project3

June 6, 2025

Hyperparameter Tuning of ML Models

Data Loading

```python
[1]: import pandas as pd
     from sklearn.model_selection import train_test_split
     from sklearn.preprocessing import StandardScaler
     from sklearn.linear_model import LogisticRegression
     from sklearn.ensemble import RandomForestClassifier
     from sklearn.svm import SVC
     from sklearn.model_selection import GridSearchCV, RandomizedSearchCV
     from sklearn.metrics import classification_report

     # Load and prepare dataset
     df = pd.read_csv("emails.csv.zip")
     df.drop(columns=['Email No.'], inplace=True)
     X = df.drop("Prediction", axis=1)
     y = df["Prediction"]

     # Train-test split
     X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2,␣
      ↪random_state=42)

     # Feature scaling
     scaler = StandardScaler()
     X_train_scaled = scaler.fit_transform(X_train)
     X_test_scaled = scaler.transform(X_test)
```

Grid Search

```python
[2]: # Grid Search with Logistic Regression
     lr = LogisticRegression()
     lr_param_grid = {'C': [0.001, 0.01, 0.1, 1, 10, 100]}
     lr_grid_search = GridSearchCV(lr, lr_param_grid, cv=5)
     lr_grid_search.fit(X_train_scaled, y_train)

     print("Best parameters for Logistic Regression (Grid Search): ", lr_grid_search.
      ↪best_params_)
```

```
print("Best cross-validation score for Logistic Regression (Grid Search): ",␣
 ↪lr_grid_search.best_score_)
```

Best parameters for Logistic Regression (Grid Search): {'C': 0.01}
Best cross-validation score for Logistic Regression (Grid Search):
0.9772789139489102

Random Search

```
[10]: param_dist_rf = {
          'n_estimators': [50, 100, 150],
          'max_depth': [None, 10, 20, 30],
          'min_samples_split': [2, 5, 10]
      }

      random_search_rf = RandomizedSearchCV(RandomForestClassifier(),␣
       ↪param_distributions=param_dist_rf,
                                            n_iter=10, cv=5, scoring='f1',␣
       ↪random_state=42, n_jobs=-1)
      random_search_rf.fit(X_train, y_train)

      print("Best Params (Random Forest):", random_search_rf.best_params_)
      y_pred_rf = random_search_rf.predict(X_test)
      print("\nRandom Forest Report:\n", classification_report(y_test, y_pred_rf))
```

Best Params (Random Forest): {'n_estimators': 150, 'min_samples_split': 10,
'max_depth': 30}

Random Forest Report:
               precision   recall f1-score   support

           0   0.99   0.98   0.99   739
           1   0.96   0.97   0.97   296

    accuracy   0.98   1035
   macro avg   0.97   0.98   0.98   1035
weighted avg   0.98   0.98   0.98   1035

```

**Model Evaluation**

```
[4]: from sklearn.metrics import accuracy_score, precision_score, recall_score,␣
      ↪f1_score, confusion_matrix, ConfusionMatrixDisplay

     # Assume you have a trained and tuned model: lr_grid_search
     y_pred = lr_grid_search.predict(X_test_scaled)

     # Evaluation Metrics
     print("Accuracy:", accuracy_score(y_test, y_pred))
```

```python
print("Precision:", precision_score(y_test, y_pred))
print("Recall:", recall_score(y_test, y_pred))
print("F1 Score:", f1_score(y_test, y_pred))

# Confusion Matrix
cm = confusion_matrix(y_test, y_pred)
disp = ConfusionMatrixDisplay(confusion_matrix=cm, display_labels=["Not Spam",
  ↪"Spam"])
disp.plot()
```

