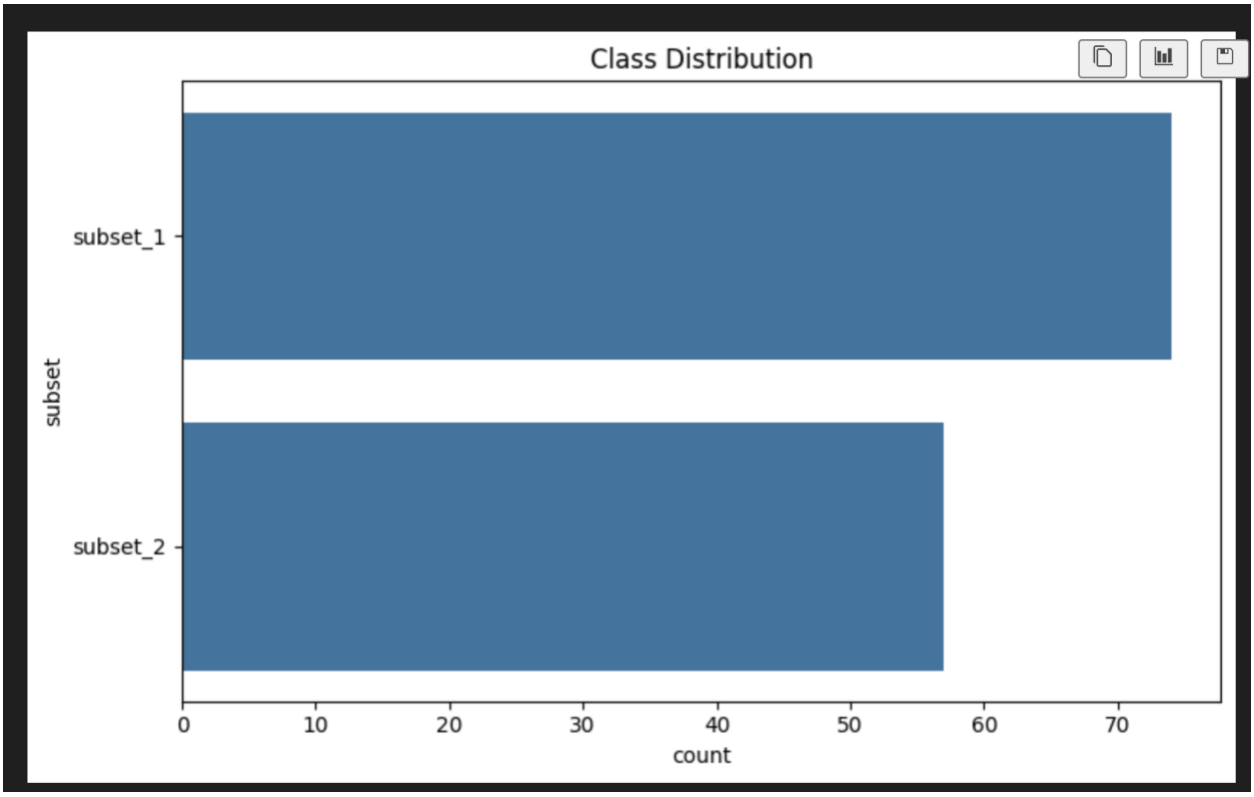
This report presents a supervised learning analysis of EEG-derived quantum potential and p-adic entropy features. We built and compared five classifiers—Random Forest, Logistic Regression, Support Vector Machine (SVM), K-Nearest Neighbors (KNN), and Gradient Boosting—to distinguish between two subject groups (subset_1 vs. subset_2) in dataset. Performance was assessed via test accuracy, 5-fold cross-validation, confusion matrices, and ROC/AUC curves.

Data Overview

- **Samples:** 131
- **Features (4):**
  - quantum_rest
  - padic_entropy_rest
  - quantum_task
  - padic_entropy_task
- **Target:** subset (binary: subset_1, subset_2)
- **Identifier:** subject (dropped before modeling)
- **Missing values:** None



