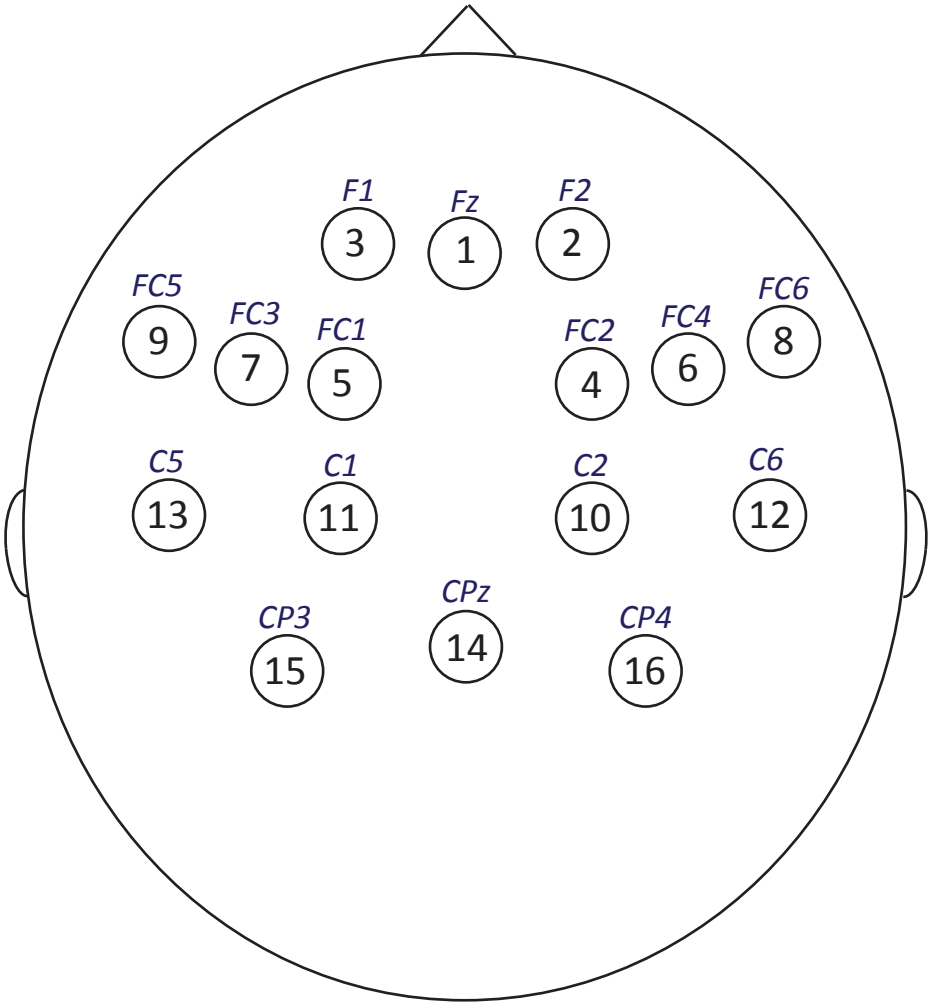
COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

Lab Instruction 9

Decoding Imagined Movement

Brain Computer Interface Lab

ECBM 4090



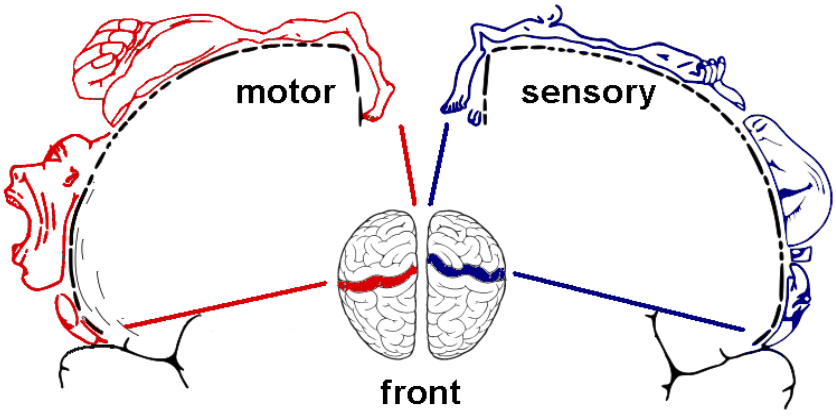
Some materials adapted from g.tec medical engineering (www.gtec.at).