```
Accuracy: 0.978743961352657
Precision: 0.9566666666666667
Recall: 0.9695945945945946
F1 Score: 0.9630872483221476
```

[4]: <sklearn.metrics._plot.confusion_matrix.ConfusionMatrixDisplay at
0x7cba4ab4b590>
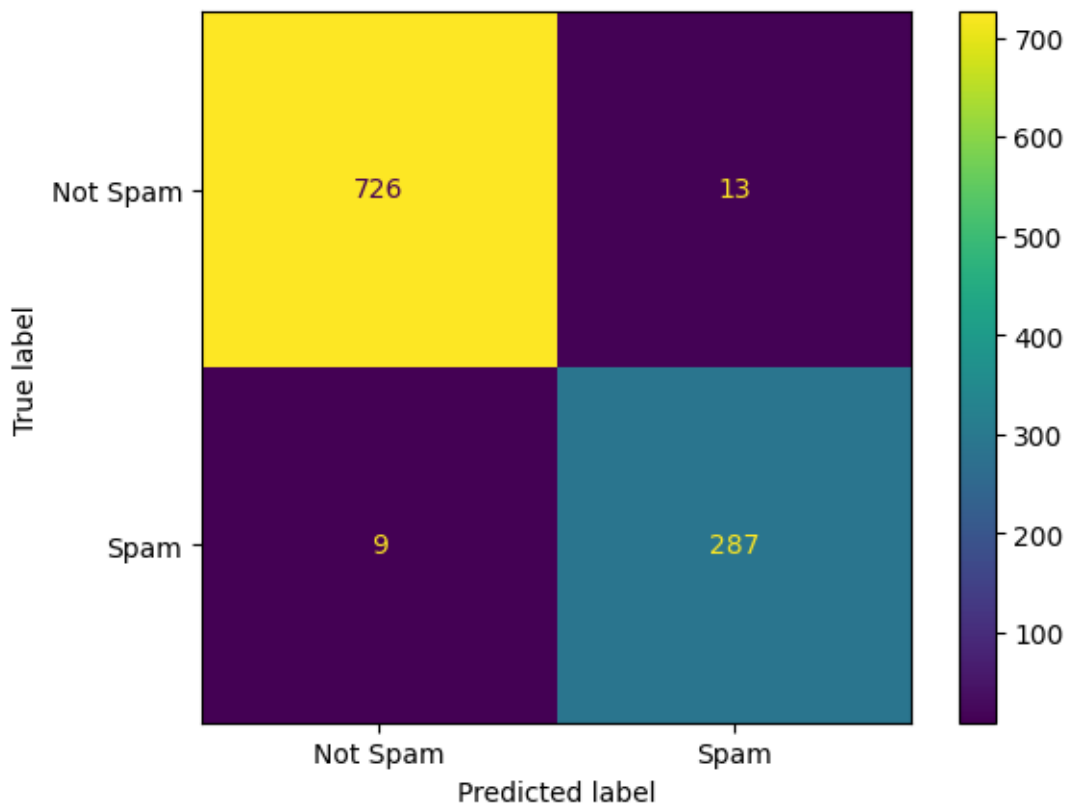
Start With a Coarse Search

```python
[5]: # Example coarse grid for Logistic Regression
     param_grid = {
         'C': [0.01, 0.1, 1, 10, 100],
         'solver': ['liblinear', 'lbfgs']
     }
```

```python
[6]: # Refined grid
     param_grid = {
         'C': [0.5, 0.8, 1, 1.2, 1.5]
     }
```

Use GridSearchCV and RandomizedSearchCV

```python
[8]: from sklearn.model_selection import GridSearchCV, RandomizedSearchCV
     from sklearn.linear_model import LogisticRegression # Import LogisticRegression

     # Define the estimator (e.g., Logistic Regression)
     estimator = LogisticRegression()

     # Grid Search
     grid = GridSearchCV(estimator, param_grid, cv=5, scoring='f1')
     grid.fit(X_train, y_train)

     # Random Search
     # Use param_grid as param_distributions for demonstration
     param_distributions = param_grid
     random = RandomizedSearchCV(estimator, param_distributions, n_iter=10,␣
       ↪scoring='f1', cv=5)
     random.fit(X_train, y_train)
```

```
/usr/local/lib/python3.11/dist-packages/sklearn/linear_model/_logistic.py:465:
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STOP: TOTAL NO. OF ITERATIONS REACHED LIMIT.

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```

```
regression
  n_iter_i = _check_optimize_result(
/usr/local/lib/python3.11/dist-packages/sklearn/model_selection/_search.py:317:
UserWarning: The total space of parameters 5 is smaller than n_iter=10. Running
5 iterations. For exhaustive searches, use GridSearchCV.
  warnings.warn(
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Please also refer to the documentation for alternative solver options:
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  n_iter_i = _check_optimize_result(
```

[8]: RandomizedSearchCV(cv=5, estimator=LogisticRegression(),
                        param_distributions={'C': [0.5, 0.8, 1, 1.2, 1.5]},
                        scoring='f1')

Track Results

```
[9]: results_df = pd.DataFrame(grid.cv_results_)
     results_df.sort_values('mean_test_score', ascending=False).head()
```

[9]:   mean_fit_time std_fit_time mean_score_time std_score_time param_C \
     0   4.364476   0.695901   0.121765   0.046383   0.5
     1   4.001417   0.271668   0.080484   0.014562   0.8
     3   4.205673   0.401289   0.112075   0.026958   1.2
     4   4.349746   0.714231   0.091505   0.023804   1.5
     2   3.863801   0.201868   0.086902   0.014264   1.0

            params split0_test_score split1_test_score split2_test_score \
     0 {'C': 0.5}   0.948875   0.931174   0.933602
     1 {'C': 0.8}   0.932515   0.933333   0.935743
     3 {'C': 1.2}   0.924644   0.940695   0.937626
     4 {'C': 1.5}   0.940452   0.929577   0.933602

```
2    {'C': 1}          0.927835          0.927126          0.937626

    split3_test_score  split4_test_score  mean_test_score  std_test_score  \
0          0.937500           0.953975         0.941025        0.008876
1          0.931393           0.950207         0.936638        0.006933
3          0.919588           0.955975         0.935705        0.012819
4          0.925000           0.949367         0.935600        0.008552
2          0.929167           0.945378         0.933426        0.007065

    rank_test_score
0                 1
1                 2
3                 3
4                 4
2                 5
```