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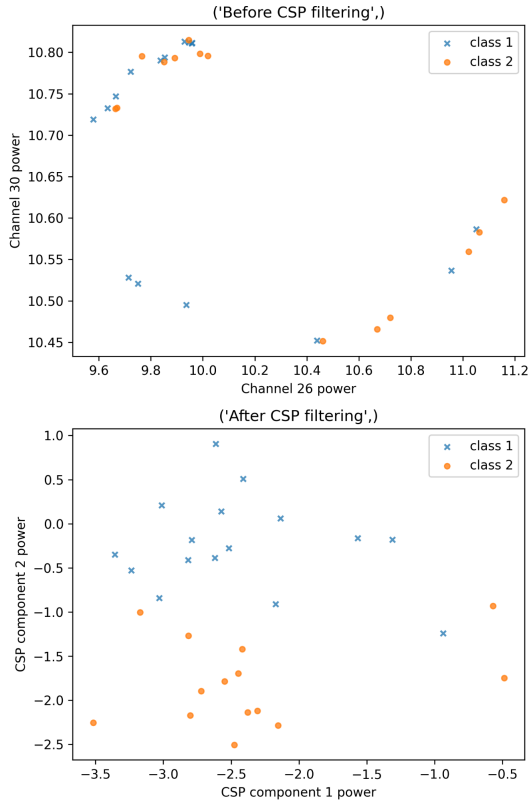
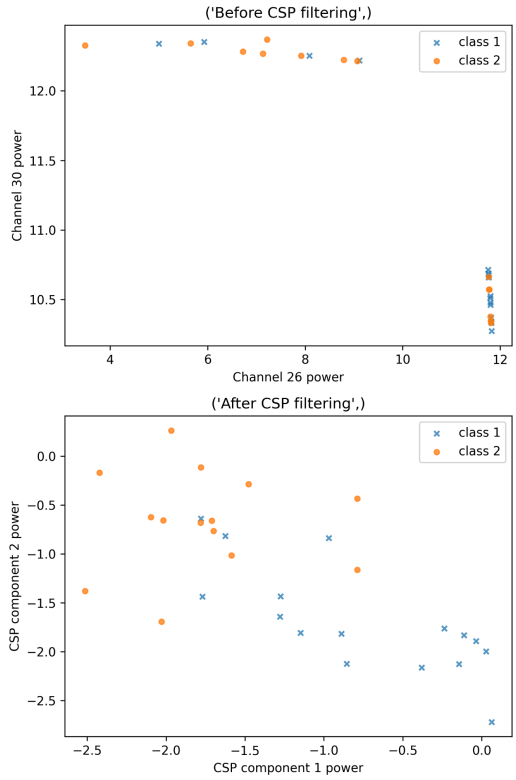
Homework 8:
EEG Decoding: Common Spatial Pattern (CSP) + Linear Discriminant Analysis (LDA)



a) 1.AssignmentData01.mat:

CSP+LDA accuracy: 93.33%; Online accuracy: 23.33%

For data01, the offline model performed very well (93.33%), but the BCI's online performance was poor (23.33%), suggesting that while the EEG signals contained clear and decodable information, the classifier used during the live experiment was maybe not well-calibrated for that specific session.



2.AssignmentData02.mat:

CSP+LDA accuracy: 86.67%; Online accuracy: 90.00%

For Data02, both the offline model (86.67%) and the online BCI (90.00%) performed well, indicating that the subject produced consistent brain patterns and the online classifier was effectively trained for this task.

For both datasets, we find that the "Before CSP" plot shows the two classes heavily overlapping and indicates they were not separable using raw channel power. However, the "After CSP" plot shows the classes forming two distinct, linearly separable clusters. The graphs suggest that our CSP filtering is working appropriately.

b)

Pros:

- High Performance: The results show (93.33% and 86.67%) that CSP+LDA is very effective for discriminating motor imagery states.
- Computational Efficiency: It is a fast method to train and test, making it very useful for real-time BCI applications.
- Interpretability: The CSP filters can be plotted as scalp maps (topomaps), which allows to visualize which brain areas are most important for classification.

Cons:

- Sensitivity to Frequency Band: The method's performance is very dependent on choosing the correct frequency band during preprocessing.
- Linearity: Both CSP and LDA are linear methods. They assume the classes can be separated by a straight line so they can fail if there are complex or non-linear relationships in the data.
- Requires Subject-Specific Calibration: The spatial filters are tailored to an individual user and a specific session, meaning a new model must be trained for each person.

When compared to the simpler linear classifiers often used for online control, CSP+LDA have a better feature extraction, since it has the ability to decode data from a session where the online BCI failed. Also, when compared to machine learning approaches like deep learning, CSP+LDA requires significantly less data and is more transparent, even though it would probably be outperformed by end-to-end networks that have the capacity to learn more complex features from large datasets.

c)

I tested different frequency bands on Data01. First changing it from [4, 40] to [8, 12], the classification accuracy remained the same (93.33%). Then, testing with [13-30], I found a large drop in accuracy (83.33%), which means that the mu band contains most of the necessary information for classification. We can also infer that the mu band is not only necessary but also sufficient for decoding motor imagery. The CSP algorithm allowed it to isolate this key signal component even within a much broader frequency range, which is the reason [4-40] was as effective.