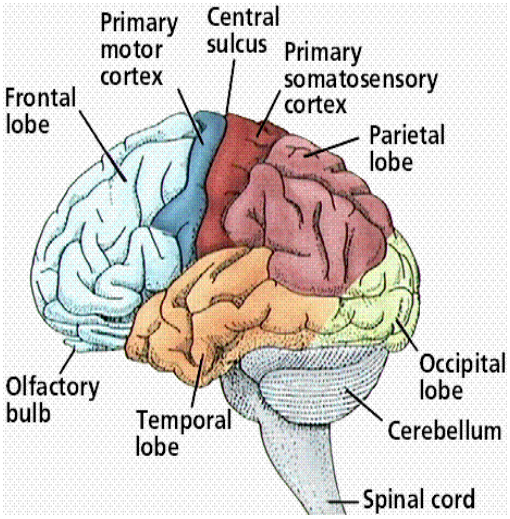
Decoding Imagined Movement

Decoding imagined movement is a successful BCI paradigm. It is based on Mu Waves, which are synchronized patterns that appear when the motor cortex (the part of the brain that controls voluntary movement) is idle. It has been shown that when a person performs or imagines a movement, mu waves are desynchronized and thereby suppressed. We can detect the change in the suppression of mu waves in the left and right cortices and use this information in BCI applications, as we will explore today.

Because the right motor cortex controls the left hand and vice versa, we can use changes in the spatial pattern of mu wave activity across the scalp to decode left and right imagined movements. The most commonly used method for decoding imagined movement is Common Spatial Pattern (CSP) filtering. CSP finds the best linear combination of electrodes that maximizes the differences between the patterns of activity across conditions.

In this project, we collect data with an existing Simulink module, train a CSP filter, train an LDA classifier, and perform an online demonstration. We will use this data to train our own CS, compare left and right mu wave activations, and determine decoding accuracy.





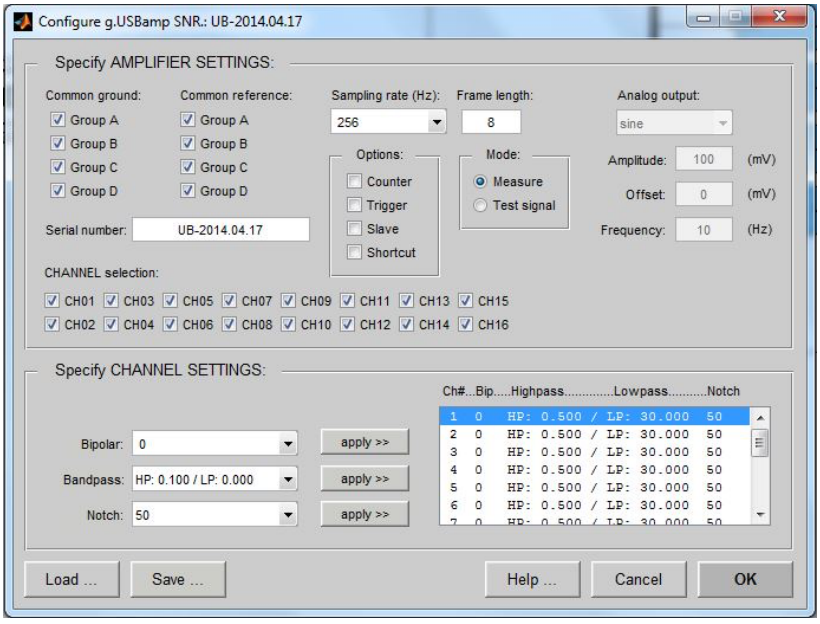
Phase 1: Setup

1. In order to maximize coverage over the motor cortex, we use the following 16 electrode locations: **FZ, F1, F2, FC5, FC3, FC1, FC2, FC4, FC6, C5, C1, C2, C6, CP3, CPz, and CP4** (see the diagram on Page 1).