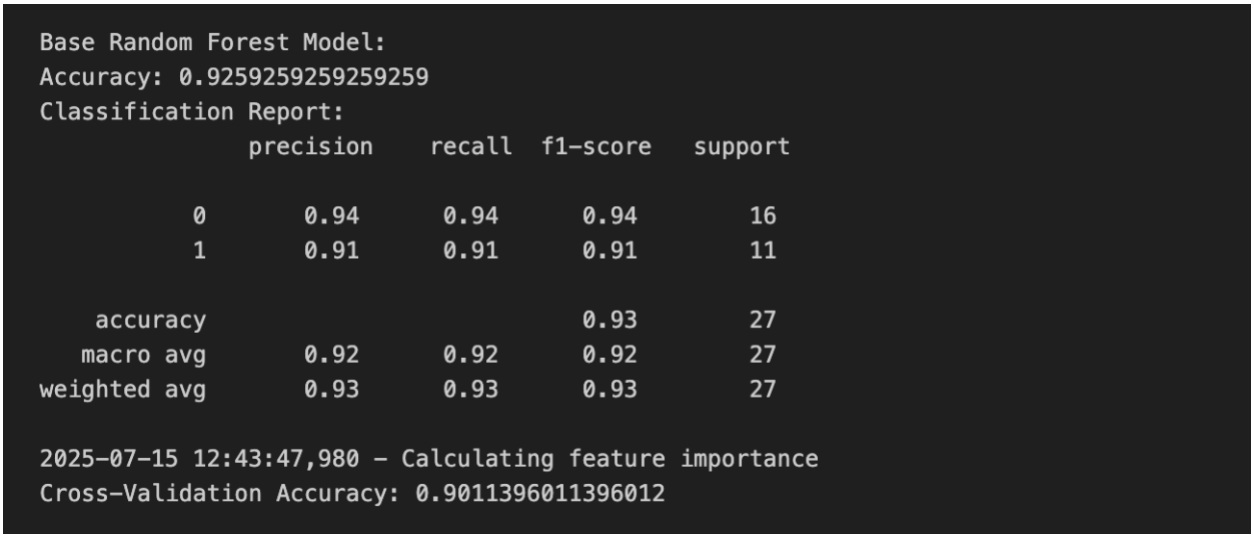
The classes are reasonably balanced (about 57% vs. 43%), so no special balancing techniques were applied.

Preprocessing & Methodology

1. **Label Encoding:** Converted subset to 0/1.

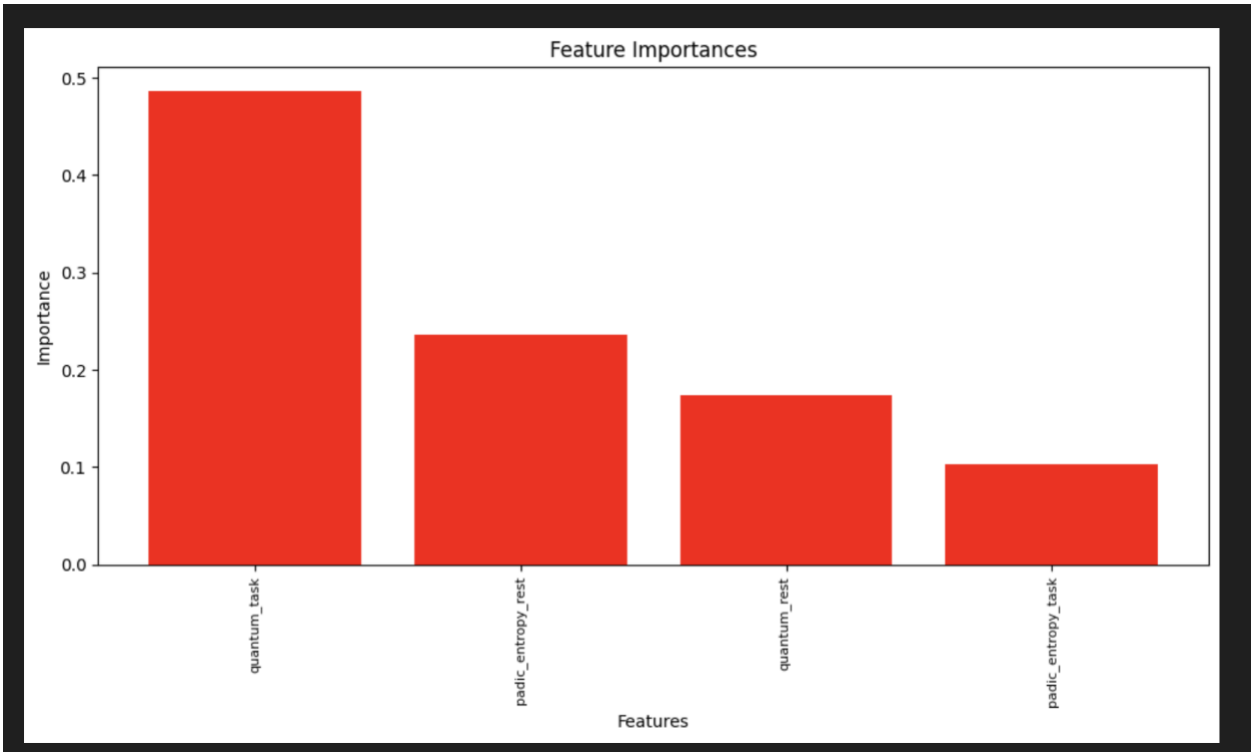
2. **Train/Test Split:** 80% train, 20% test (27 samples held out).
3. **Scaling:** Features standardized via StandardScaler.
4. **Models Trained:**
    - Random Forest (100 trees)
    - Logistic Regression (L2 penalty)
    - SVM (RBF kernel)
    - KNN (k=5)
    - Gradient Boosting (default scikit-learn settings)
5. **Evaluation Metrics:**
    - Test accuracy & classification report
    - 5-fold cross-validation accuracy
    - Confusion matrix
    - ROC curves & AUC

