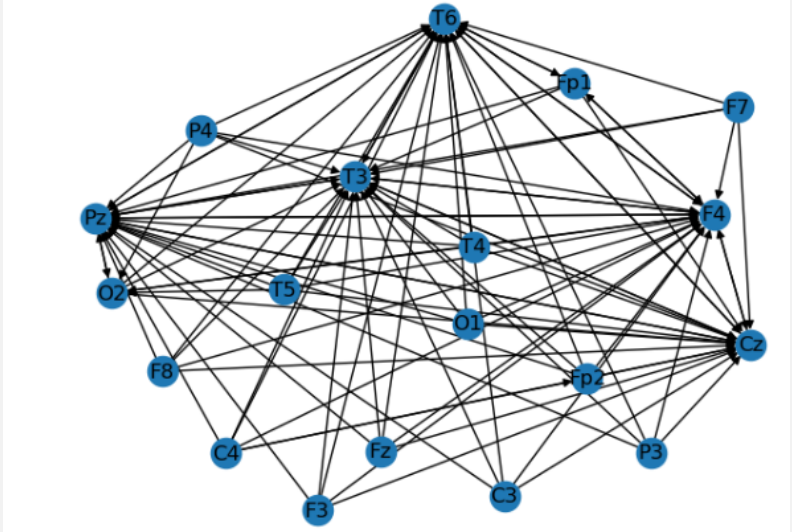

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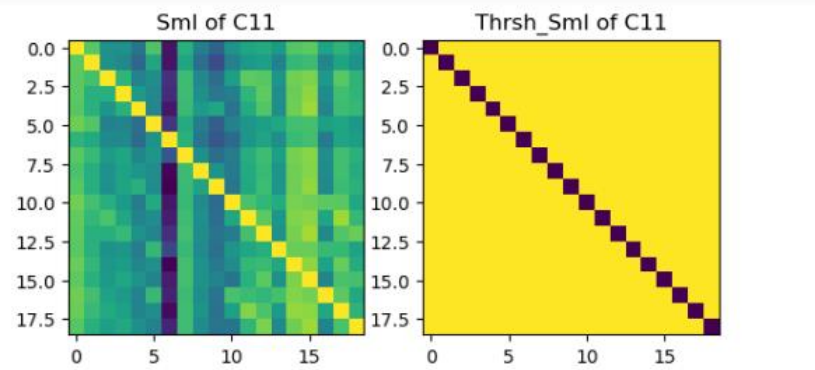

