Data Visualization

```
import numpy as np
import pandas as pd
import pandas as pd
import seaborn as sns
import numpy as np
import matplotlib.pyplot as plt

from google.colab import drive
import os
import pandas as pd

# Mount Google Drive
drive.mount('/content/drive', force_remount=True)

# Specify the folder path in your Google Drive
folder_path = '/content/drive/MyDrive/CIC-IDS- 2017'  # Replace 'CIC-
IDS-2017' with the actual folder name

# Get the list of file names in the folder
file_names = os.listdir(folder_path)

# Initialize an empty list to store DataFrames
dfs = []

# Loop through each file in the folder
for file_name in file_names:
    if file_name.endswith('.csv'):
        file_path = os.path.join(folder_path, file_name)
        # Read the CSV file into a DataFrame
        df = pd.read_csv(file_path)
        # Append the DataFrame to the list
        dfs.append(df)

# Concatenate the list of DataFrames into a single DataFrame
combined_df = pd.concat(dfs, ignore_index=True)

# Display the combined DataFrame
print(combined_df)
```

```
Mounted at /content/drive
         Destination Port   Flow Duration   Total Fwd Packets  \
0                      22         1266342                  41
1                      22         1319353                  41
2                      22             160                   1
3                      22         1303488                  41
4                   35396              77                   1
```

```
...                     ...             ...                    ...
2830738                  53           32215                      4
2830739                  53             324                      2
2830740               58030              82                      2
2830741                  53         1048635                      6
2830742                  53           94939                      4

         Total Backward Packets  Total Length of Fwd Packets  \
0                             44                         2664
1                             44                         2664
2                              1                            0
3                             42                         2728
4                              2                            0
...                          ...                          ...
2830738                        2                          112
2830739                        2                           84
2830740                        1                           31
2830741                        2                          192
2830742                        2                          188

         Total Length of Bwd Packets   Fwd Packet Length Max  \
0                             6954                       456
1                             6954                       456
2                                0                         0
3                             6634                       456
4                                0                         0
...                            ...                       ...
2830738                      152                         28
2830739                      362                         42
2830740                        6                         31
2830741                      256                         32
2830742                      226                         47

         Fwd Packet Length Min   Fwd Packet Length Mean  \
0                            0                64.975610
1                            0                64.975610
2                            0                 0.000000
3                            0                66.536585
4                            0                 0.000000
...                        ...                      ...
2830738                     28                28.000000
2830739                     42                42.000000
2830740                      0                15.500000
2830741                     32                32.000000
2830742                     47                47.000000

         Fwd Packet Length Std  ...   min_seg_size_forward  Active
Mean  \
0                   109.864573  ...                     32
0.0
```

```
1                    109.864573  ...                    32
0.0
2                      0.000000  ...                    32
0.0
3                    110.129945  ...                    32
0.0
4                      0.000000  ...                    32
0.0
...                         ...  ...                   ...           .
..
2830738                0.000000  ...                    20
0.0
2830739                0.000000  ...                    20
0.0
2830740               21.920310  ...                    32
0.0
2830741                0.000000  ...                    20
0.0
2830742                0.000000  ...                    20
0.0

          Active Std   Active Max   Active Min  Idle Mean   Idle
Std  \
0                0.0            0            0        0.0        0.0

1                0.0            0            0        0.0        0.0

2                0.0            0            0        0.0        0.0

3                0.0            0            0        0.0        0.0

4                0.0            0            0        0.0        0.0

...              ...          ...          ...        ...        ...

2830738          0.0            0            0        0.0        0.0

2830739          0.0            0            0        0.0        0.0

2830740          0.0            0            0        0.0        0.0

2830741          0.0            0            0        0.0        0.0

2830742          0.0            0            0        0.0        0.0


          Idle Max   Idle Min   Label
0                0          0  BENIGN
1                0          0  BENIGN
2                0          0  BENIGN
```

```
3                0          0  BENIGN
4                0          0  BENIGN
...            ...        ...     ...
2830738          0          0  BENIGN
2830739          0          0  BENIGN
2830740          0          0  BENIGN
2830741          0          0  BENIGN
2830742          0          0  BENIGN

[2830743 rows x 79 columns]

df.columns

Index([' Destination Port', ' Flow Duration', ' Total Fwd Packets',
       ' Total Backward Packets', 'Total Length of Fwd Packets',
       ' Total Length of Bwd Packets', ' Fwd Packet Length Max',
       ' Fwd Packet Length Min', ' Fwd Packet Length Mean',
       ' Fwd Packet Length Std', 'Bwd Packet Length Max',
       ' Bwd Packet Length Min', ' Bwd Packet Length Mean',
       ' Bwd Packet Length Std', 'Flow Bytes/s', ' Flow Packets/s',
       ' Flow IAT Mean', ' Flow IAT Std', ' Flow IAT Max', ' Flow IAT
Min',
       'Fwd IAT Total', ' Fwd IAT Mean', ' Fwd IAT Std', ' Fwd IAT
Max',
       ' Fwd IAT Min', 'Bwd IAT Total', ' Bwd IAT Mean', ' Bwd IAT
Std',
       ' Bwd IAT Max', ' Bwd IAT Min', 'Fwd PSH Flags', ' Bwd PSH
Flags',
       ' Fwd URG Flags', ' Bwd URG Flags', ' Fwd Header Length',
       ' Bwd Header Length', 'Fwd Packets/s', ' Bwd Packets/s',
       ' Min Packet Length', ' Max Packet Length', ' Packet Length
Mean',
       ' Packet Length Std', ' Packet Length Variance', 'FIN Flag
Count',
       ' SYN Flag Count', ' RST Flag Count', ' PSH Flag Count',
       ' ACK Flag Count', ' URG Flag Count', ' CWE Flag Count',
       ' ECE Flag Count', ' Down/Up Ratio', ' Average Packet Size',
       ' Avg Fwd Segment Size', ' Avg Bwd Segment Size',
       ' Fwd Header Length.1', 'Fwd Avg Bytes/Bulk', ' Fwd Avg
Packets/Bulk',
       ' Fwd Avg Bulk Rate', ' Bwd Avg Bytes/Bulk', ' Bwd Avg
Packets/Bulk',
       'Bwd Avg Bulk Rate', 'Subflow Fwd Packets', ' Subflow Fwd
Bytes',
       ' Subflow Bwd Packets', ' Subflow Bwd Bytes',
'Init_Win_bytes_forward',
       ' Init_Win_bytes_backward', ' act_data_pkt_fwd',
       ' min_seg_size_forward', 'Active Mean', ' Active Std', ' Active
Max',
       ' Active Min', 'Idle Mean', ' Idle Std', ' Idle Max', ' Idle
```

```
Min',
       ' Label'],
      dtype='object')
```

```
set(list(df.dtypes))
```

```
{dtype('int64'), dtype('float64'), dtype('O')}
```

```
import pandas as pd

# Assuming df is the combined DataFrame
categorical_columns = [col for col in df.columns if df[col].dtype ==
"O"]

# Detect the label column dynamically
label_column = next((col for col in df.columns if 'label' in
col.lower()), None)

if label_column:
    # Map "BENIGN" to itself and all other values to "INTRUSION"
    df[label_column] = df[label_column].map(lambda x: "BENIGN" if x ==
"BENIGN" else "INTRUSION")

    # Print the unique values in the modified label column
    print(df[label_column].unique())
else:
    print("Label column not found in the DataFrame.")

# Rest of your code using the categorical_columns variable...
```

```
['BENIGN' 'INTRUSION']
```

```
df_Categorical=df[categorical_columns]
df_Categorical
```

```
{"type":"dataframe","variable_name":"df_Categorical"}
```

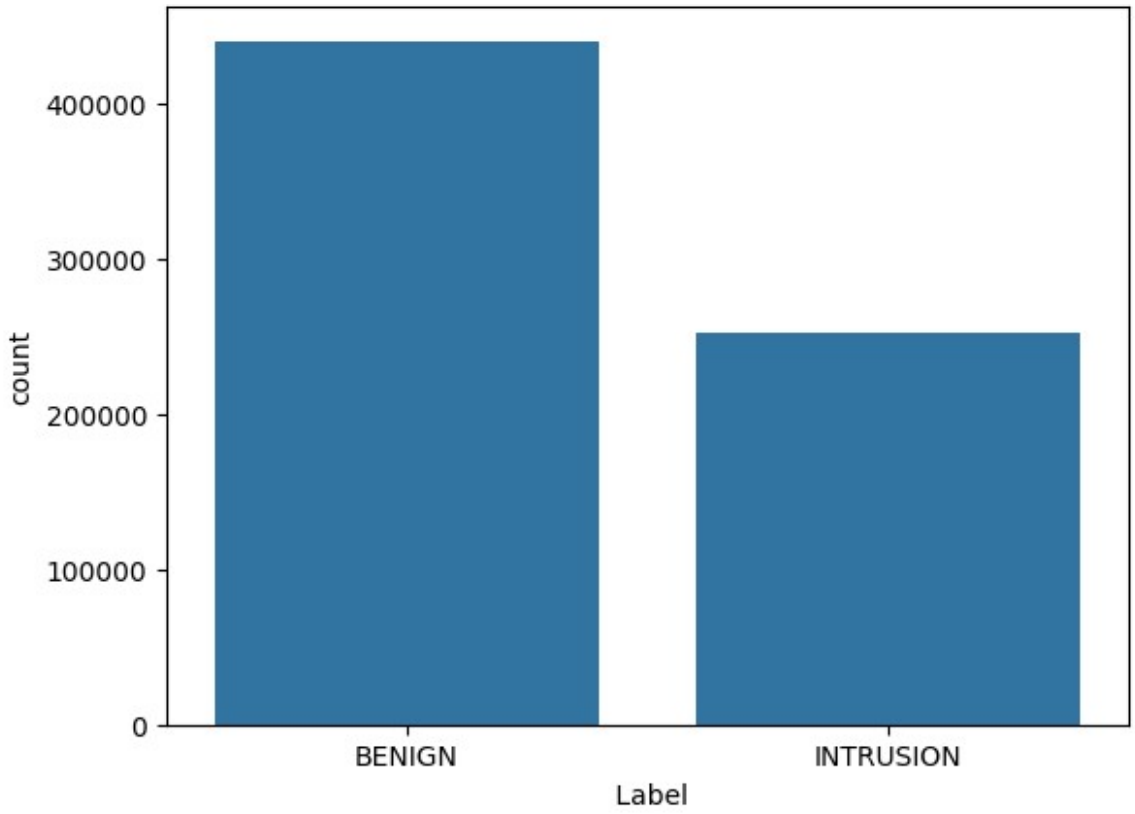
```
df_Numerical=df.copy()
df_Numerical.drop([" Label"],axis=1,inplace=True)

df_Numerical
```

```
{"type":"dataframe","variable_name":"df_Numerical"}
```

```
df_Categorical["
Label"].value_counts(),sns.countplot(x=df_Categorical[' Label'])
```

```
( Label
 BENIGN       440031
 INTRUSION    252672
 Name: count, dtype: int64,
 <Axes: xlabel=' Label', ylabel='count'>)
```




```
for i in df_Numerical.columns:
    #if df[i].unique()<
    print(f" {i} Column has {df[i].nunique()} unique values and those
are {df[i].unique()}\n\n")

for i in df_Numerical.columns:
    if df[i].isnull().sum()>0:
        print(i)
```

```
Flow Bytes/s
```

```
df_Numerical["Flow Bytes/s"].isnull().sum()
```

```
1008
```

```
for index, row in df_Numerical.iterrows():
    if pd.isna(row["Flow Bytes/s"]):
        print(row["Flow Bytes/s"],df_Categorical["
Label"].iloc[index])

df_Numerical.dropna(inplace=True)
```

