Project 3

Neurorobotics & Neurorehabilitation 2022/2023

Objective:
Students are asked to analyze the data collected during a 3-day experiment with 8 healthy subjects and to simulate the whole BCI loop.

Data description:
Data has been recorded with 16-channel EEG amplifier (g.USBamp, g.Tec) at 512 Hz. Electrodes were placed accordingly to the 10-20 international layout. Position and order of the electrodes are reported in Figure 1. Each subject participated in at least 2 recording days. In the first day, subjects performed 3 “offline” (calibration, no real feedback) and 2 “online” (with real feedback) runs. In the second day and third day, they performed 2 “online” runs each.

The task and the visual paradigm:
Participants were asked to perform 2 motor imagery tasks: both hands vs. both feet. Furthermore, they were asked to rest. The visual paradigm exploited during the training is illustrated in Figure 2. The color of the cue indicated which motor imagery task to perform (e.g., both hands, both feet or rest). During the calibration runs, the feedback associated to the cue was automatically moving towards the correct direction. During the online runs, the feedback moved accordingly to the output of the classifier.
Data: https://cloud.dei.unipd.it/index.php/s/DLJfJccgFnFiDZY

Assignments:
Students are asked to analyze the data with the techniques provided in class. In particular, two types of analyses are requested:

1. Grand average analyses on the whole population and on representative subjects
   a. Process the data and apply the convenient filters;
   b. Identify and extract the most suitable features;
   c. Report the achieved results.

2. Analyses on BMI decoding on each subject
   a. Calibration phase:
      - Consider only the offline runs;
      - Process the data, compute the features, select the most disciminant features;
      - Create a classifier based on those features.
   b. Evaluation phase:
      - Consider only the online runs;
      - Process the data, compute the features, and extract those already selected during the calibration phase;
      - Use this data to evaluate the classifier created during the calibration phase;
      - Implement and apply a evidence accumulation framework on the posterior probabilities.
   c. Report on the achieved results in terms of (but not limited to): single sample accuracy (offline/online), trial accuracy (online/offline), average time to deliver a command.

3. [Optional] Implement a simulated BMI online loop, taking into account:
   a. Data is acquired in chunk of [32 samples x 17 channels] by the amplifier. Given the SampleRate of 512 Hz and the length of the chunk (32 samples), new data arrive each 62.5 ms;

b. Each chunck is accumulated in a FIFO buffer of 1 second (512 samples);
c. Processing must be applied only to the data currently in the buffer;
d. At each iteration, the time to process and decode must be less than 62.5 ms;
e. Report and compare the classification results with respect to point 2.
f. Report the histogram of the processing time for all the iterations
g. *(You can add 2 extra pages in the report for this optional task)*

Reference:

Tonin L et al. The role of the control framework for continuous tele-operation of a BMI driven mobile robot. IEEE Transactions on Robotics, 36(1):78-91, 2020. doi: 10.1109/TRO.2019.2943072

Pfurtscheller G et al. Motor imagery and direct brain-computer communication. Proceedings of the IEEE, 89(7):1123-34, 2001. doi: 10.1109/5.939829

Wolpaw JR et al. Control of a two-dimensional movement signal by a noninvasive brain-computer interface in humans. Proc Natl Acad Sci USA, 101(51):17849-54, 2004.
doi: 10.1073/pnas.0403504101

Leeb R et al. Transferring brain–computer interfaces beyond the laboratory: Successful application control for motor-disabled users. Artificial Intelligence in Medicine, 59(2):121-32, 2013.
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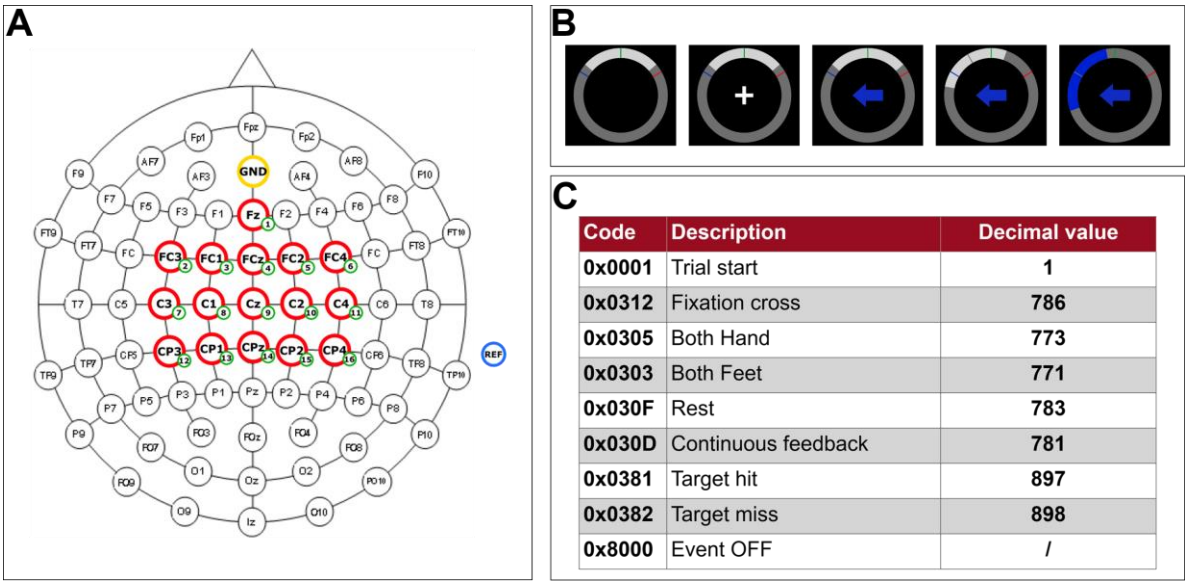
Perdikis S et al. The Cybathlon BCI race: Successful longitudinal mutual learning with two tetraplegic users. PLOS Biology 16(5):e2003787, 2018. doi: 10.1371/journal.pbio.2003787



Code	Description	Decimal value
0x0001	Trial start	1
0x0312	Fixation cross	786
0x0305	Both Hand	773
0x0303	Both Feet	771
0x030F	Rest	783
0x030D	Continuous feedback	781
0x0381	Target hit	897
0x0382	Target miss	898
0x8000	Event OFF	/

Figure 1: A) 16-channel layout. Red circles indicate the electrode positions, small green circles the electrode number; B) Example of visual paradigm used in the offline and online runs. C) Event codes in the GDF