   Note: You will need to change the location of the electrodes for this experiment.

2. Run MATLAB as administrator.
3. Open Simulink file **cspbci_twoclass.slx** from Courseworks.

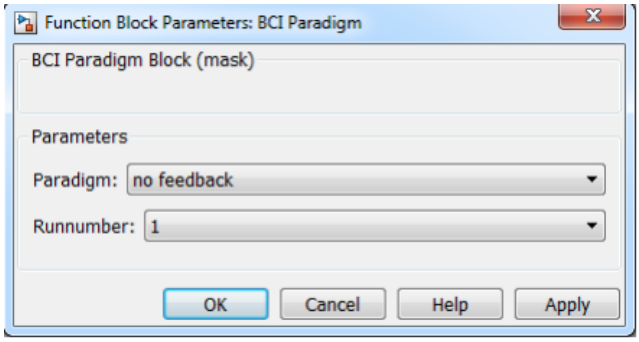
4. Within the **g.USBamp** block, use the following settings:
   a. Band pass filter between 0.5Hz and 30Hz. Notch filter at 60Hz.
   b. Sampling rate: 256Hz.
   c. Frame length: 8.



5. Access the **Select Channels** block. Since this experiment involves 16 electrodes and thus 16 active channels, "Total Channels" should be set to 16.

6. The model needs a classifier in order to operate. Click on the **Apply Classifier** block.
   a. Go to "g.CSP", then to "TestData".
   b. Select the file "….template_classifier_CSP_TwoClasses_27Ch.mat" from C:\program files/gtec/gtech_libraraies/g.csp/test data.
   c. The left column represents error and the right-hand number is the time in milliseconds. Select the classifier in the left column with the lowest error (in the left column).
   d. Deselect "Add zero class".

7. Turn off feedback. The lab will consist of four runs of data collection, 40 trials each. The first run will have no feedback, so you need to turn it off.
    a. Access the **BCI Paradigm** block.
    b. Switch "Paradigm" to "No Feedback" as seen below.