Infinity Valued Column Detection

```
np.all(np.isfinite(df_Numerical.values))
```

```
False
```

```
np.isinf(df_Numerical).values.sum()
```

```
578
```

```
infinite_column_count = {}
infinite_Value_index_num = []

for column in df_Numerical.columns:
    count = 0
    for index, value in enumerate(df_Numerical[column]):
        if not np.isfinite(value):
            count += 1
            infinite_Value_index_num.append(index)
    if count > 0:
        infinite_column_count[column] = count

infinite_Value_index_num = set(infinite_Value_index_num)

print("Counts of non-numeric (infinite) values in each column:")
print(f"{infinite_column_count}\n")

print("Index numbers of non-numeric (infinite) values:")
print(infinite_Value_index_num)
```

```
Counts of non-numeric (infinite) values in each column:
{'Flow Bytes/s': 289, ' Flow Packets/s': 289}

Index numbers of non-numeric (infinite) values:
{659968, 578052, 589320, 639498, 355852, 436748, 537101, 477199,
637968, 21521, 672784, 569875, 3097, 657945, 21021, 9758, 583197,
420896, 682527, 607267, 408613, 424997, 14375, 499749, 420908, 436780,
352302, 548909, 481328, 666668, 572473, 389690, 441914, 608255,
625657, 389694, 412738, 311364, 610886, 438343, 415816, 394315,
568395, 523855, 191568, 349776, 660562, 636501, 63062, 24152, 361560,
383577, 493145, 423004, 500825, 538715, 647258, 685662, 7780, 25702,
147558, 335976, 366694, 393832, 431210, 555115, 26221, 48237, 13423,
8816, 423023, 334962, 314994, 486003, 383606, 599670, 594040, 324217,
416377, 425594, 29825, 348290, 681601, 26244, 51334, 340615, 455303,
431241, 339082, 514184, 336015, 541842, 450707, 20632, 429209, 621721,
625818, 407708, 466079, 639142, 393383, 426152, 649895, 683690, 15019,
40620, 474797, 476340, 357557, 45238, 514230, 496312, 468666, 44731,
345277, 540862, 468671, 528063, 581311, 648895, 399555, 224454,
504521, 3789, 4301, 473805, 373968, 431825, 473809, 646354, 681166,
684237, 608470, 415447, 612567, 382684, 28381, 143070, 388317, 644319,
323809, 478946, 66787, 66788, 29413, 438503, 483048, 405737, 483052,
```

```
295661, 382702, 49903, 348912, 649453, 685806, 520435, 340725, 415989,
340215, 6904, 357112, 418041, 429815, 486140, 351485, 604917, 650487,
668416, 677625, 380675, 356616, 532749, 477457, 441106, 670483,
340758, 570648, 129306, 651547, 484125, 30495, 671523, 431397, 583467,
337709, 451373, 480047, 575794, 426293, 59190, 471355, 593726, 651583,
343873, 402754, 439105, 509249, 44358, 566599, 353610, 4939, 360266,
23375, 418131, 662868, 50517, 682838, 433496, 2395, 384866, 337252,
562534, 512874, 578924, 519533, 1392, 340849, 51569, 57202, 64368,
666997, 522617, 597370, 44411, 648573, 8064, 465794, 466820, 603524,
24456, 361352, 531336, 623497, 686986, 50577, 416146, 530326, 6551,
406935, 418712, 514970, 45472, 463780, 550313, 683946, 362414, 607665,
671666, 431539, 572339, 671161, 568250, 466363, 503231, 324034,
406979, 59844, 418761, 421324, 501197, 636365, 56271, 336336, 394704,
474577, 339413, 349142, 428503, 440792, 622039, 577498, 15835, 346587,
536028, 557049, 555999, 587231, 631770, 593890, 647656, 539117,
672750, 530927, 469489, 498673, 442867, 529908, 2041, 20991}

Benign=0
Intrusion=0
for i in infinite_Value_index_num:
    if df_Categorical[" Label"].iloc[i]=="BENIGN":
        Benign+=1
    else:
        Intrusion+=1

print(f" Normal counts are {Benign}\n\n")
print(f" Intrusion counts are {Intrusion}")

 Normal counts are 276


 Intrusion counts are 13

df_Numerical.replace([np.inf, -np.inf], np.nan, inplace=True)
df_Numerical.dropna(inplace=True)

np.all(np.isinf(df_Numerical)),np.any(np.isnan(df_Numerical))

(False, False)

df_Numerical

{"type":"dataframe","variable_name":"df_Numerical"}

df_Numerical.shape,df_Categorical.shape

((691406, 78), (692703, 1))

index_numbers_to_fetch = df_Numerical.index.tolist()

df_Categorical = df_Categorical.loc[index_numbers_to_fetch]
```

```
df_Categorical.shape
```

```
(691406, 1)
```

```
y=pd.get_dummies(data=df_Categorical[" Label"], drop_first=True)
y
```

```
{"type":"dataframe","variable_name":"y"}
```

```
df_Numerical
```

```
{"type":"dataframe","variable_name":"df_Numerical"}
```

Min Max Scaler / Standarization

```
df_Numerical_Scaled_data=pd.DataFrame()
from sklearn.preprocessing import MinMaxScaler
scaler = MinMaxScaler()
df_Numerical_Scaled_data[df_Numerical.columns] =
scaler.fit_transform(df_Numerical[df_Numerical.columns])

df_Numerical_Scaled_data
```

```
{"type":"dataframe","variable_name":"df_Numerical_Scaled_data"}
```

```
X=df_Numerical_Scaled_data

from sklearn.model_selection import train_test_split
X_train, X_test, y_train, y_test = train_test_split(X, y,
test_size=0.33, random_state=42)

X_train.shape,y_train.shape,X_test.shape,y_test.shape
```

```
((463242, 78), (463242, 1), (228164, 78), (228164, 1))
```

```
from sklearn.linear_model import LogisticRegression

# Instantiate logistic regression model with increased max_iter
logistic_model = LogisticRegression(max_iter=1000)

# Fit the model to the training data
logistic_model.fit(X_train, y_train)
```

```
/usr/local/lib/python3.10/dist-packages/sklearn/utils/
validation.py:1143: DataConversionWarning: A column-vector y was
passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
```

```
LogisticRegression(max_iter=1000)
```

```
y_pred = logistic_model.predict(X_test)

from sklearn.metrics import *

accuracy = accuracy_score(y_test,y_pred)*100
confusion_mat = confusion_matrix(y_test,y_pred)
print("Accuracy is",accuracy)
print("Confusion Matrix")
print(confusion_mat)
```

```
Accuracy is 96.94430322049053
Confusion Matrix
[[141509   3673]
 [  3299  79683]]
```

Fitting Different Models

```
from sklearn.svm import SVC
from sklearn.naive_bayes import BernoulliNB
from sklearn import tree
from sklearn.model_selection import cross_val_score
from sklearn.neighbors import KNeighborsClassifier
from sklearn.linear_model import *
from sklearn.tree import *
from sklearn.model_selection import train_test_split, cross_val_score
from sklearn.metrics import accuracy_score, classification_report,
confusion_matrix
from sklearn.neighbors import KNeighborsClassifier
from sklearn.linear_model import LogisticRegression
from sklearn.naive_bayes import BernoulliNB
from sklearn.tree import DecisionTreeClassifier
from sklearn.ensemble import RandomForestClassifier, VotingClassifier
```

