Neuroengineering 2023-2024

Exam January 10th, 2025

Part II

How to submit your answers.

The answers can be typed in the provided text file, following the template. Do not modify or move the lines containing the headers.

Textual answers must be typed in the editor. When graphical elements are required in the answer, the latter can be written on paper.

Keep your answers tidy. Messy, hard-to-read answers may penalize your mark.

The maximum total score for part II is **8**.

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

A Brain-Computer Interface based (BCI) based on Event Related Potentials (ERPs) is designed as follows.

Stimulation
Visual stimuation is provided on a computer monitor. It consists of one out of four possible stimuli (S1, S2, S3, or S4), plus a "neutral" background (see Figure 1).
During a stimulation sequence, a random stimulus is "flashed", i.e. it appears on the screen for a 100 ms. The background is then shown for 400 ms. The sequence continues with another random stimulus (see Figure 2).
The stimulation sequence is completed when each stimulus has been presented exactly 10 times (the randomization algorithm is designed to make sure that each of the four stimuli is presented an equal number of times).
Stimulation sequences are repeated several times in each experimental run. EEG data acquired during each sequence is fed into the BCI and leads to the output of a classification (see below).

Subject task
The subject is requested to focus on one of the four stimuli for the duration of a sequence. Expectedly, a P300 potential is generated when (and only when) the stimulus he/she is focusing on is flashed.

EEG acquisition
EEG data are acquired from scalp Ag/AgCl electrodes (positions are shown in Figure 3) using a commercial 8-channel biosignal acquisition device. Potentials are reference to the right mastoid. Internally, analog signals are amplified (CMRR = 105 dB), passed through a 0.1-200 Hz analog bandpass filter, sampled 256 times a second and quantized into 12 bit values.
Digitized potentials are sent via a USB connection to the acquisition PC, where they are recorded to a file along with metadata (markers) describing the timing of stimulus appearance (see *Stimulation* above).

Classification
For each stimulation sequece, EEG epochs are segmented from the continuous recording. Epochs start at the time of the stimulus appearance and end when the next stimulus appears. Four sets of 10 epochs are collected, one set for each stimulus class (S1 to S4), and then epochs belonging to the same set are averaged. The result of this feature extraction is represented as a set of four feature vectors (one per stimulus), whose length is given by the number of EEG channels times the number of samples in an epoch.
A pre-trained classifier (unspecified) takes each of the feature vectors as input, and outputs the probability that a P300 potential was observed following the stimulus Sx. The prediction of which of the stimuli the subject was focusing on is given by the class with the highest probability.

Actuation
An action corresponding to the predicted class is initiated after each classification (e.g. a navigation command is sent to an autonomous robot).

Questions

Write all your answers in the provided text file, following the template

Q1. (1 point) How many electrodes must be mounted on the subject's head?
Justify in max 2 lines.

Q2. (2 points) (a) What is the SOA of the stimulation? (b) What is the interstimulus interval? (c) What is the duration of a stimulation sequence?
State all values in seconds and, for (a) and (b) in samples.
Justify in max 5 lines.

Q3. (2 points) Are the settings of the biosignal acquisition device correct?
Justify in max 3 lines.

Q4. (2 points) What is the length of each feature vector?
Justify in max 3 lines.

Q5. (1 point) How many actuations per minute is the BCI expected to perform?
Justify in max 3 lines.

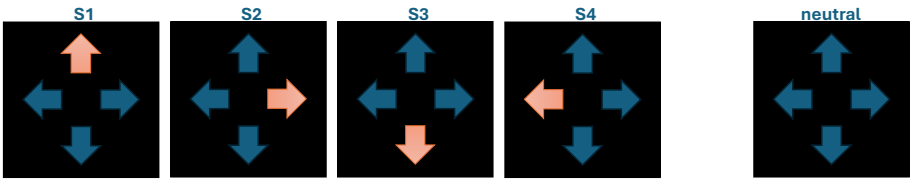

Figure 1. Stimuli

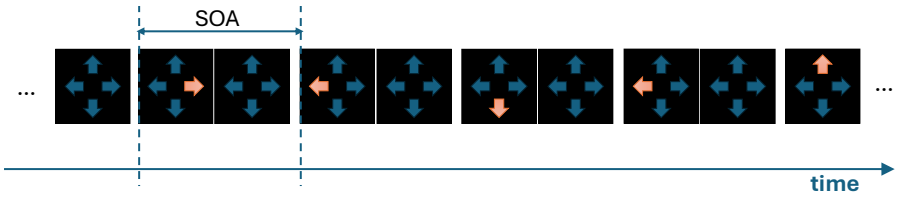

Figure 2. Stimulation sequence

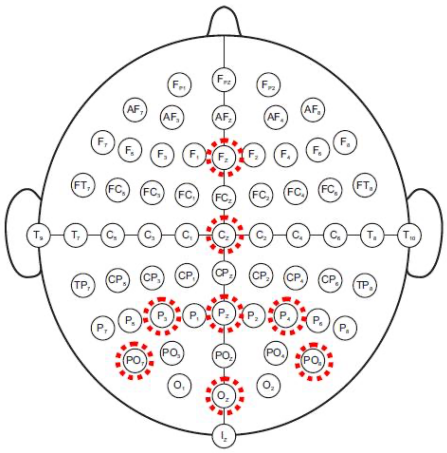

Figure 3. Electrode montage. Only electrodes highlighted in red were used.