Introduction to Machine Learning: Mini-Project 2

Brain-Computer Interface Movement Decoding

ECE 580
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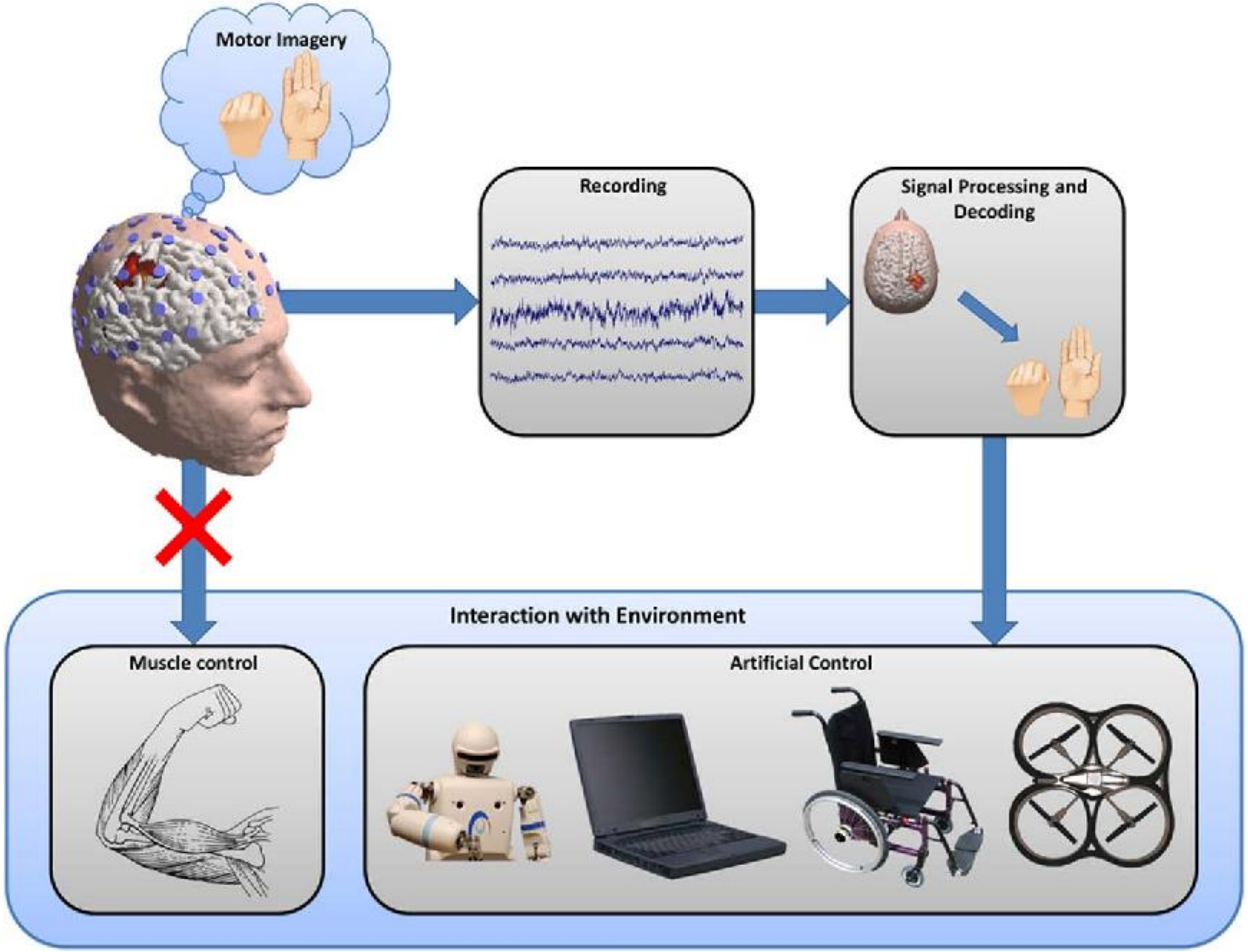
Objective

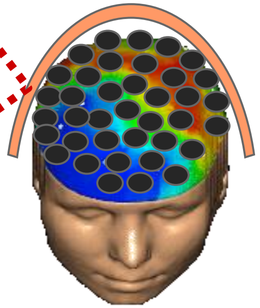
Brain-computer interfaces (BCIs) can provide an ability to independently interact with the environment for individuals who have do not have neuromuscular control

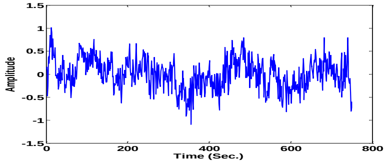
GOAL: Determine if a BCI user wishes to select “left” or “right”