Quick Analysis and Results

```
from sklearn.metrics import accuracy_score, confusion_matrix,
classification_report
from sklearn.ensemble import RandomForestClassifier, VotingClassifier
from sklearn.linear_model import LogisticRegression
from sklearn.naive_bayes import BernoulliNB
from sklearn.tree import DecisionTreeClassifier
from sklearn.model_selection import train_test_split

def split_data(X, y, test_size=0.2, random_state=None):
    X_train, X_test, y_train, y_test = train_test_split(X, y,
test_size=test_size, random_state=random_state)
```

```
    return X_train, X_test, y_train, y_test

def train_model(model, X_train, y_train):
    y_train = y_train.values.ravel() if len(y_train.shape) > 1 and
y_train.shape[1] == 1 else y_train
    model.fit(X_train, y_train)

def evaluate_model(model, X, y, dataset_name):
    accuracy = accuracy_score(y, model.predict(X))
    confusion_matrix_result = confusion_matrix(y, model.predict(X))
    classification = classification_report(y, model.predict(X))

    print(f'{dataset_name} Model Evaluation')
    print()
    print("Model Accuracy:\n", accuracy)
    print()
    print("Confusion matrix:\n", confusion_matrix_result)
    print()
    print("Classification report:\n", classification)
    print()

X_train, X_test, y_train, y_test = split_data(X, y, test_size=0.2,
random_state=42)

classifiers = [
    ('Naive Baye Classifier', BernoulliNB()),
    ('Decision Tree Classifier',
DecisionTreeClassifier(criterion='entropy', random_state=0)),
    ('Random Forest Classifier',
RandomForestClassifier(n_estimators=100, random_state=0)),
    ('Logistic Regression', LogisticRegression(n_jobs=-1,
random_state=0))
]

models = [
    ('Naive Baye Classifier', BernoulliNB()),
    ('Logistic Regression', LogisticRegression(n_jobs=-1,
random_state=0)),
    ('Voting Classifier', VotingClassifier(estimators=classifiers,
voting='soft'))
]

# Train and evaluate individual models
for model_name, model in models:
    train_model(model, X_train, y_train)
    evaluate_model(model, X_train, y_train, f'Training -
{model_name}')
    evaluate_model(model, X_test, y_test, f'Test - {model_name}')
```

```
Training - Naive Baye Classifier Model Evaluation

Model Accuracy:
 0.8217199036744022

Confusion matrix:
 [[273087  78713]
 [ 19898 181426]]

Classification report:
              precision    recall  f1-score   support

       False       0.93      0.78      0.85    351800
        True       0.70      0.90      0.79    201324

    accuracy                           0.82    553124
   macro avg       0.81      0.84      0.82    553124
weighted avg       0.85      0.82      0.82    553124


Test - Naive Baye Classifier Model Evaluation

Model Accuracy:
 0.8237225380020538

Confusion matrix:
 [[68336 19547]
 [ 4829 45570]]

Classification report:
              precision    recall  f1-score   support

       False       0.93      0.78      0.85     87883
        True       0.70      0.90      0.79     50399

    accuracy                           0.82    138282
   macro avg       0.82      0.84      0.82    138282
weighted avg       0.85      0.82      0.83    138282


Training - Logistic Regression Model Evaluation

Model Accuracy:
 0.9721093281072598

Confusion matrix:
 [[342962   8838]
 [  6589 194735]]

Classification report:
              precision    recall  f1-score   support
```

```
       False       0.98      0.97      0.98    351800
        True       0.96      0.97      0.96    201324

    accuracy                           0.97    553124
   macro avg       0.97      0.97      0.97    553124
weighted avg       0.97      0.97      0.97    553124


Test - Logistic Regression Model Evaluation

Model Accuracy:
 0.9725850074485471

Confusion matrix:
 [[85699  2184]
 [ 1607 48792]]

Classification report:
              precision    recall  f1-score   support

       False       0.98      0.98      0.98     87883
        True       0.96      0.97      0.96     50399

    accuracy                           0.97    138282
   macro avg       0.97      0.97      0.97    138282
weighted avg       0.97      0.97      0.97    138282


Training - Voting Classifier Model Evaluation

Model Accuracy:
 0.9989676817494811

Confusion matrix:
 [[351249    551]
 [    20 201304]]

Classification report:
              precision    recall  f1-score   support

       False       1.00      1.00      1.00    351800
        True       1.00      1.00      1.00    201324

    accuracy                           1.00    553124
   macro avg       1.00      1.00      1.00    553124
weighted avg       1.00      1.00      1.00    553124


Test - Voting Classifier Model Evaluation
```

```
Model Accuracy:
 0.998633227751985

Confusion matrix:
 [[87707   176]
 [   13 50386]]

Classification report:
              precision    recall  f1-score   support

       False       1.00      1.00      1.00     87883
        True       1.00      1.00      1.00     50399

    accuracy                           1.00    138282
   macro avg       1.00      1.00      1.00    138282
weighted avg       1.00      1.00      1.00    138282
```

Stacking

```python
def evaluate_model_extended(model, X_train, y_train, X_test, y_test,
dataset_name):
    train_accuracy = accuracy_score(y_train, model.predict(X_train))
    test_accuracy = accuracy_score(y_test, model.predict(X_test))
    f1_score_val = f1_score(y_test, model.predict(X_test))
    precision_val = precision_score(y_test, model.predict(X_test))
    recall_val = recall_score(y_test, model.predict(X_test))

    # Calculate ROC curve and AUC
    y_train_pred_prob = model.predict_proba(X_train)[:, 1]
    fpr_train, tpr_train, _ = roc_curve(y_train, y_train_pred_prob)
    roc_auc_train = roc_auc_score(y_train, y_train_pred_prob)

    y_test_pred_prob = model.predict_proba(X_test)[:, 1]
    fpr_test, tpr_test, _ = roc_curve(y_test, y_test_pred_prob)
    roc_auc_test = roc_auc_score(y_test, y_test_pred_prob)

    # Plot ROC curve
    plt.figure(figsize=(8, 6))
    plt.plot(fpr_train, tpr_train, label=f'Train ROC Curve (AUC =
{roc_auc_train:.2f})')
    plt.plot(fpr_test, tpr_test, label=f'Test ROC Curve (AUC =
{roc_auc_test:.2f})')
    plt.plot([0, 1], [0, 1], 'k--')
    plt.xlabel('False Positive Rate')
    plt.ylabel('True Positive Rate')
    plt.title(f'ROC Curve - {dataset_name}')
```

```
    plt.legend()
    plt.show()

    # Calculate confusion matrix
    train_conf_matrix = confusion_matrix(y_train,
model.predict(X_train))
    test_conf_matrix = confusion_matrix(y_test, model.predict(X_test))

    # Plot confusion matrix
    fig, axes = plt.subplots(1, 2, figsize=(12, 6))

    sns.heatmap(train_conf_matrix, annot=True, fmt='d', cmap='Blues',
cbar=False, ax=axes[0])
    axes[0].set_title(f'Training Confusion Matrix - {dataset_name}')
    axes[0].set_xlabel('Predicted Labels')
    axes[0].set_ylabel('True Labels')

    sns.heatmap(test_conf_matrix, annot=True, fmt='d', cmap='Blues',
cbar=False, ax=axes[1])
    axes[1].set_title(f'Test Confusion Matrix - {dataset_name}')
    axes[1].set_xlabel('Predicted Labels')
    axes[1].set_ylabel('True Labels')

    plt.tight_layout()
    plt.show()

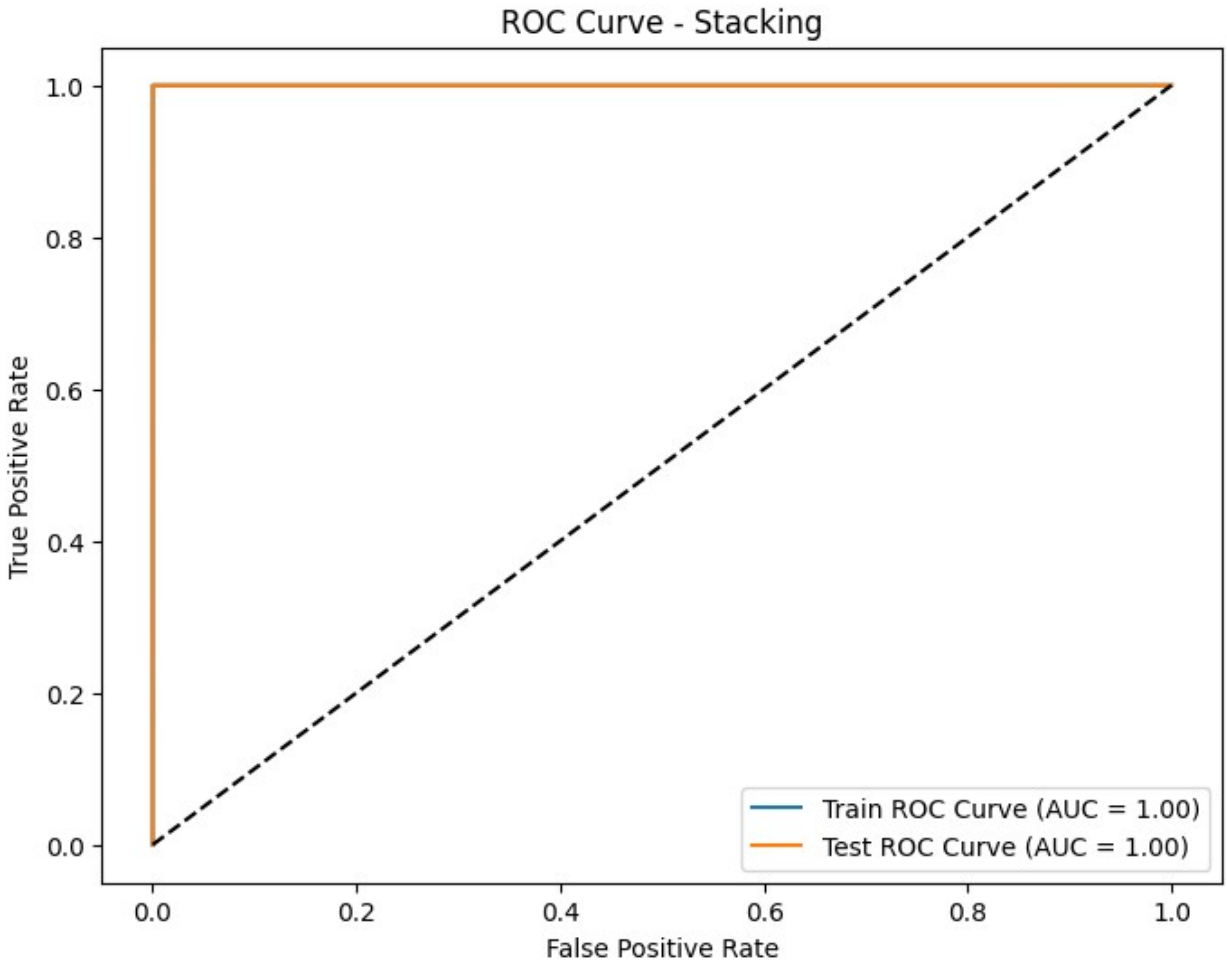
    # Print evaluation metrics
    print(f'{dataset_name} Model Evaluation')
    print()
    print("Train Accuracy:", train_accuracy)
    print("Test Accuracy:", test_accuracy)
    print("F1 Score:", f1_score_val)
    print("Precision:", precision_val)
    print("Recall:", recall_val)
    print("ROC AUC (Train):", roc_auc_train)
    print("ROC AUC (Test):", roc_auc_test)
    print()
# Implement Stacking
base_model_predictions_train = []
base_model_predictions_test = []

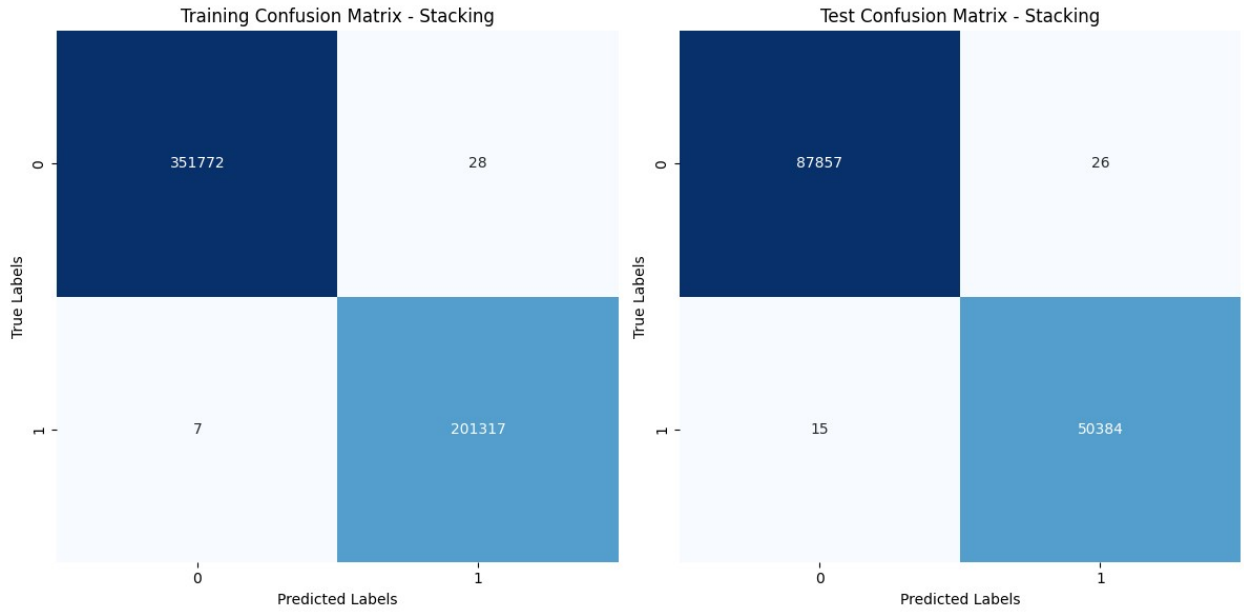
# Generate predictions from base models for training and test data
for model_name, model in classifiers:
    train_model(model, X_train, y_train)
    base_model_predictions_train.append(model.predict(X_train))
    base_model_predictions_test.append(model.predict(X_test))

# Train meta-model (Voting Classifier) on predictions from base models
stacked_X_train = np.column_stack(base_model_predictions_train)
stacked_X_test = np.column_stack(base_model_predictions_test)
```

```
stacked_model = VotingClassifier(estimators=classifiers,
voting='soft')
train_model(stacked_model, stacked_X_train, y_train)

# Evaluate stacked model
evaluate_model_extended(stacked_model, stacked_X_train, y_train,
stacked_X_test, y_test, "Stacking")
```






```
Stacking Model Evaluation

Train Accuracy: 0.9999367230494428
Test Accuracy: 0.9997035044329703
F1 Score: 0.9995932902816218
Precision: 0.9994842293195795
Recall: 0.999702375047124
ROC AUC (Train): 0.9999619980058335
ROC AUC (Test): 0.9998862821145618


for model_name, model in models:
    if 'Decision Tree' in model_name or 'Random Forest' in model_name:
        importances = model.feature_importances_
        feature_names = X.columns
        indices = np.argsort(importances)[::-1]

        plt.figure(figsize=(10, 6))
        plt.title(f'Feature Importance for {model_name}')
        plt.bar(range(X.shape[1]), importances[indices],
align='center')
        plt.xticks(range(X.shape[1]), [feature_names[i] for i in
indices], rotation=90)
        plt.xlim([-1, X.shape[1]])
        plt.show()
    elif 'Voting Classifier' in model_name:
        # Voting classifier doesn't have feature importances
        print(f"No feature importances for {model_name}")
    else:
        # Handle other models if needed
        pass
```

```
No feature importances for Voting Classifier
```

```
import matplotlib.pyplot as plt
from sklearn.model_selection import train_test_split
from sklearn.metrics import *
from sklearn.neighbors import KNeighborsClassifier
from sklearn.linear_model import LogisticRegression
from sklearn.naive_bayes import BernoulliNB
from sklearn.tree import DecisionTreeClassifier
from sklearn.ensemble import RandomForestClassifier
from sklearn.ensemble import RandomForestClassifier, VotingClassifier
```