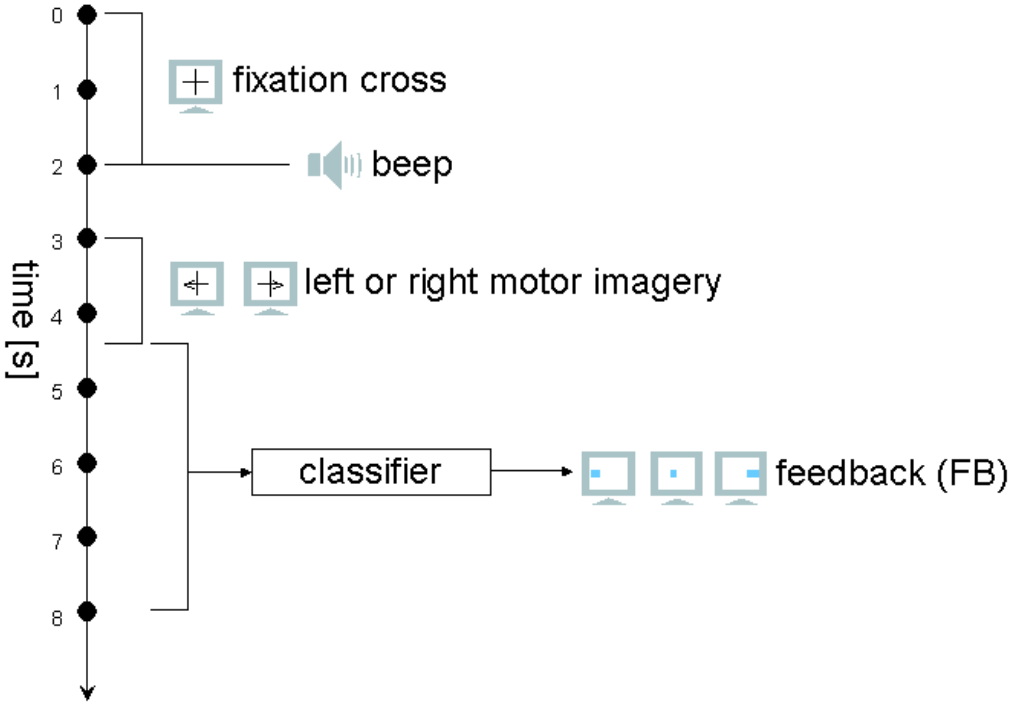


8. Remember to name the file (in the "To File" block) based on the run number you choose.

Note: If the **Select Classifier** block is failing to work, simply delete it and replace it with the same block from the Simulink library. Make sure **Select Channels** block has only 16 channels; if it has 27 channels, change it to 16, save, close MATLAB, and then reopen to continue.

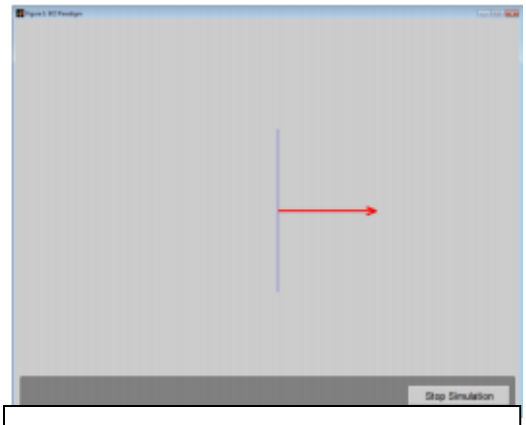
Phase 2: Run the experimental paradigm

1. Familiarize yourself with the experimental paradigm, pictured and described below:



a. The experiment begins with a display of a vertical line in the center of the monitor.
b. The subject will be cued to imagine left- or right-hand movement by the appearance of an arrow pointing left or right.
c. While the arrow is on screen, the subject must imagine left or right movement.
d. We will use feedback later in the experiment after we have trained the classifier. When feedback is on, a bar will show the classification result in real time. For example:

When the arrow points left, imagine left-hand movement.



When the arrow points right, imagine right-hand movement.

2. Begin the first session and collect the data for run 1. We will use this data to train a classifier for decoding imagined movement.

IMPORTANT TIPS: You will be using motor imagery in this experiment. Visualization of motor movements can be difficult. Avoid all muscle movement. Try to mentally picture your hand opening and closing.
Most importantly, try to **be consistent** across trials!

Phase 3: Analyze the data

1. After recording the first session, start *gbsanalyze* to begin calculating the CSPs and weight vector.
    a. Load the session's data file.
    b. Access **Appearance Settings** under **Options**.
    c. In **Edit USER DIRECTORY**,
    select "C:\Program Files\gtec\gtech_libraries\gCSP\Batch".
    d. Select "CreateClassifier_CSP_TwoClass" in the **User** menu in the toolbar. This automatically calculates the filters and classifier.
    e. Click on "CreateClassifier_CSP_TwoClass" and select "Enable automatic artifact detection."