Random Forest Baseline



```
Base Random Forest Model:
Accuracy: 0.9259259259259259
Classification Report:
              precision    recall  f1-score   support

           0       0.94      0.94      0.94        16
           1       0.91      0.91      0.91        11

    accuracy                           0.93        27
   macro avg       0.92      0.92      0.92        27
weighted avg       0.93      0.93      0.93        27

2025-07-15 12:43:47,980 - Calculating feature importance
Cross-Validation Accuracy: 0.9011396011396012
```

- **Test Accuracy:** 92.6%
- **5-Fold CV Accuracy:** 90.1%
- **Precision / Recall / F1:**
    - Class 0: 0.94 / 0.94 / 0.94
    - Class 1: 0.91 / 0.91 / 0.91



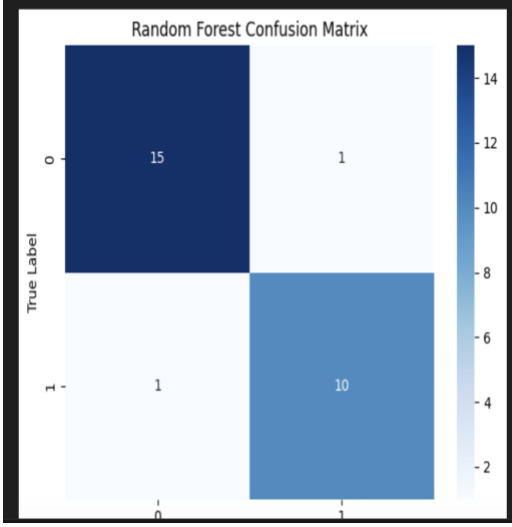
Key Insights:

- **quantum_task** is the dominant predictor (≈ 48%).
- **padic_entropy_rest** (23%) and **quantum_rest** (17%) also contribute meaningfully.
- **padic_entropy_task** has the smallest, but non-negligible, importance (10%).