Visualisations Using ROC & Precision-Recall Curve

```
def split_data(X, y, test_size=0.2, random_state=None):
    X_train, X_test, y_train, y_test = train_test_split(X, y,
test_size=test_size, random_state=random_state)
    return X_train, X_test, y_train, y_test

def train_model(model, X_train, y_train):
    model.fit(X_train, y_train)

def evaluate_model(model, X, y):
    y = np.ravel(y)

    X_np = np.array(X)

    y_pred = model.predict(X_np)

    accuracy = accuracy_score(y, y_pred)
    confusion_matrix_result = confusion_matrix(y, y_pred)
    classification = classification_report(y, y_pred)
    f1 = f1_score(y, y_pred)
    precision = precision_score(y, y_pred)
    recall = recall_score(y, y_pred)

    return {
        'accuracy': accuracy,
        'confusion_matrix': confusion_matrix_result,
        'classification_report': classification,
        'f1_score': f1,
        'precision': precision,
        'recall': recall
    }
```

```
def plot_roc_curve(fpr, tpr, auc, model_name):
    plt.figure(figsize=(8, 6))
    plt.plot(fpr, tpr, color='darkorange', lw=2, label='ROC curve
(area = {:.2f})'.format(auc))
    plt.plot([0, 1], [0, 1], color='navy', lw=2, linestyle='--')
    plt.xlim([0.0, 1.0])
    plt.ylim([0.0, 1.05])
    plt.xlabel('False Positive Rate')
    plt.ylabel('True Positive Rate')
    plt.title('Receiver Operating Characteristic for
{}'.format(model_name))
    plt.legend(loc='lower right')
    plt.show()

def plot_precision_recall_curve(precision, recall, auc, model_name):
    plt.figure(figsize=(8, 6))
    plt.plot(recall, precision, color='darkorange', lw=2, label='PR
curve (area = {:.2f})'.format(auc))
    plt.xlim([0.0, 1.0])
    plt.ylim([0.0, 1.05])
    plt.xlabel('Recall')
    plt.ylabel('Precision')
    plt.title('Precision-Recall Curve for {}'.format(model_name))
    plt.legend(loc='lower left')
    plt.show()

models = [
    ('Naive Baye Classifier', BernoulliNB()),
    ('Random Forest Classifier',
RandomForestClassifier(n_estimators=100, random_state=0)),
    ('Logistic Regression', LogisticRegression(n_jobs=-1,
random_state=0)),
    ('Voting Classifier', VotingClassifier(estimators=classifiers,
voting='soft'))
]


results_df = pd.DataFrame(columns=['Model', 'Train Accuracy', 'Test
Accuracy', 'F1 Score', 'Precision', 'Recall'])

for model_name, model in models:
    train_model(model, X_train, y_train)
    train_evaluation = evaluate_model(model, X_train, y_train)
    test_evaluation = evaluate_model(model, X_test, y_test)

    results_df = pd.concat([results_df, pd.DataFrame({
        'Model': [model_name],
        'Train Accuracy': [train_evaluation['accuracy']],
        'Test Accuracy': [test_evaluation['accuracy']],
        'F1 Score': [test_evaluation['f1_score']],
```

```
        'Precision': [test_evaluation['precision']],
        'Recall': [test_evaluation['recall']],
    })], ignore_index=True)

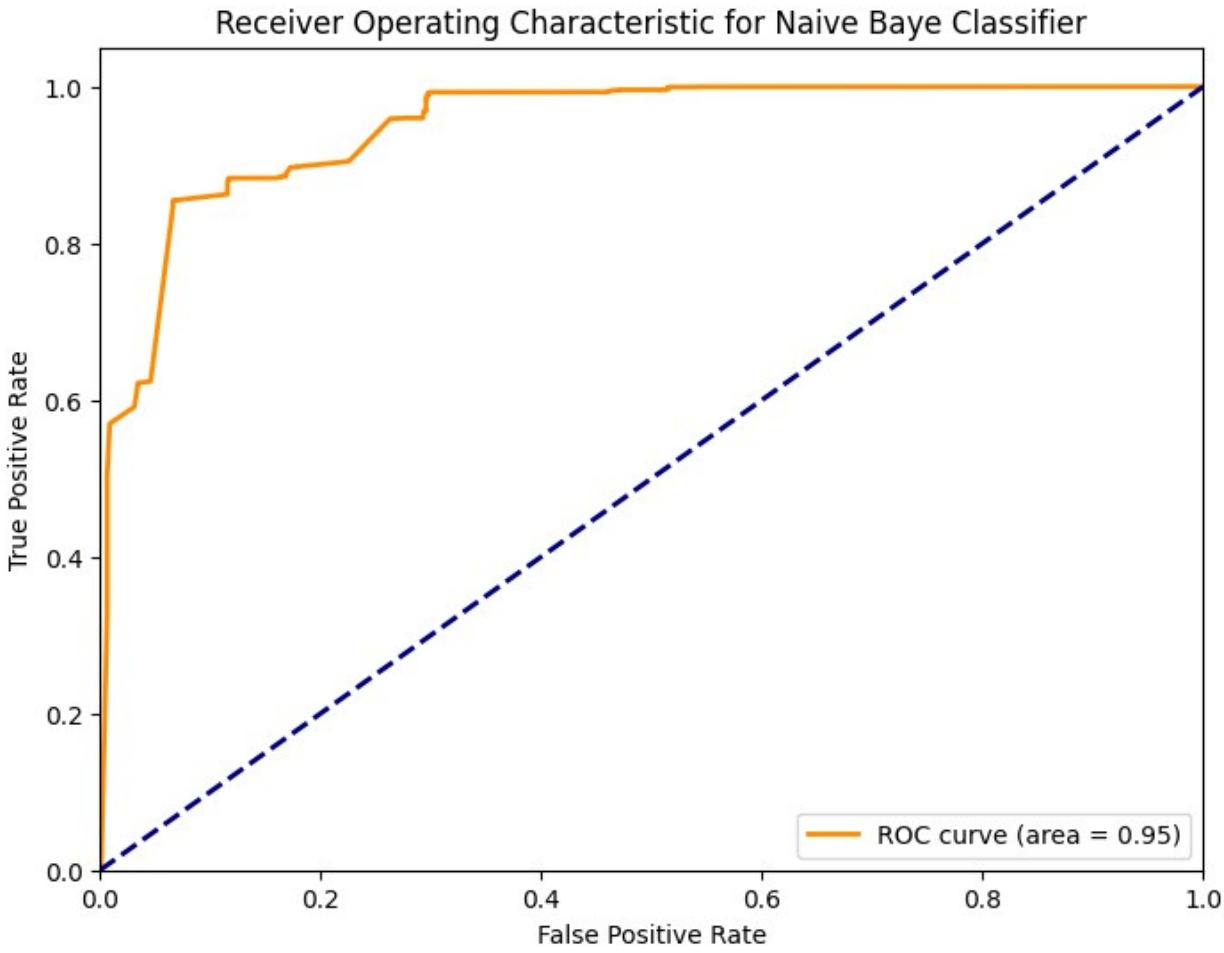
    if model_name != 'Voting Classifier':
      y_prob = model.predict_proba(X_test)[:, 1]
      fpr, tpr, _ = roc_curve(y_test, y_prob)
      roc_auc = auc(fpr, tpr)

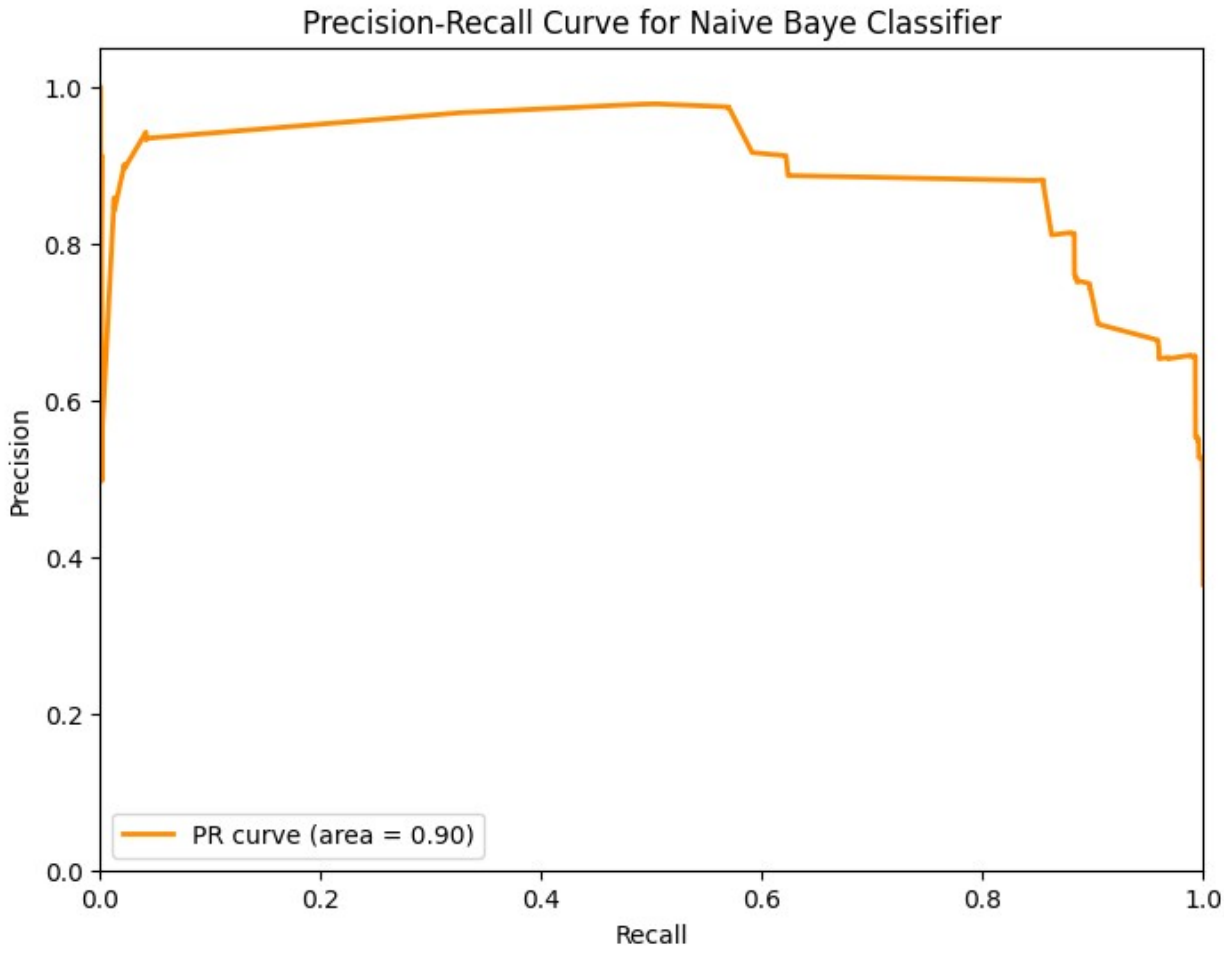
      precision, recall, _ = precision_recall_curve(y_test, y_prob)
      pr_auc = auc(recall, precision)

      plot_roc_curve(fpr, tpr, roc_auc, model_name)
      plot_precision_recall_curve(precision, recall, pr_auc,
model_name)

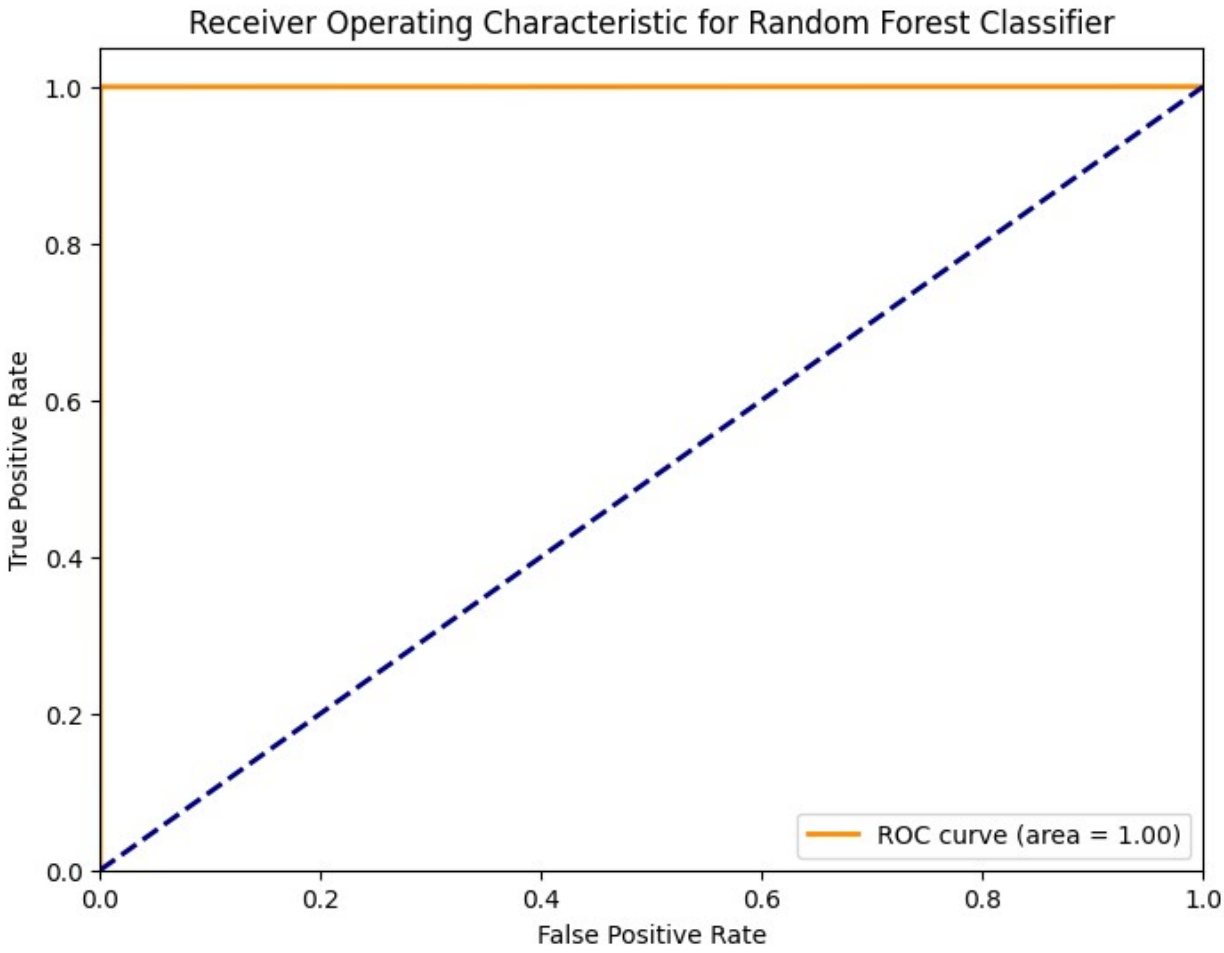
print(results_df)
```

