

SOLUTIONS

Carefully read the following scenario and answer the questions listed below.

A patient needs to undergo **brain surgery** because she has frequent (daily) epileptic seizures that fail to respond to any antiepileptic medications (pharmacoresistant epilepsy). Before and after the intervention, when her skull has to be open to perform the surgery, her **neuroelectrical data** are collected **for several hours**.

The aim is to build **directed brain functional networks**, to quantify the **role of specific regions** and to compare **the brain network properties before and after the surgery**.

The regions to be monitored are all subcortical. Their behavior at rest is known to occur in **Theta and Alpha bands**.

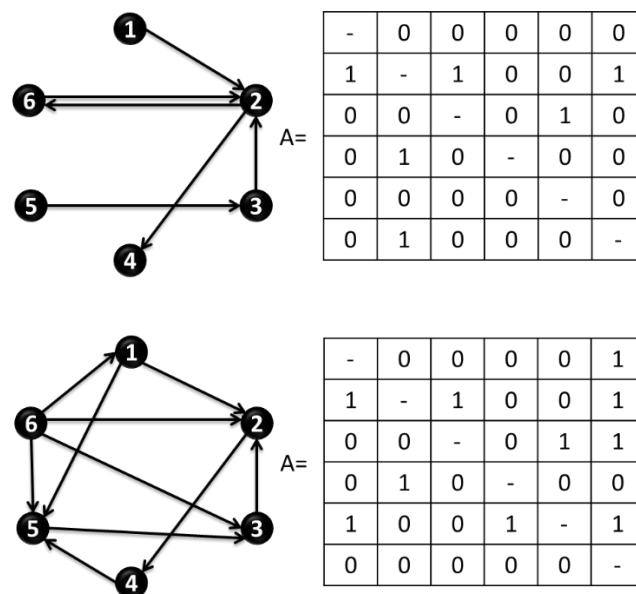


Fig. 1: Graphs obtained for the patient before (Pre, first row) and after (Post, second row) the brain surgery

Questions:

Q1. Indicate which **level of invasiveness** and **EEG method** you would choose to the study's purposes and **why**. (2 points)

A1: The patient needs to undergo surgery, which justifies the use of intracranial measures. These are advisable in this scenario because the maximum spatio-temporal precision is strongly required in the preparation of brain surgery. Among the EEG measures we discussed during the course, SEEG is the most indicated. In fact, the regions to be monitored are all subcortical and cannot be reached by ECoG.

Q2. Indicate which **connectivity estimator** (among those studied in the course) would be more appropriate to the purposes of the study. **Justify your choice.** Indicate **the pros and cons** of this estimator. (3 points)

A2: Choice and justification: The text states that the aim of the study is to build a directed functional network of the brain. This means that an estimator of causality (and not correlation) is needed. This rules out Ordinary Coherence, which is spectral but undirected. In addition, the activity of the selected regions at rest is known to occur in the theta and alpha bands, which means that a spectral estimator is needed. This also rules out the Granger test, which is directed but not defined in the frequency domain. The resulting method is Partial Directed Coherence, which has the further advantage of being more accurate on a multivariate data set, since it is multivariate and therefore less prone to the hidden source problem. The recordings are known to last several hours, so we can assume that the amount of data is sufficient to estimate the large number of parameters of the MVAR model required by the method.

Pros: PDC is a spectral, multivariate (more accurate), directed estimator that implements Wiener-Granger causality.

Cons: In the presence of insufficient data, the estimation of a large number of model parameters would be incorrect. We also need a statistical threshold to assess the significance of the resulting values.

Q3 – Assuming that the analysis returns the functional networks and the corresponding adjacency matrices reported in **Fig. 1**:

Q3.1: Compute the network **Density** for each graph (Pre and Post conditions) (1 point)

A3.1: For directed graphs the density k is equal to: $k = \frac{L}{N(N-1)}$, where L = number of existing arcs, N = number of nodes.

Pre-surgery:

$$L=6; N=6, k = \frac{6}{6(6-1)} = 0.2$$

Post-surgery:

$$L=10; N=6, k = \frac{10}{6(6-1)} = 0.33$$

Q3.2: Compute the **In-degree** and the **Out-degree** for each node and for each graph (Pre and Post conditions) (1 point)

A3.2: You need to sum up all the elements for each row (In-degree) and for each column (Out-degree):

In-degree Pre: 0 3 1 1 0 1

Out-degree Pre: 1 2 1 0 1 1

In-degree Post: 1 3 2 1 3 0

Out-degree Post: 2 1 1 1 1 4

Q3.3: Comparing the Density and the Degrees in the Pre and Post conditions, describe how the network changed after the surgery. (1 point)

A3.3: After the surgery, the network density has increased from 20% to about 33%. This results in stronger communication between nodes and higher network integration. By observing the in-degrees and out-degrees of individual nodes, we can infer the changes in the role of specific nodes. In particular, node 6 assumes a role as a source of information for the network (its out-degree increases from 1 to 4); node 5, which didn't receive any information from the network in the pre, becomes a sink in the post (its in-degree moves from 0 to 3). The role of the other nodes is not significantly affected.