Integrated Lecture
"Brain-Computer Interfacing"

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In total there are $35 + 5 = 40$ points for the tasks (5 being bonus points). Additional bonus points can be obtained for very well explained solutions. Answers may be written in German.

Task 1 – Modulation of brain rhythms during motor imagery (6+3 = 9 Points)

We consider data of an experiment, where in each trial an arrow appears for 4 seconds that points to either the left or the right side. The participant is instructed to perform motor imagery corresponding to the left or the right hand during that time, respectively. There are also trials in which a dot appears, representing the instruction just to relax. Assume that the participant is also relaxed during the performance of motor imagery, i.e., the difference between the motor imagery conditions and the relax condition is just specific to motor imagery.

(a) Draw the frequency spectra in the range of 1 to 35 Hz that are typically observed during motor imagery of the *left hand* and of the *right hand*. Draw the spectra for two appropriate channels (covering the sensorimotor areas of the two hands). Describe the modulation of the sensorimotor rhythms during imagined hand movements in about 2 sentences.

(b) Imagine that a common spatial pattern (CSP) analysis has been performed for the classification between the conditions *left hand* and *relax* in a suitable frequency band. Sketch a spatial pattern that would be plausible as the pattern corresponding to the CSP filter which maximizes the relative band power for *relax*.

In both tasks, there is no unique true solution. The task is about sketching a plausible case, taking into account general neurophysiology.

Task 2 – Classification of modulated brain rhythms (6+4 = 10 Points)

We consider the same data set as introduced in task 1, but only the two motor imagery classes and not the *relax* class. Assume that a suitable frequency band and time interval has been determined and let $\mathbf{\Sigma}_1$ and $\mathbf{\Sigma}_2$ denote the covariance matrices of the concatenated band-pass filtered trials of the two classes.

(a) Write down the optimization problem which defines the CSP filter $\mathbf{w}$ that maximizes band-power in class 2 in relation to the total band-power in both classes. Describe the meaning of the formula in one sentence.

(b) How can that filter $\mathbf{w}$ be determined practically from $\mathbf{\Sigma}_1$ and $\mathbf{\Sigma}_2$? (No derivation is required.) In what regard does this solution provide more information than the optimization problem of (a)?

(more tasks on page 2)

Task 3 – Validation of CSP-based classification
(9 Points)

Describe the procedure for obtaining the expected (generalization) error of a CSP-based classification using 5-fold cross-validation. You may assume that a suitable frequency band and time interval is already determined. (About five sentences are expected. Since task 2 is about **how** the CSP filter matrix is determined, there is no need to describe it here again.)

Task 4 – Quick questions
(2+2+2+2+2+2 = 12 Points)

This task consist of **'quick questions'**. Each should be answered briefly to the point with one senctence (or sketch), or with some bullet points.

(a) When the so-called median nerve is electrically stimulated, the amplitude of the sensorimotor rhythm (at about 11 Hz) is attenuated for 2 seconds. Given a dataset which the median nerve is stimulated every 5 seconds, how should CSP be applied to obtain a spatial filter that shows this modulation best?

(b) If there is the choice between one CSP filter with generalized Eigenvalue of 0.6 and another CSP filter with generalized Eigenvalue of 0.25, which one would you expect to contribute more to classification?

(c) Why can the generalized Eigenvalue in CSP be misleading about the usefulness of a particular spatial filter concerning its importance for discriminability?

(d) Assume that in an ERP speller (based on *target* vs. *nontarget* classification) the signals change during usage due to changes in the impedances of the electrodes. How should the LDA classifier be adapted (mention the essential parameter)?

(e) Assume resting state data in a particular person shows an unusual brain rhythm with a frequency of 19 Hz. Which decomposition method should be used best to determine the spatial filter for extracting the component of that brain rhythm?

(f) Assume an experiment in which the participant performs a *problem solving task* for 5 minutes and then rests for 1 minute. This is repeated three times. From those data, trials of non-overlapping 1 s windows are extracted (i.e., 60 trials per minute of data). What needs to be considered when evaluating the performance of the classification of *problem solving* vs. *rest* trials using cross-validation?

Good luck!