Neuroengineering 2019-2020

Exam Example – Part II

Solutions

Problem A

A1. *1st mistake:* (first index) to select as index for the spatial navigation the EEG activity generated by a subcortical region which produces a closed field. A region with these properties produces little or no EEG signal on the scalp.
Solution: to select a different region, preferably chosen among the cortical ones. *(N.B. using invasive measures is theoretically feasible, but impractical).*

2nd mistake: (second index) to use PDC when the data segments available are short. With 64 channels, the MVAR model required for the computation of PDC would need long data segments in order to allow the correct estimation of several model parameters.
Solution: to use a bivariate approach.

3rd mistake: (second index) to compute the Density of a graph obtained by PDC by using only the upper triangular adjacency matrix. PDC is a directed estimator and therefore the resulting network is non-symmetrical. All the indices computed for directed graphs require the full adjacency (or distance) matrix. *(N.B. the directionality of the adjacency matrices is known in advance, as it is a consequence of the properties of PDC).*
Solution: to use the full adjacency matrix.

A2.

A2.1 - Density:

Tennis Imagery:

$N = 6$

$L = 10$

$L_{tot} = N(N-1) = 30$

$k = {}^{L}/_{L_{tot}} = {}^{10}/_{30} = 0{,}33$

Spatial Navigation:

$N = 6$

$L = 10$

$L_{tot} = N(N-1) = 30$

$k = {}^{L}/_{L_{tot}} = {}^{10}/_{30} = 0{,}33$

A2.2 Global Efficiency:

Tennis Imagery:

D=

-	2	∞	1	2	3
1	-	∞	1	2	1
3	2	-	1	1	1
2	1	∞	-	1	2
∞	∞	∞	∞	-	∞
2	1	∞	2	3	-

$$E_g = \frac{1}{N(N-1)} \sum_{i,j=1,\, i\neq j}^{N} \frac{1}{d_{ij}} = \frac{1}{6(6-1)}\left[10 + \frac{8}{2} + \frac{3}{3}\right] = \frac{15}{30} = 0.5$$

Spatial Navigation:

D=

-	1	∞	1	2	2
∞	-	∞	∞	∞	1
∞	1	-	1	1	1
∞	1	∞	-	1	1
∞	∞	∞	∞	-	∞
∞	∞	∞	∞	∞	-

$$E_g = \frac{1}{N(N-1)} \sum_{i,j=1,\, i\neq j}^{N} \frac{1}{d_{ij}} = \frac{1}{6(6-1)}\left[10 + \frac{2}{2}\right] = \frac{11}{30} = 0.37$$

A.2.3

The Global Efficiency, since there the density is the same for the two conditions.

Problem B

Question B1.
There are several possible correct answers, depending on how the four amplifiers were electrically coupled.

Case 1 – all amplifiers are independent.
3*(8+1+1) + (2+1) = 33 electrodes
Each of the three EEG amplifiers requires 1 electrode per monopolar channel, 1 for the reference, 1 for the ground. The EMG amplifier requires 2 electrodes for the bipolar channel, 1 for the ground.

Case 2 – shared ground among all amplifiers.
30 electrodes.
3 electrodes carrying the ground potential are replaced by electrical shunts

Case 3 – shared ground among all amplifiers + shared reference for monopolar channels.
28 electrodes.
2 electrodes carrying the reference potential are replaced by electrical shunts

Question B2
A-c, B-a, C-b, D-d.
Traces in (c) show blink artifacts, visible on the frontal channels → A.
Traces in (a) show arc-shaped activity in the alpha band = mu rhythm, which is visible on central channels -→ B
Traces in (b) show regular, waxing and waning activity in the alpha band = alpha rhythm, which is visible on parieto-occipital channels → C
Traces in (d) show high frequency, intermittent activity, in burst spaced about 2 s. This is compatible with the EMG activity recorded according to the experimental task → D

Question B3
Mistakes 1-2 – wrong ERD/S estimation procedure.
The procedure is wrong in two respects.
1. Trials are averaged first, and then filtered and squared. Averaging should follow the other two steps to estimate the power in a selected frequency EEG band.
2. The sequence is incomplete, missing normalization with respect to the average baseline value. Since ERD/S is relative measure of change, power it is expressed as percentage of the rest value.

Mistake 3 – Task pacing of task is too fast.
Movement-related ERD/S is a phenomenon that develops over several seconds, with alpha desynchronization occurring even 2-3 seconds before the movement onset and lasting a comparable amount of time after the movement. Finger movements should be spaced at least 8 seconds.

Mistake 4 – Segmentation with no room for a baseline.
Related to the fast pacing, segmentation should always contain latencies in which the brain response is not occurring. In this case, trials should start at least 3-4 seconds before movement onset.

Mistake 5 – Trials overlap repetitions of the task.
Also related to the fast pacing, trials contain in average two repetition of the finger movement.

Not mistakes
- Using a single EMG channel is acceptable since it is only used to detect the onset of a simple movement
- Monopolar acquisition for EEG and bipolar for EMG is acceptable (it is in fact how recordings are done).

- The signal under analysis is the EEG, and its expected reactivity is in the alpha band. Bandpassing the EEG in a narrower band specific for the subject improves detectability of ERD/S. Note that this is not an analysis of the EMG signal, thus this justification to suggest using broader filters to include the beta band is not correct.
- Use of FIR filter is appropriate – efficiency is not a requirement for off-line analysis of a small amount of data, and the linear phase property justify its use.
- Using separate amplifiers is possible, provided that they all share the same ground potential.