Assignment 1

Neurorobotics 2024/2025

Objective:
Students are tasked with analyzing data collected during a 3-day Motor Imagery (MI) Brain-Computer Interface (BCI) experiment involving 8 healthy participants.

Data description:
The data was recorded using a 16-channel EEG amplifier (g.USBamp, g.Tec) at a sampling rate of 512 Hz. Electrodes were positioned according to the 10-20 international system. The placement and order of electrodes are illustrated in Figure 1A. Each participant completed at least two recording days:

- **Day 1:** 3 "offline" runs (calibration, without real feedback) and 2 "online" runs (with real feedback).
- **Day 2 and Day 3**: 2 "online" runs per day.

Data Link: Access the dataset

The task and the visual paradigm:
Participants performed two motor imagery tasks—imagining movements of **both hands** or **both feet**—and a **rest** task. The training visual paradigm is shown in Figure 1B. The color of the cue indicated which motor imagery task to perform (e.g., both hands, both feet, or rest).

- During the **calibration runs**, feedback associated with the cue automatically moved in the correct direction.
- During the **online runs**, feedback movement was determined by the output of the classifier.

Assignments:
Students are required to analyze the data using techniques covered in class. The following analyses must be performed:

1. Grand average analyses on the whole population and on representative subjects
   a. Process the data using appropriate methods.
   b. Identify and extract the most relevant 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 discriminant 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 an evidence accumulation framework on the posterior probabilities
   c. Report and discuss the achieved results in terms of (but not limited to): single sample accuracy (offline/online), trial accuracy (offline/online), average time to deliver a command.

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

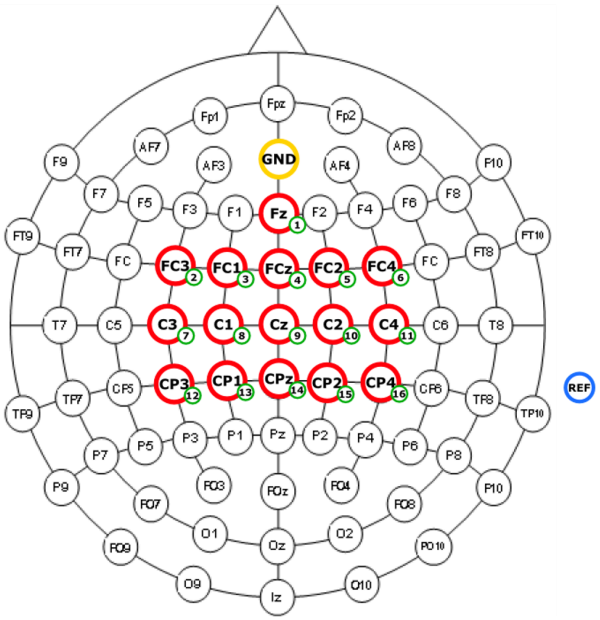
Pfurtscheller G et al. Motor imagery and direct brain-computer communication. Proceedings of the IEEE, 89(7):1123-34, 2001. doi: 10.1109/5.939829

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

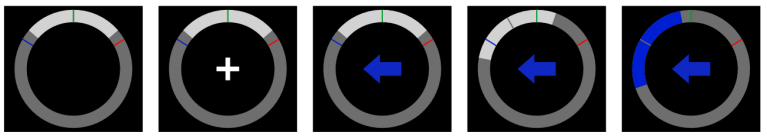
Leeb R et al. Transferring brain–computer interfaces beyond the laboratory: Successful application control for motor-disabled users. Artificial Intelligence in Medicine, 59(2):121-32, 2013.
doi: 10.1016/j.artmed.2013.08.004

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

A



B



C

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) The 16-channel EEG 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

Guidelines for the report

1. Format:

- The report must be submitted in **PDF format**
- The report must be accompanied by all MATLAB scripts used to compute the results
- The report must be accompanied by a README file to run the scripts
- Each group member's contribution must be clearly specified in the README file

2. Data:

- **Do not include** raw EEG data or processed data in the submission.

3. Length and Layout:

- Maximum length: **12 pages**, double-column format
- Margins:
    - Top: **1.5 cm**
    - Bottom: **1.3 cm**
    - Inner: **1.5 cm**
    - Outer: **1.5 cm**

4. Content Requirements:

- **Methods**: Provide a clear justification for all methods used.
- **Results**: Present results clearly and comprehensively.

5. Plagiarism Check:

- A plagiarism check will be conducted on both the report and the submitted MATLAB code.