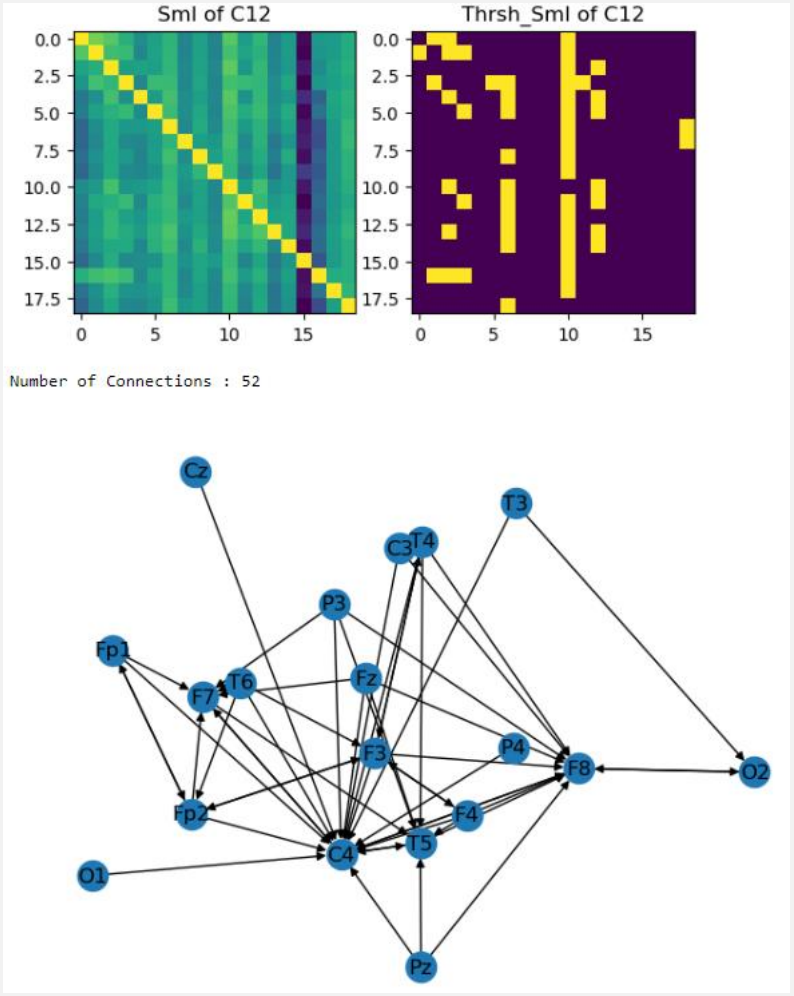

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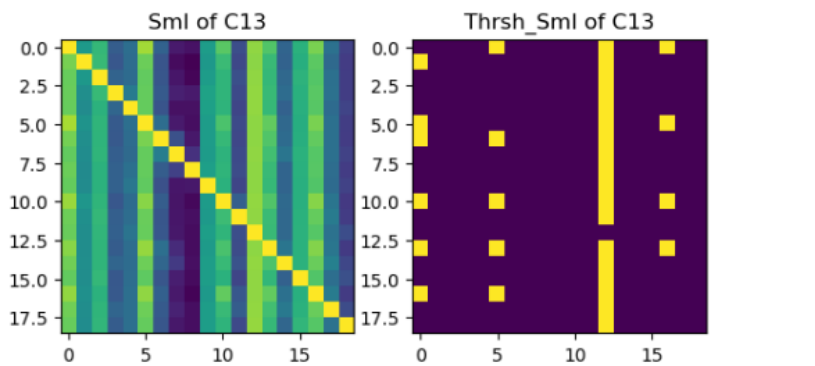

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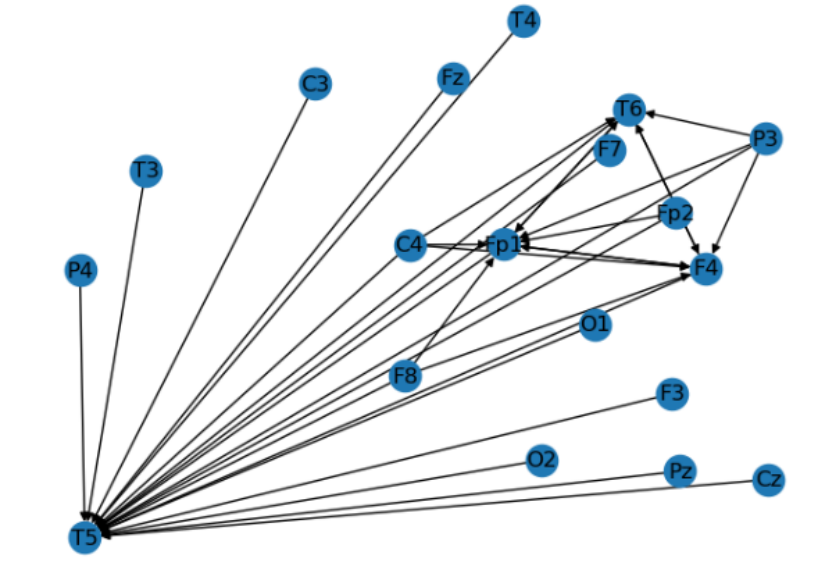

