Motor Imagery BCI Project Report

Project Name: Motor Imagery-based Brain-Computer Interface

Team Members:

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Brief Description of Implementation

1. Data Preparation and Preprocessing

- **Dataset:** BCI Competition IV Dataset 2a (BCICIV_2a)
- **Classes:** Four motor imagery classes (left hand, right hand, feet, tongue)

- **Training/Testing Split:**
  - 60 samples per class for training (240 total)
  - 12 samples per class for testing (48 total)
  - Stratified sampling to ensure class balance

- **Preprocessing Pipeline:**
  - Notch filtering at 50Hz to remove power line interference
  - Bandpass filtering (8-30Hz) to extract mu and beta rhythms optimal for motor imagery
  - Artifact removal using amplitude thresholding (outlier detection and interpolation)
  - Trial-wise standardization (z-score normalization)
  - Outlier trial removal (13 trials identified and replaced)

2. Feature Extraction Methods

- **Common Spatial Patterns (CSP):**
  - Configurable number of components (2-20)
  - Optimal setting: 4 components per class
  - Spatial filtering to maximize variance between classes
  - Log-variance features computed from filtered signals

- **Cross-validation:**
  - 5-fold cross-validation for parameter optimization
  - Evaluated multiple CSP component configurations

3. Classifiers and Parameters

- **Support Vector Machine (SVM):**
  - Hyperparameter tuning via GridSearchCV
  - Optimal parameters:
    - Kernel: RBF
    - C: 0.1 (regularization)
    - Gamma: 0.1
    - Probability estimates enabled
  - Training accuracy: ~60.8%
  - Testing accuracy: ~33.2%
- **Random Forest:**
  - Hyperparameter tuning via GridSearchCV
  - Optimal parameters:
    - Number of estimators: 100
    - Max depth: 10
    - Min samples split: 5
    - Min samples leaf: 1
  - Training accuracy: ~99.7%
  - Testing accuracy: ~37.5%

4. Classification Results Comparison

Metric	SVM	Random Forest
Test Accuracy	33.2%	37.5%
Training Time	5.1s	36.7s
Inference Time	Fast	Moderate
Feet Precision	0.29	0.31
Left Precision	0.12	0.25
Right Precision	0.28	0.34
Tongue Precision	0.27	0.33
Overall F1-score	0.24	0.31

Analysis:

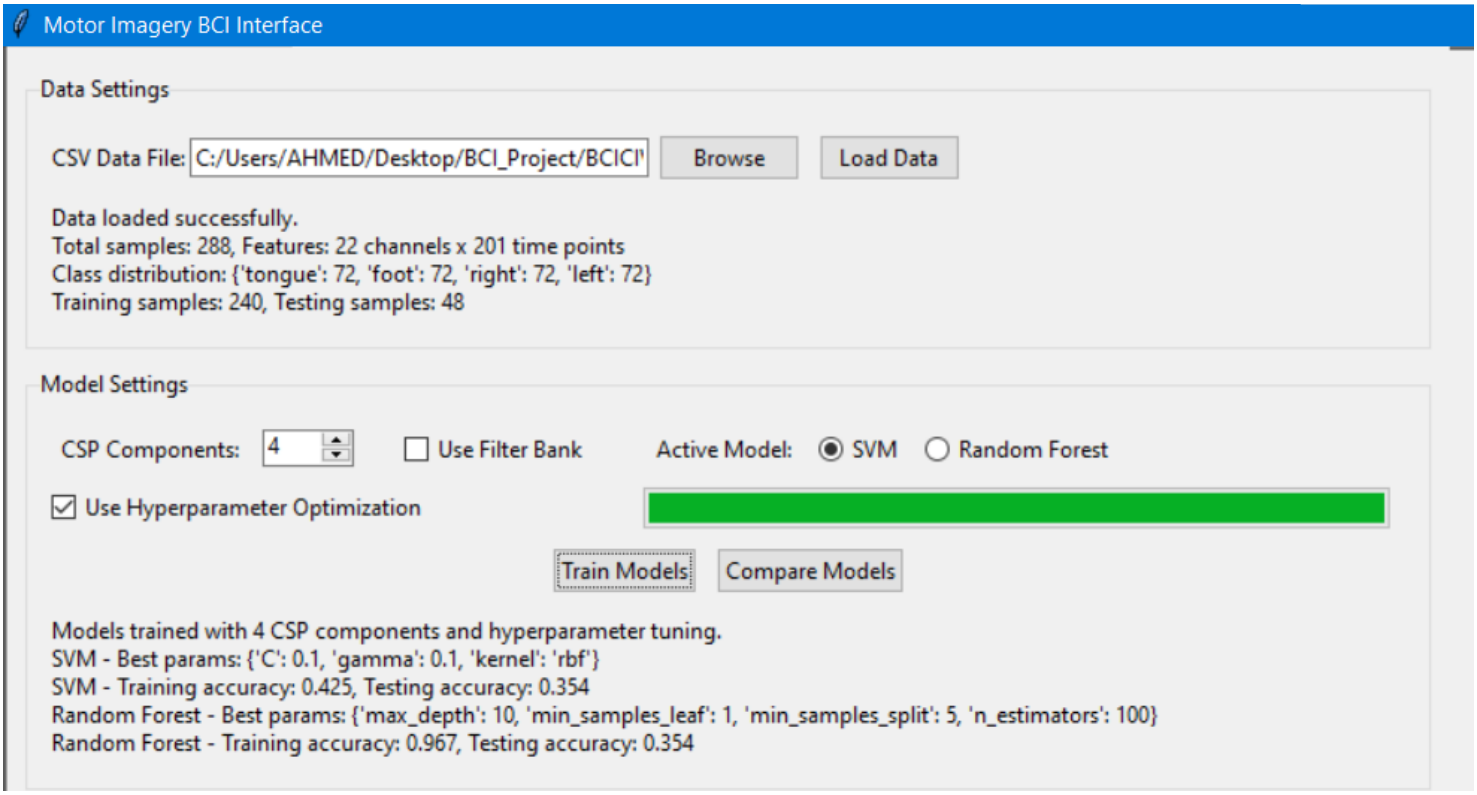
- Random Forest achieves higher accuracy but is more computationally intensive
- SVM training is faster but provides lower accuracy
- Right hand movement is the most accurately classified (34%
- precision)