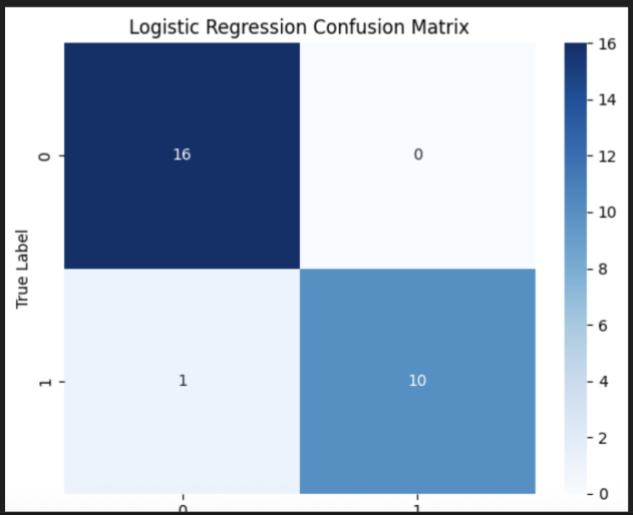
Multi-Model Comparison

Confusion Matrices

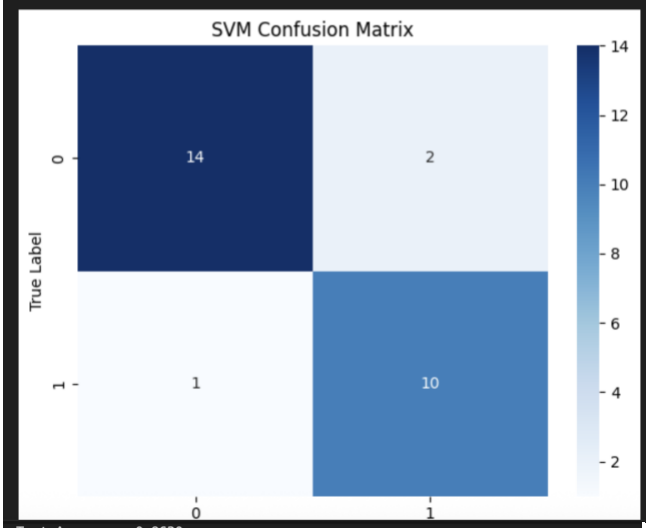
```
Test Accuracy: 0.9259
Cross-Validation Accuracy: 0.9011
              precision    recall  f1-score   support

           0       0.94      0.94      0.94        16
           1       0.91      0.91      0.91        11

    accuracy                           0.93        27
   macro avg       0.92      0.92      0.92        27
weighted avg       0.93      0.93      0.93        27
```



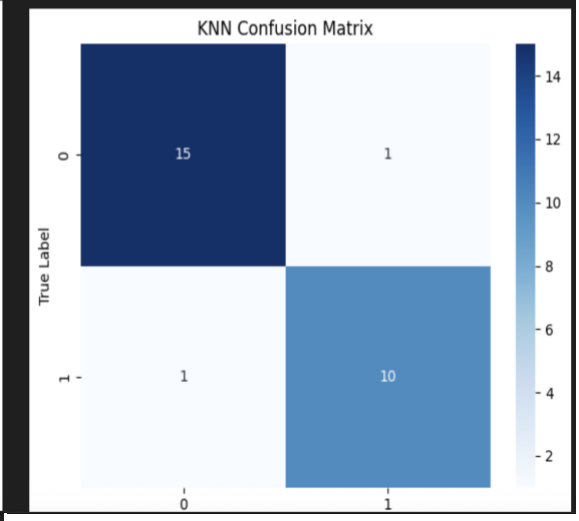

```
Test Accuracy: 0.9630
Cross-Validation Accuracy: 0.9023
              precision    recall  f1-score   support

           0       0.94      1.00      0.97        16
           1       1.00      0.91      0.95        11

    accuracy                           0.96        27
   macro avg       0.97      0.95      0.96        27
weighted avg       0.97      0.96      0.96        27
```



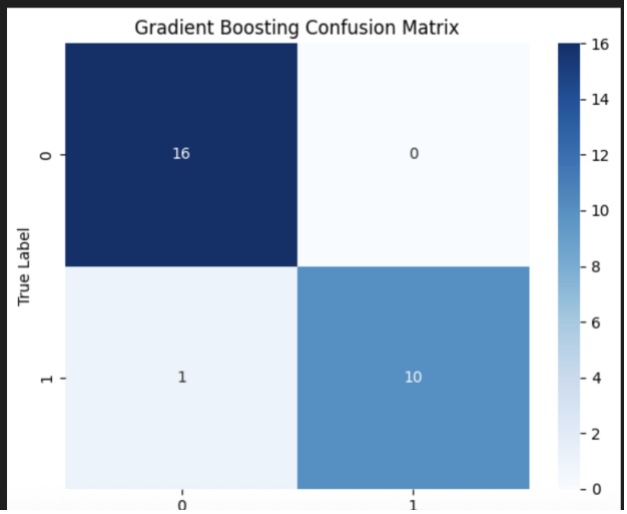
```
Test Accuracy: 0.8889
Cross-Validation Accuracy: 0.8630
              precision    recall  f1-score   support

           0       0.93      0.88      0.90        16
           1       0.83      0.91      0.87        11

    accuracy                           0.89        27
   macro avg       0.88      0.89      0.89        27
weighted avg       0.89      0.89      0.89        27
```




```
Test Accuracy: 0.9259
Cross-Validation Accuracy: 0.8712
              precision    recall  f1-score   support

           0       0.94      0.94      0.94        16
           1       0.91      0.91      0.91        11

    accuracy                           0.93        27
   macro avg       0.92      0.92      0.92        27
weighted avg       0.93      0.93      0.93        27
```