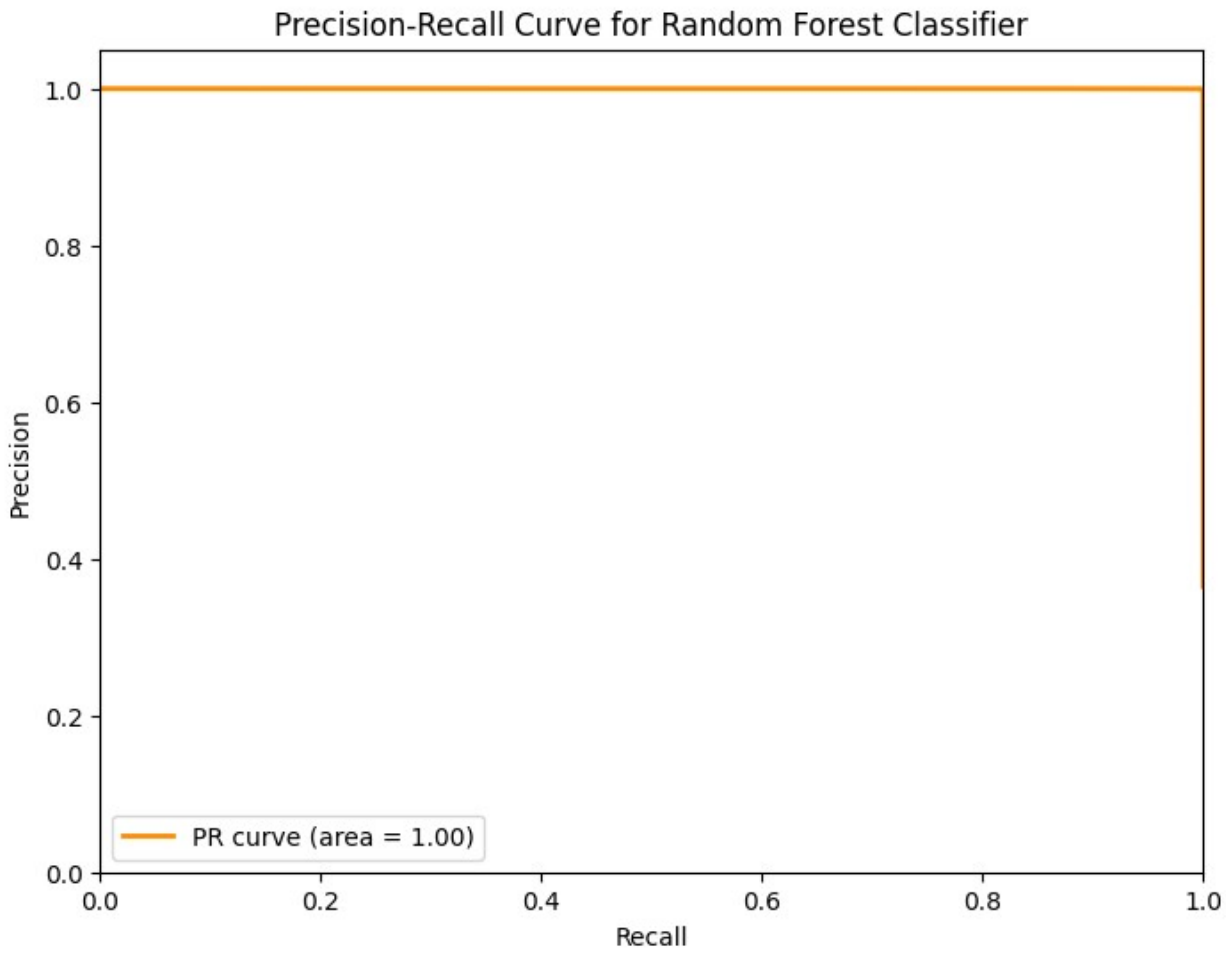
```
/usr/local/lib/python3.10/dist-packages/sklearn/utils/
validation.py:1143: DataConversionWarning: A column-vector y was
passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.10/dist-packages/sklearn/base.py:439:
UserWarning: X does not have valid feature names, but BernoulliNB was
fitted with feature names
  warnings.warn(
/usr/local/lib/python3.10/dist-packages/sklearn/base.py:439:
UserWarning: X does not have valid feature names, but BernoulliNB was
fitted with feature names
  warnings.warn(
```