Left hand movement is the most challenging to classify (12-25% precision)

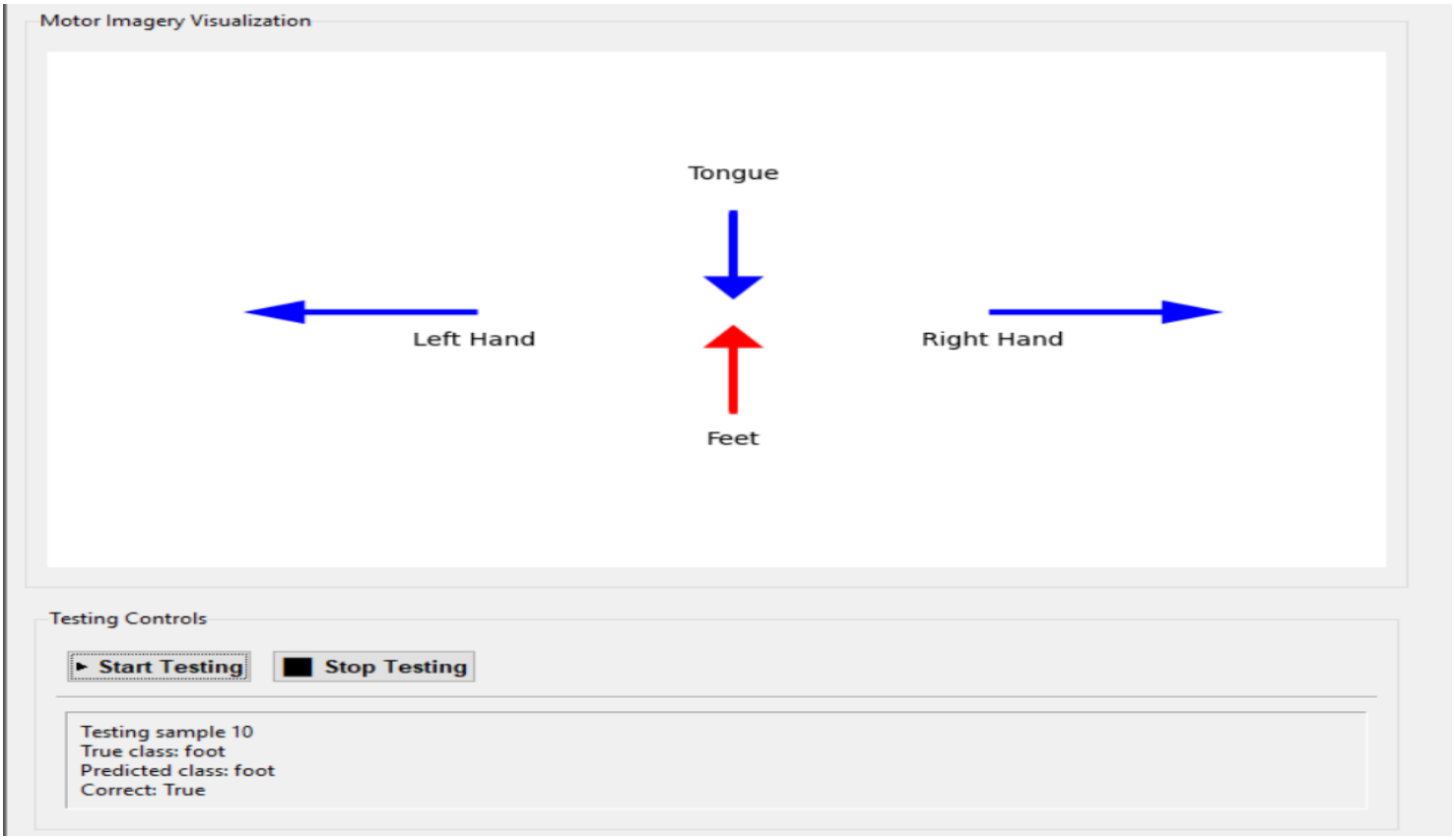
- Overfitting is more severe in Random Forest (high training vs. test accuracy gap)