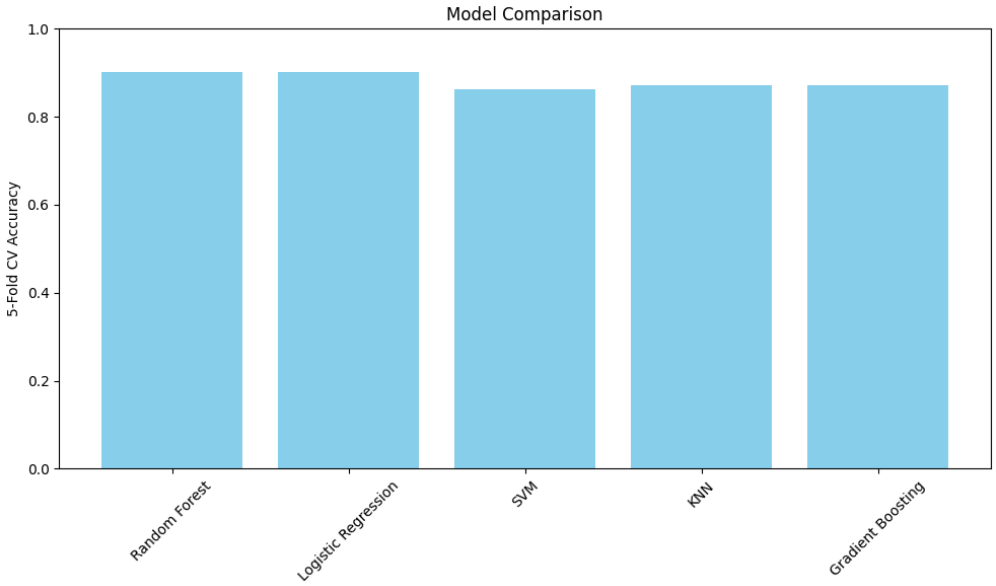



```
Test Accuracy: 0.9630
Cross-Validation Accuracy: 0.8707
              precision    recall  f1-score   support

           0       0.94      1.00      0.97        16
           1       1.00      0.91      0.95        11

    accuracy                           0.96        27
   macro avg       0.97      0.95      0.96        27
weighted avg       0.97      0.96      0.96        27
```

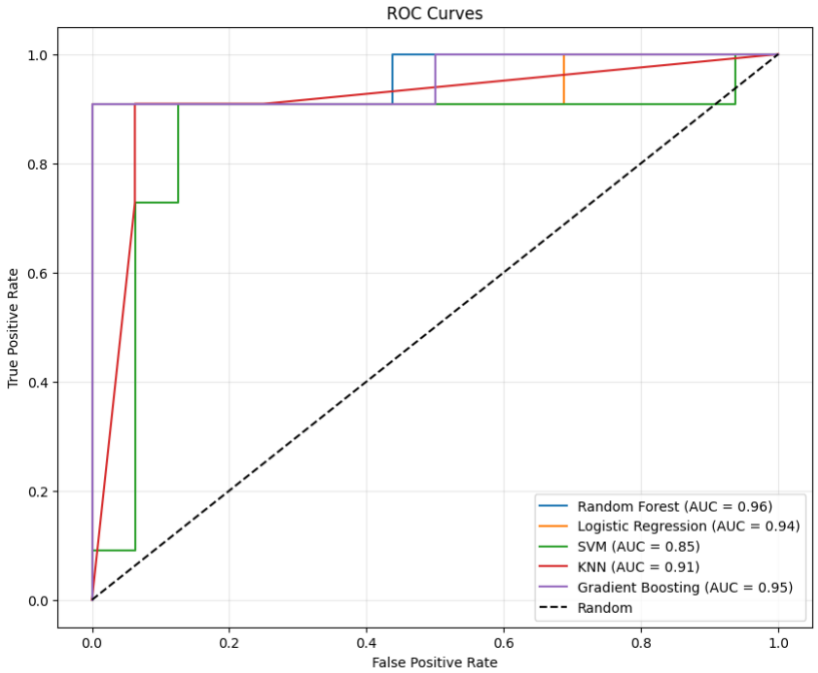


- **Logistic Regression** and **Gradient Boosting** both achieved **96.3%** test accuracy, each misclassifying only 1 out of 27 samples.
- **Random Forest** and **KNN** each misclassified 2 samples; **SVM** misclassified 3.

Cross-Validation & AUC



- **AUC Scores:**
  - Random Forest: 0.96
  - Gradient Boosting: 0.95
  - Logistic Regression: 0.94
  - KNN: 0.91
  - SVM: 0.85



- **CV Accuracy:**
  - RF & LR: ≈ 90.1%

- GB & KNN: ≈ 87.0%
- SVM: ≈ 86.3%

Conclusions & Recommendations

1. **Top Models:**
   - **Logistic Regression** offers the best balance of simplicity and performance (96.3% test accuracy, 90.2% CV).
   - **Random Forest** and **Gradient Boosting** are close runners-up—both highly robust (AUC ≈ 0.95–0.96).
2. **Feature Insights:**
   - **quantum_task** is the single most informative feature, warranting deeper neurophysiological investigation.
   - The rest/rest vs. task feature split suggests state-dependent EEG dynamics are key discriminators.