Receiver Operating Characteristic for Naive Baye Classifier
True Positive Rate
False Positive Rate
0.0
0.2
0.4
0.6
0.8
1.0
ROC curve (area = 0.95)

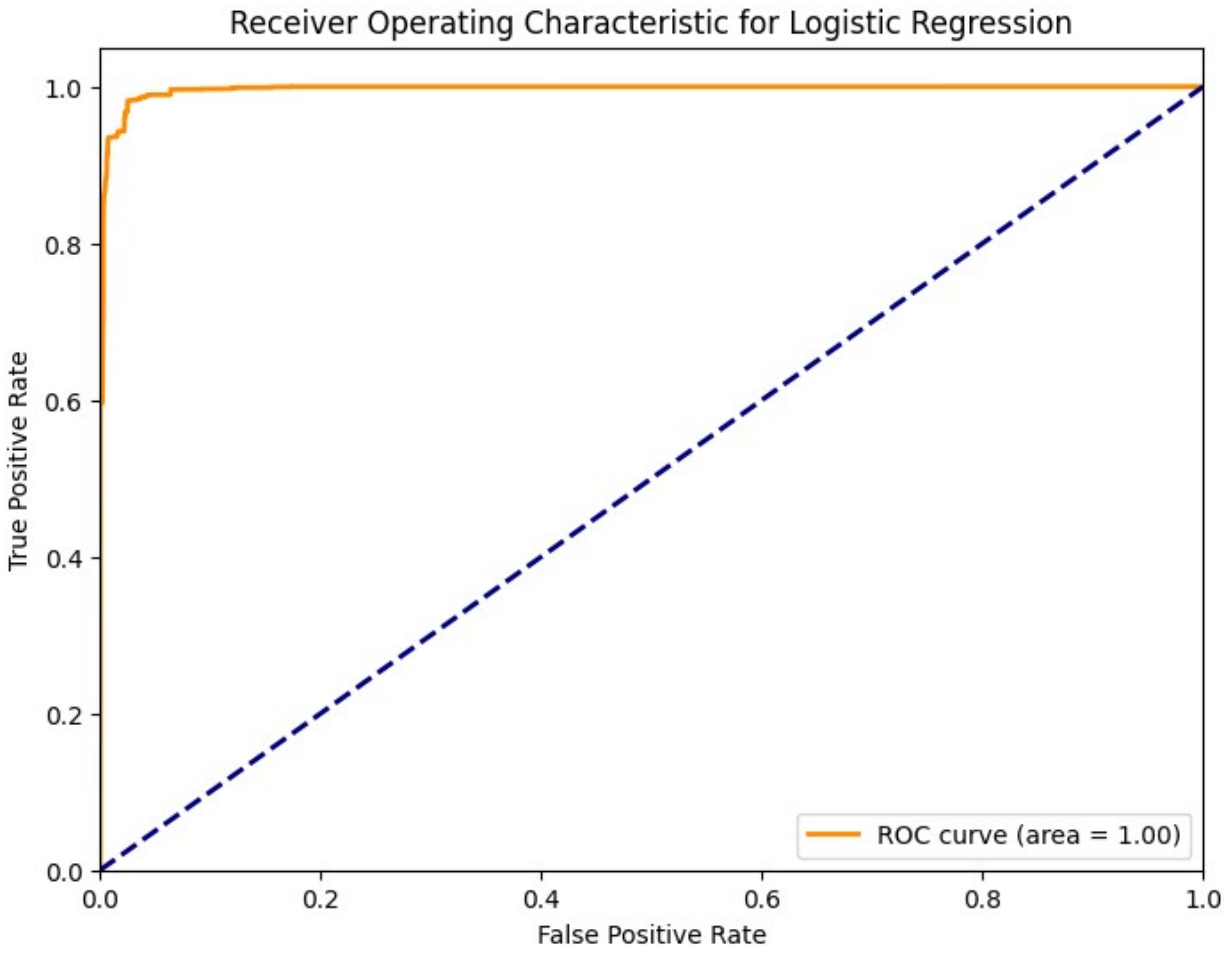


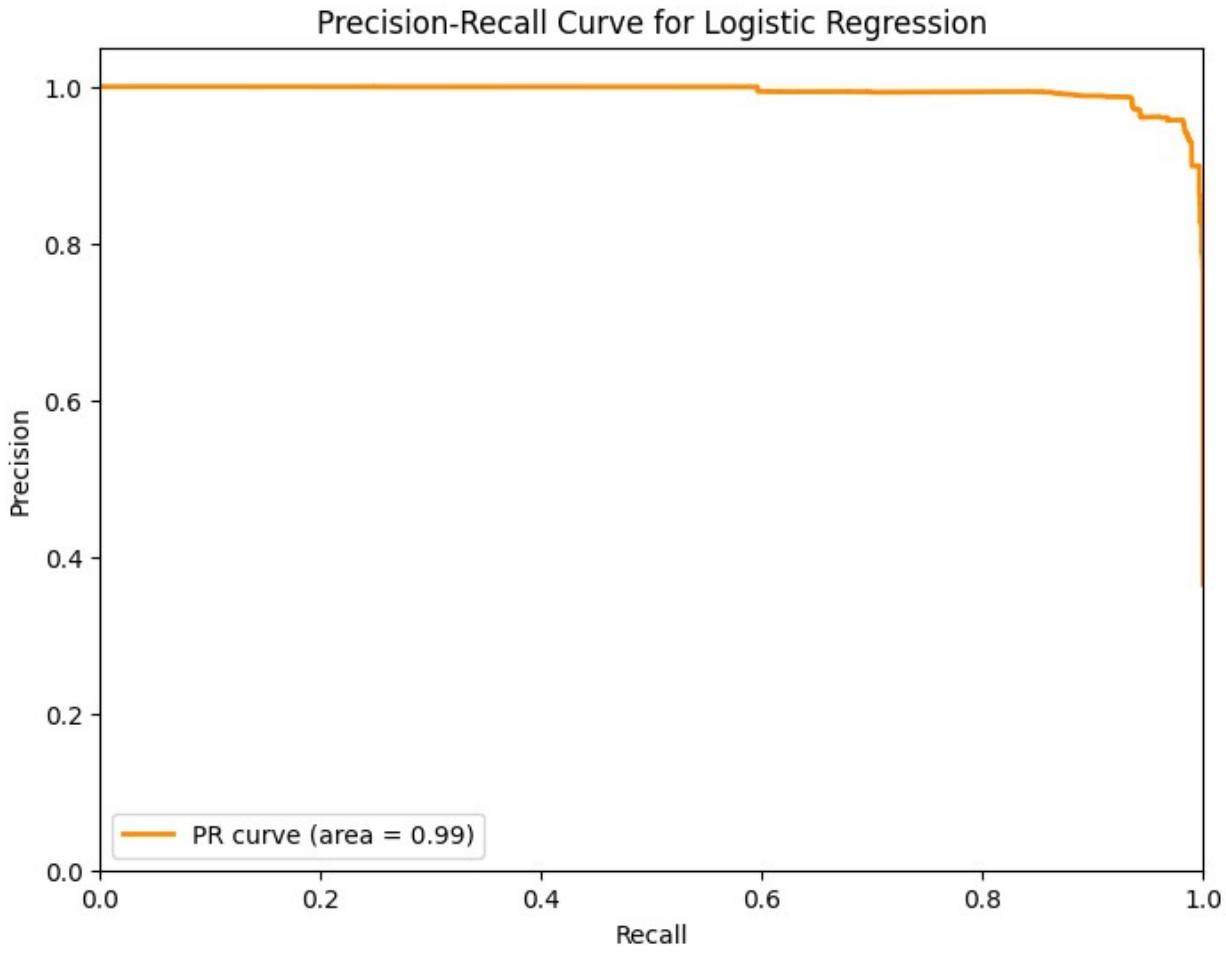

```
<ipython-input-48-c8a1ed5953ad>:6: DataConversionWarning: A column-
vector y was passed when a 1d array was expected. Please change the
shape of y to (n_samples,), for example using ravel().
  model.fit(X_train, y_train)
/usr/local/lib/python3.10/dist-packages/sklearn/base.py:439:
UserWarning: X does not have valid feature names, but
RandomForestClassifier was fitted with feature names
  warnings.warn(
/usr/local/lib/python3.10/dist-packages/sklearn/base.py:439:
UserWarning: X does not have valid feature names, but
RandomForestClassifier was fitted with feature names
  warnings.warn(
```