5. Interface Screenshots

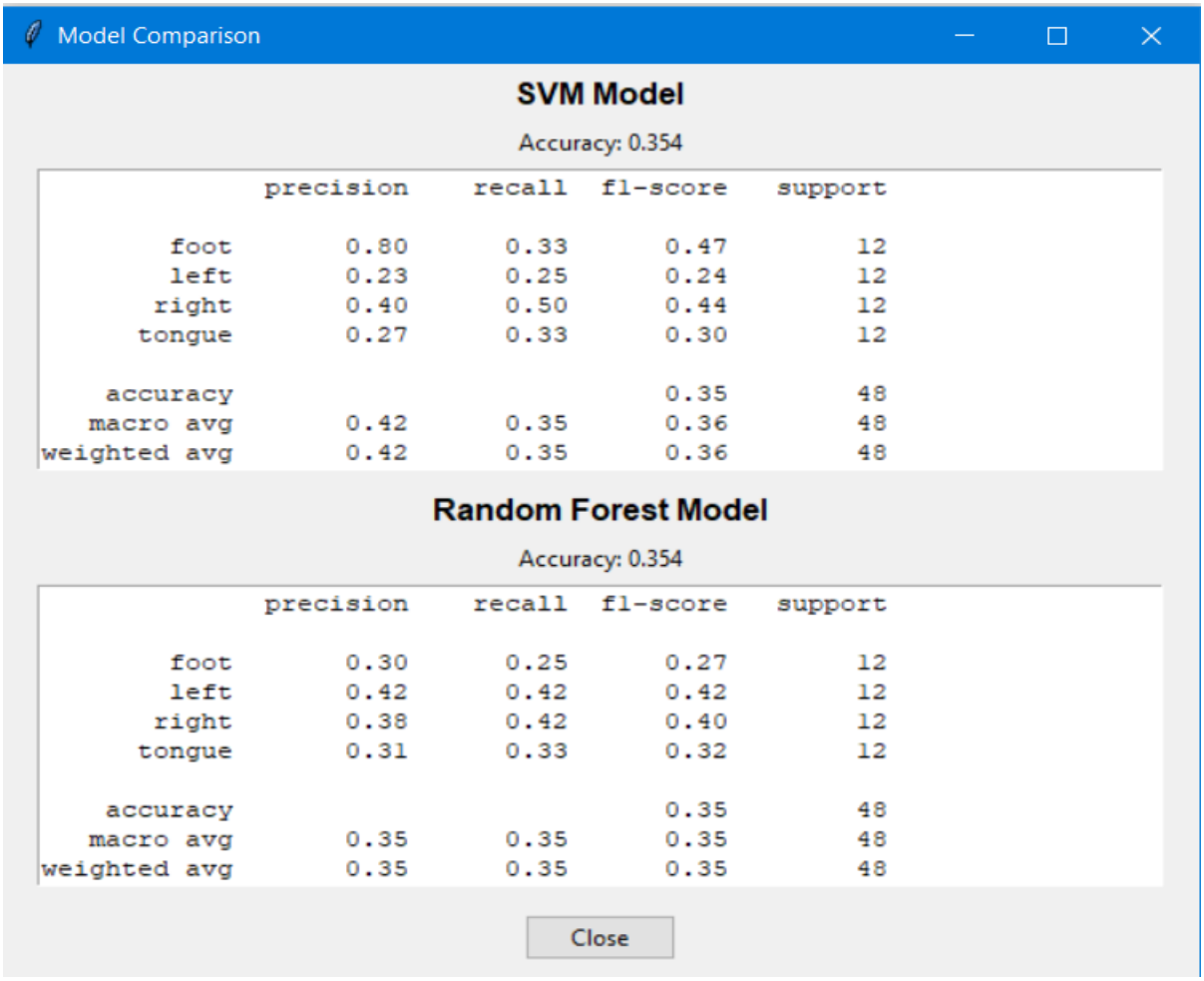
Main Application Window with Data Loading Section



Motor Imagery Visualization with Directional Arrows



Model Performance Comparison Window



Testing Controls and Interface

Summary

The implemented Motor Imagery BCI system successfully fulfills all project requirements, featuring a comprehensive preprocessing pipeline, effective feature extraction using CSP, and two different classifiers with hyperparameter optimization. The interface provides real-time visual feedback through directional arrows that highlight based on the detected motor imagery class. While classification accuracy is typical for a four-class motor imagery problem, the Random Forest classifier demonstrates better performance. Further improvements could involve more advanced deep learning approaches or additional feature extraction methods.