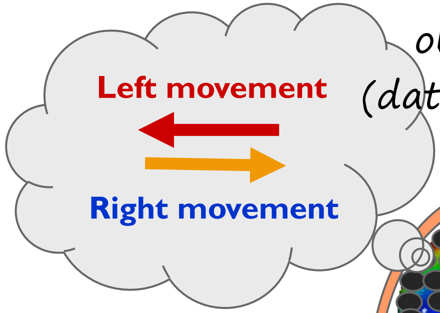
B. He, B. Baxter, B. J. Edelman, C. C. Cline and W. W. Ye, "Noninvasive Brain-Computer Interfaces Based on Sensorimotor Rhythms," in *Proceedings of the IEEE*, vol. 103, no. 6, pp. 907-925, June 2015, doi: 10.1109/JPROC.2015.2407272.

BCI Measurement Classification

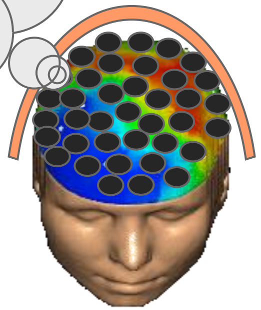




204 features (204 electrodes)



observations (data or features)
X

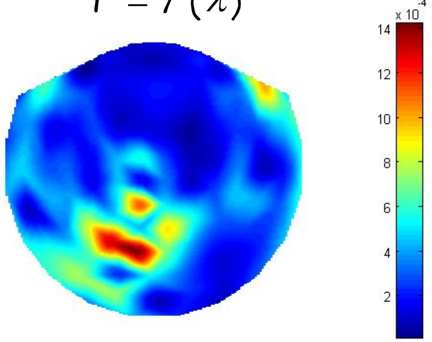


decision statistic (scalar)
$\lambda = f(X)$

Decision function

decision function is a two-class SVM

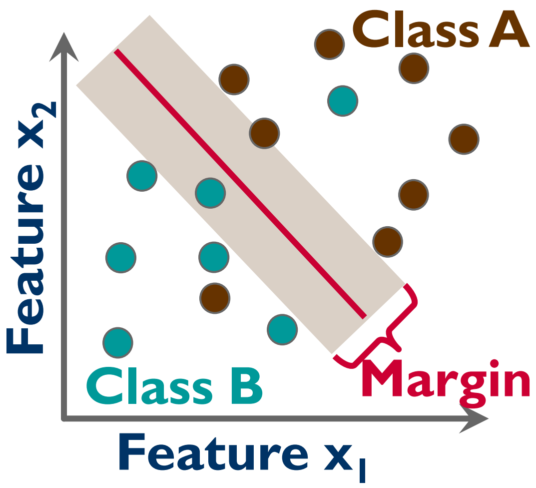
decision ("L" or "R")
$Y = f(\lambda)$



Left or Right

SVM Classifier

Convex optimization problem



$$\begin{aligned} \min_{W,C,\xi} \quad & \sum \xi_i + \lambda \cdot W^T W \\ \text{S.T.} \quad & y_i \cdot \left(W^T X_i + C \right) \geq 1 - \xi_i \\ & \xi_i \geq 0 \\ & \left(i = 1, 2, \cdots, N \right) \end{aligned}$$

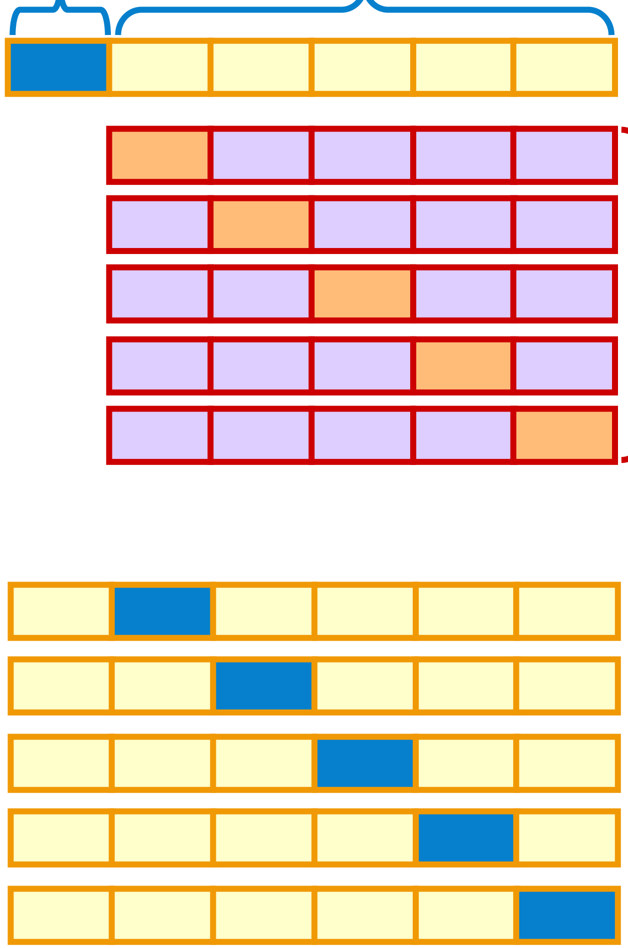
Implement a two-class **linear** SVM for classification (DO NOT use kernels!)