Receiver Operating Characteristic for Random Forest Classifier
True Positive Rate
False Positive Rate
0.0
0.2
0.4
0.6
0.8
1.0
ROC curve (area = 1.00)




```
/usr/local/lib/python3.10/dist-packages/sklearn/utils/
validation.py:1143: DataConversionWarning: A column-vector y was
passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.10/dist-packages/sklearn/base.py:439:
UserWarning: X does not have valid feature names, but
LogisticRegression was fitted with feature names
  warnings.warn(
/usr/local/lib/python3.10/dist-packages/sklearn/base.py:439:
UserWarning: X does not have valid feature names, but
LogisticRegression was fitted with feature names
  warnings.warn(
```


Receiver Operating Characteristic for Logistic Regression
True Positive Rate
False Positive Rate
0.0
0.2
0.4
0.6
0.8
1.0
ROC curve (area = 1.00)




```
/usr/local/lib/python3.10/dist-packages/sklearn/preprocessing/
_label.py:99: DataConversionWarning: A column-vector y was passed when
a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.10/dist-packages/sklearn/preprocessing/_label.p
y:134: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples, ), for
example using ravel().
  y = column_or_1d(y, dtype=self.classes_.dtype, warn=True)
/usr/local/lib/python3.10/dist-packages/sklearn/base.py:439:
UserWarning: X does not have valid feature names, but BernoulliNB was
fitted with feature names
  warnings.warn(
/usr/local/lib/python3.10/dist-packages/sklearn/base.py:439:
UserWarning: X does not have valid feature names, but
DecisionTreeClassifier was fitted with feature names
  warnings.warn(
/usr/local/lib/python3.10/dist-packages/sklearn/base.py:439:
UserWarning: X does not have valid feature names, but
```

```
RandomForestClassifier was fitted with feature names
  warnings.warn(
/usr/local/lib/python3.10/dist-packages/sklearn/base.py:439:
UserWarning: X does not have valid feature names, but
LogisticRegression was fitted with feature names
  warnings.warn(
/usr/local/lib/python3.10/dist-packages/sklearn/base.py:439:
UserWarning: X does not have valid feature names, but BernoulliNB was
fitted with feature names
  warnings.warn(
/usr/local/lib/python3.10/dist-packages/sklearn/base.py:439:
UserWarning: X does not have valid feature names, but
DecisionTreeClassifier was fitted with feature names
  warnings.warn(
/usr/local/lib/python3.10/dist-packages/sklearn/base.py:439:
UserWarning: X does not have valid feature names, but
RandomForestClassifier was fitted with feature names
  warnings.warn(
/usr/local/lib/python3.10/dist-packages/sklearn/base.py:439:
UserWarning: X does not have valid feature names, but
LogisticRegression was fitted with feature names
  warnings.warn(
```

	Model	Train Accuracy	Test Accuracy	F1 Score
0	Naive Baye Classifier	0.821720	0.823723	0.788982
1	Random Forest Classifier	0.999669	0.999573	0.999415
2	Logistic Regression	0.972109	0.972585	0.962604
3	Voting Classifier	0.998968	0.998633	0.998128

	Precision	Recall
0	0.699817	0.904185
1	0.999108	0.999722
2	0.957156	0.968114
3	0.996519	0.999742

```
accuracy_metrics = ['Train Accuracy', 'Test Accuracy']
model_names = results_df['Model']
num_models = len(models)

bar_width = 0.35

indices = np.arange(len(model_names))

colors = ['b', 'g']

plt.figure(figsize=(12, 6))
```

```
for i, metric in enumerate(accuracy_metrics):
    x_positions = [ind + i * bar_width for ind in indices]

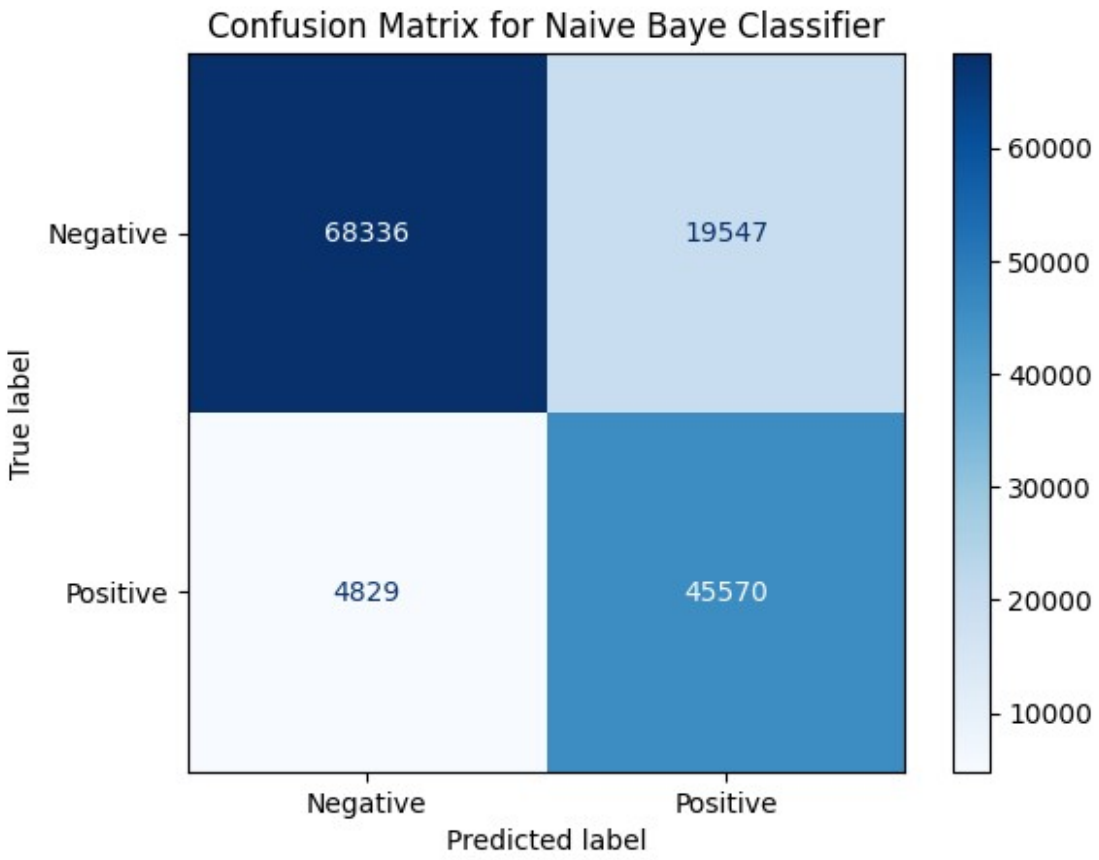
    metric_values = results_df[metric]

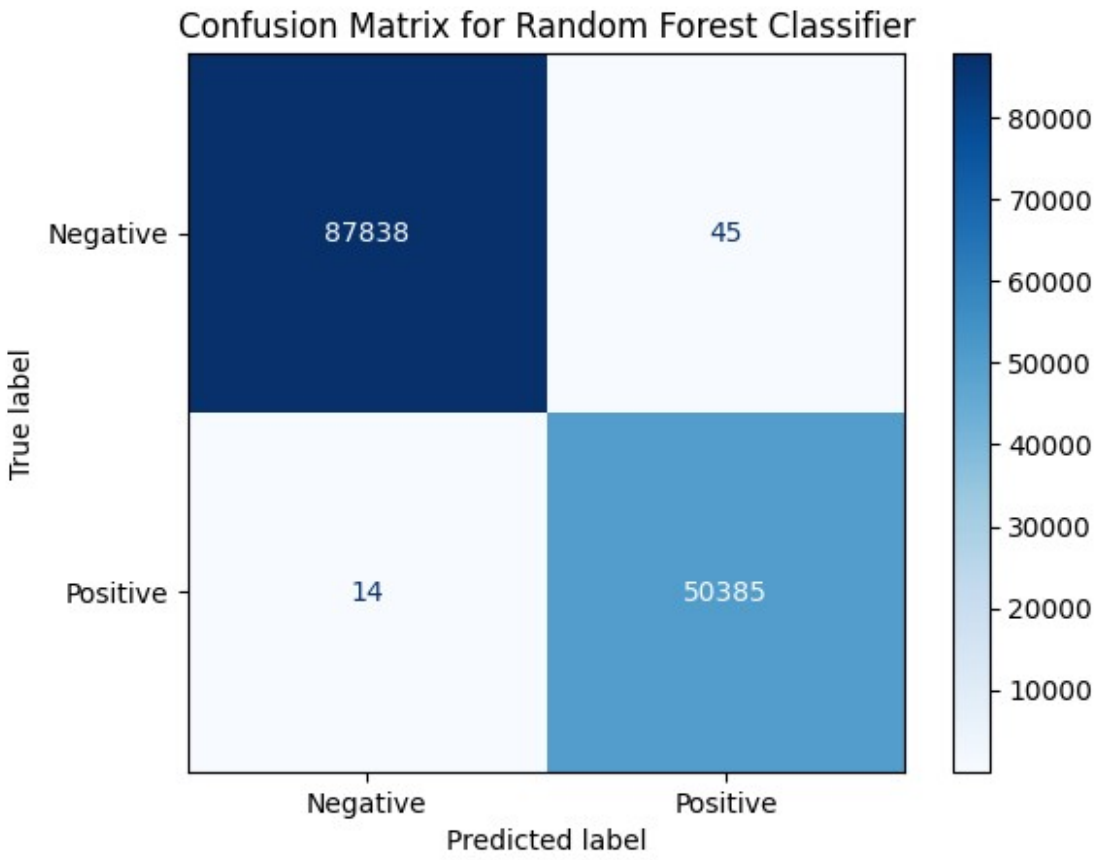
    plt.bar(x_positions, metric_values, width=bar_width, label=metric,
color=colors[i])

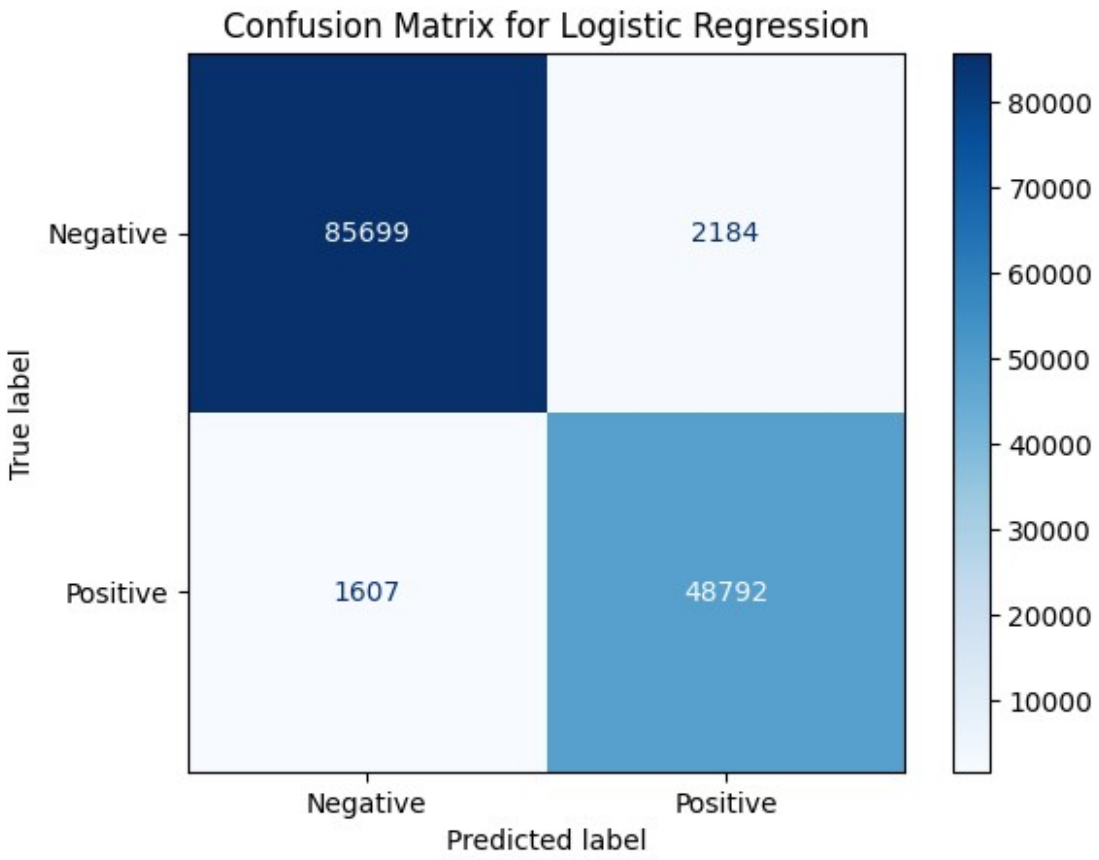
plt.xlabel('Model')
plt.ylabel('Accuracy')
plt.title('Training and Testing Accuracy Comparison')
plt.xticks(indices + (bar_width * (num_models - 1)) / 2, model_names,
rotation=45)
plt.legend(loc='lower right')

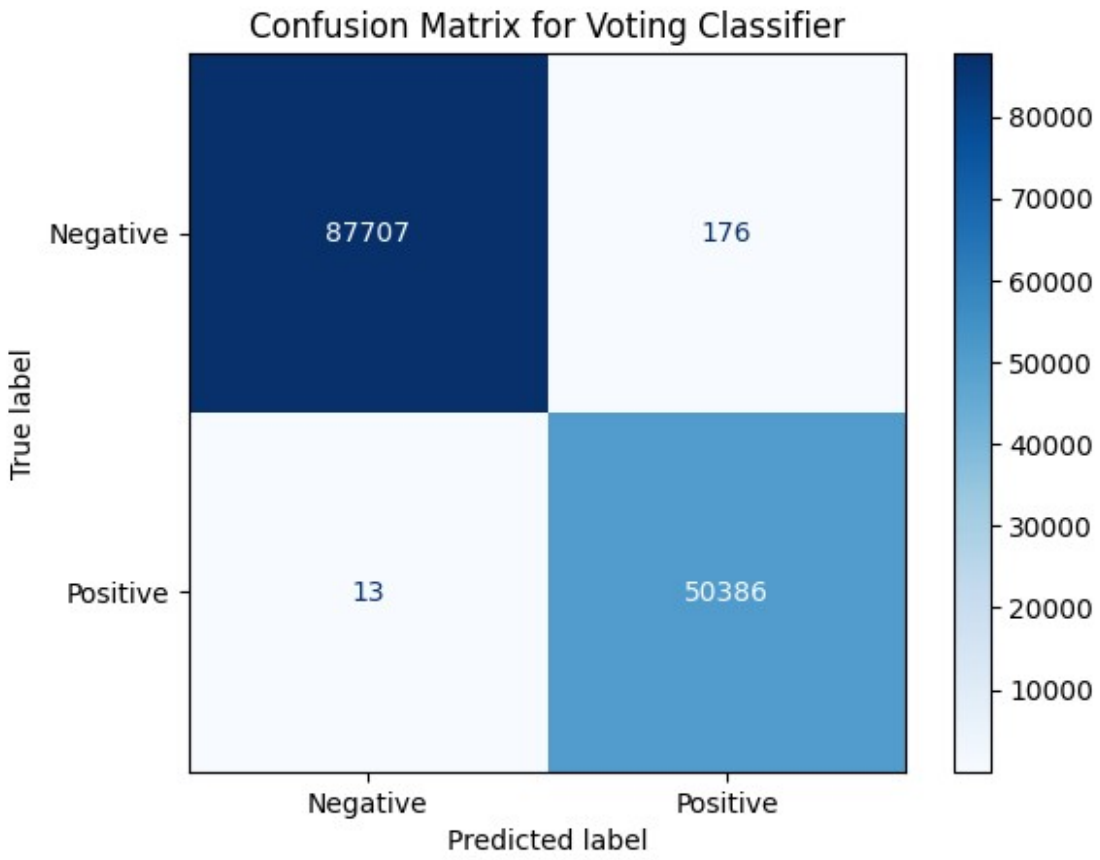
plt.tight_layout()
plt.show()
```


```
for model_name, model in models:
    y_pred = model.predict(X_test)
    cm = confusion_matrix(y_test, y_pred)
    disp = ConfusionMatrixDisplay(confusion_matrix=cm,
display_labels=["Negative", "Positive"])
    disp.plot(cmap=plt.cm.Blues, values_format='d')
    plt.title(f'Confusion Matrix for {model_name}')
    plt.show()
```