Report: Take a screenshot of all results from gbsanalyze and include them in your report. (4 pts)

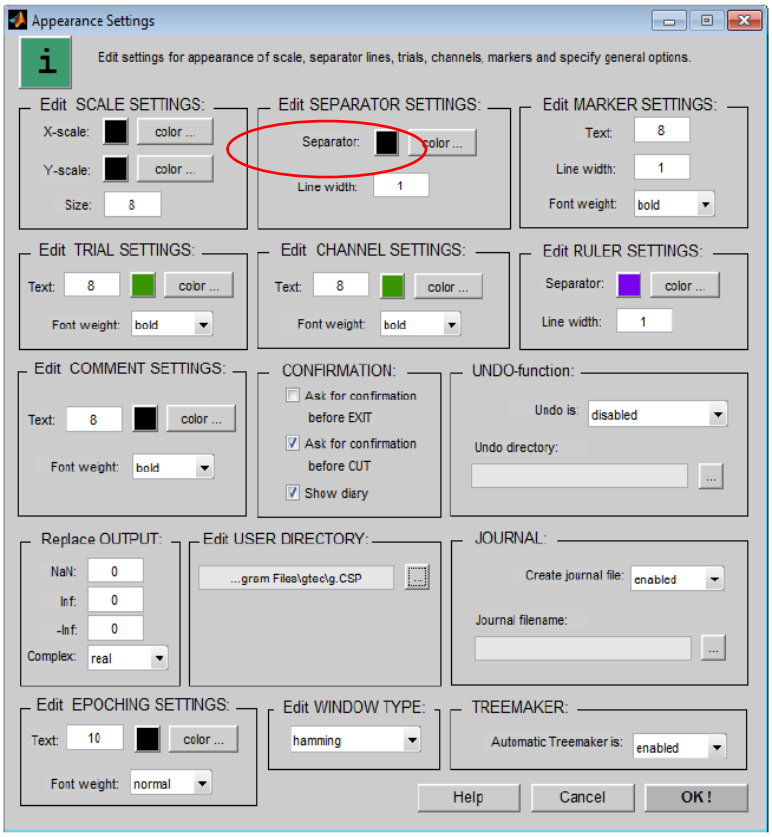
2. Select and load a classifier.
    a. Information important to your classifier selection:
        i. One of the windows details the common spatial patterns created by the model.
        ii. The other two windows provide graphs on percent error over time.
        iii. Determine which classifier has the lowest percent error.
    b. Choose one specific classifier based on the errors and the CSPs.
    c. Create the classifier by selecting the best one in **BCI Paradigm**. It will be automatically created, but you will need to manually load it after each run.
    d. Load the classifier. If opened in the same Matlab command window as the Simulink model, the classifier will appear in the CSP folder. The file name will be "classifier_CSP_TwoClasses.mat".

Report: Specify the classifier you've chosen and the reason for your choice. (6 pts)

3. Enable feedback to test the classifier in real time.

4. Begin the second run. **Make sure to save to a different file**, e.g. run2.mat.
    a. Once you complete the second run (which is the first run with feedback) you will receive a graph detailing the ability of the model to differentiate your left-hand and right-hand imagined movement. Use this information to help adapt your strategy.
    b. For example, if you are trying particular techniques while trying to move the bar, make note of which ones are most successful and try to replicate them in later testing to maximize positive results.

5. Do two more runs with feedback, making sure you save to different files and select different "Runnumber" in **BCI Paradigm**. We will use all the data in the homework.



Homework:

Load the data from runs 1-4 in MATLAB. The trigger (channel 18) marks second 2 of each trial. Information about the cue direction in each run and trial is in .mat files on Courseworks in the CSP folder. Using this information, separate the trials into two groups of left and right. There should be 80 left and 80 right. (1 pt)

Filter your data from 8-20Hz and find the average power of each channel during left versus right imagined movements. Use the time interval when the subject is actively imagining movement (4.5s to 8s after trial onset). Can you see a clear difference between the two? (6 pts)

Calculate the difference between the two conditions for all electrodes and display the subtraction on the scalp map. In which parts of the brain do you observe a bigger difference? (3 pts)