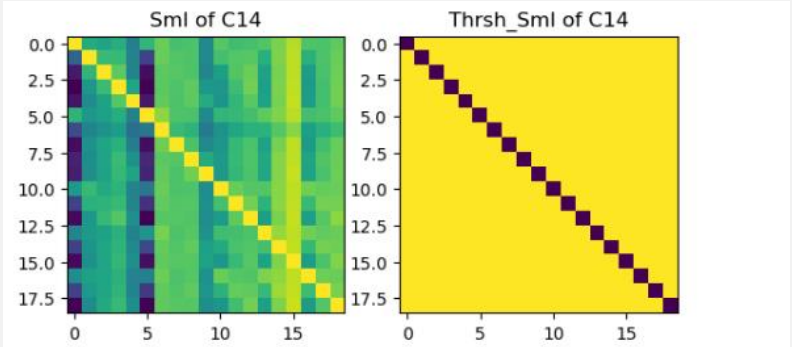

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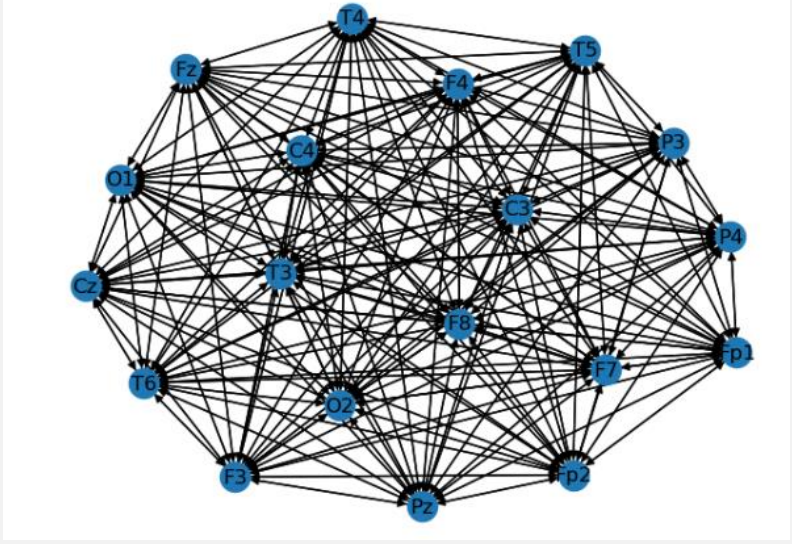

CONCLUSION

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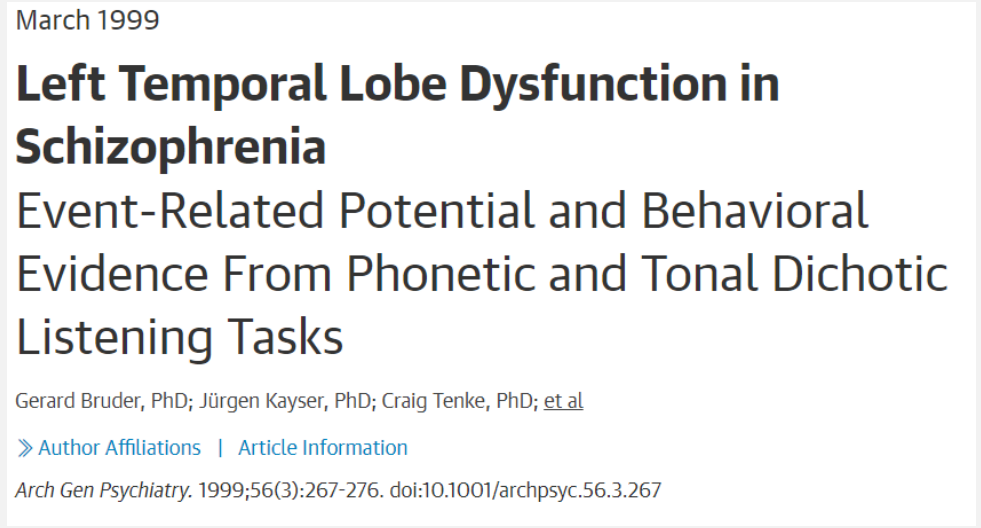
- SmI is High between all the channels (grater than 0.7) which makes sense as we know that our brain is densely connected.
- In most of the patients some of the EEG channels have high SmIs with all the other channels indicating probable dysfunctionality in that region of brain.
- T3 channels connectivity pattern in patients matches this paper :



March 1999

Left Temporal Lobe Dysfunction in Schizophrenia

Event-Related Potential and Behavioral Evidence From Phonetic and Tonal Dichotic Listening Tasks

Gerard Bruder, PhD; Jürgen Kayser, PhD; Craig Tenke, PhD; et al

» Author Affiliations | Article Information

Arch Gen Psychiatry. 1999;56(3):267-276. doi:10.1001/archpsyc.56.3.267

- Granger Causality has been test on channels with high SmIs but on most of the cases this test showed no LINEAR causality But we should be aware that SmI might be able to find nonlinear causality as well.

POTENTIAL FUTURE WORKS

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- Using better feature extractors such as autoencoders. The initial Idea for feature extraction in this project was to train an autoencoder on wavelet images of windows of data but due to the lack of time we couldn't manage to that.
- Applying Multivariate SmI to study the connection of multiple channels to one channel.
- Checking for nonlinear causality using the concept of entropy to check if SmI is really capable of finding nonlinear causality or not.

THANKS ☺