- Ensure the correct regularization is implemented (ridge vs. lasso)
- Perform your own optimization for the regularization parameter λ

Two-Level Cross Validation

Testing data

Training data



Run 1: *Accuracy(1)*

2^{nd}-level cross validation (to find λ for run 1)

Run 2: *Accuracy(2)*

Run 3: *Accuracy(3)*

Run 4: *Accuracy(4)*

Run 5: *Accuracy(5)*

Run 6: *Accuracy(6)*

1^{st}-level cross validation (use λ found by 2^{nd} level cross validation for run i to train on entire training set for fold i)

Two-Level Cross-Validation

Implement 6-folds cross-validation for the first-level cross-validation

- Data set: 120x2 trials
- Divide data into 6 folds: 20x2 trials per fold
  - Training data in each iteration: 100x2 trials
  - Testing data in each iteration: 20x2 trials
- Accuracy (probability of correct decision) is the performance metric to be optimized

For each iteration of the second-level cross validation

- Use 5-fold cross-validation to determine the optimal value of λ for that fold (recall 1st-level cross validation training data for each fold is 100x2 trials)
  - Divide the 100x2 training data into 5 folds for 2nd-level cross validation
    - 2nd-level cross validation training data: 80x2 trials
    - 2nd-level cross validation testing data: 20x2 trials
  - At a minimum, test regularization parameters λ = {0.01, 1, 100, 10000}

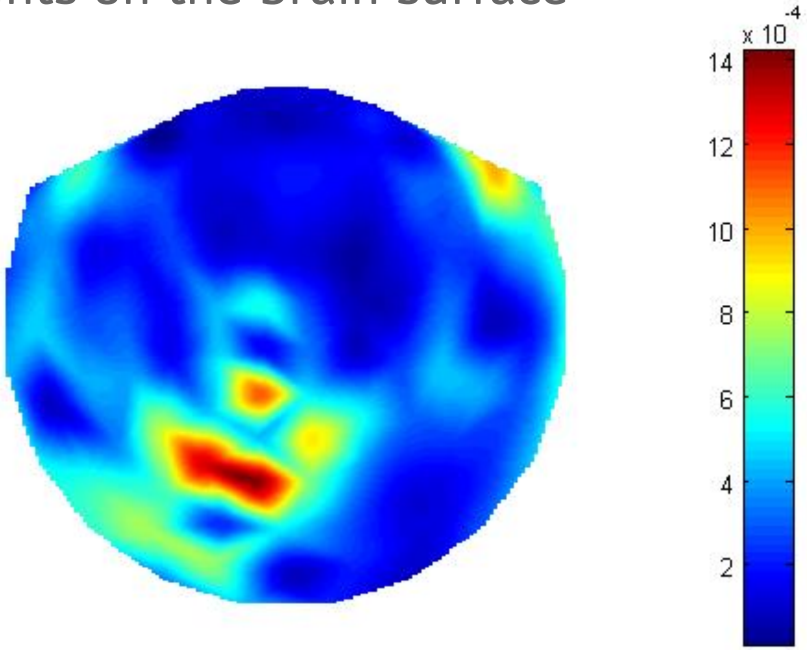
Channel (Electrode) Weight

Each element in W corresponds to the weight of a channel (electrode)

- Large amplitude → the channel carries strong directional (left/right) information

Visualize the spatial map of the channel weights on the brain surface

- Use the provided function: show_chanWeights(abs(W))
    - Input: 204x1 vector (absolute value of the weight vector W)
- Output: visualization of the weights on the brain surface



Data Sets and Files

Imagined Movement (weaker signals → expect lower classification performance)

- feaSubEImg_1: data for class 1 for imagined movement (204x120 matrix)
- feaSubEImg_2: data for class 2 for imagined movement (204x120 matrix)

Overt (actual) Movement (stronger signals → expect better classification performance)

- feaSubEOvert_1: data for class 1 for overt movement (204x120 matrix)
- feaSubEOvert_2: data for class 2 for overt movement (204x120 matrix)

In each data file:

- There are 120 trials (observations)
- Each trial is represented by a 204x1 vector
- The i^{th} feature vector is a 1x120 vector

sensors102: sensor locations, used for visualizing channel weights