Confusion Matrix for Naive Baye Classifier
Negative
Positive
True label
68336
19547
4829
45570
Negative
Positive
Predicted label
60000
50000
40000
30000
20000
10000

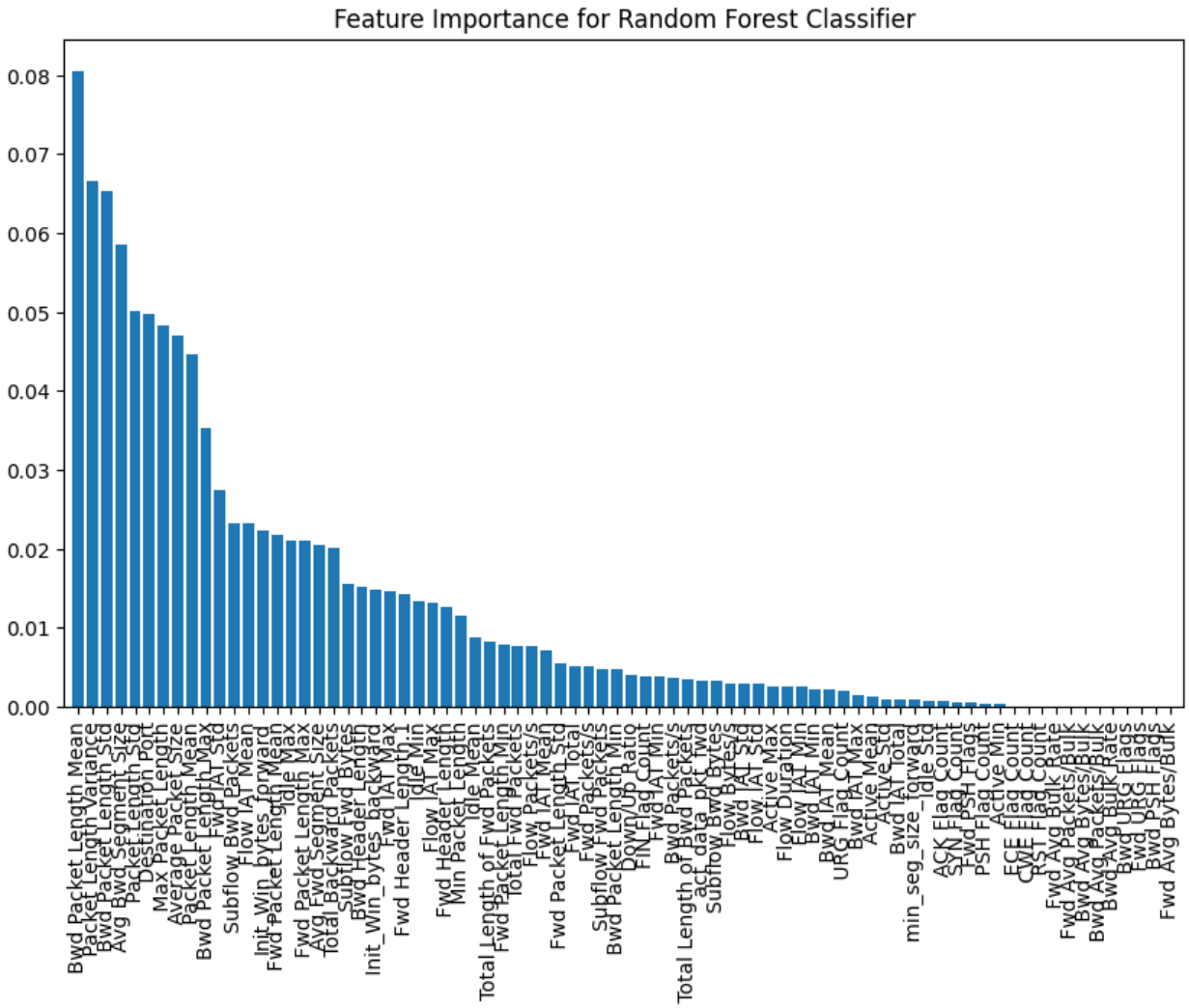

Confusion Matrix for Random Forest Classifier
Negative
Positive
True label
87838
45
14
50385
Negative
Positive
Predicted label
80000
70000
60000
50000
40000
30000
20000
10000


Confusion Matrix for Logistic Regression
Negative
Positive
True label
85699
2184
1607
48792
Negative
Positive
Predicted label
80000
70000
60000
50000
40000
30000
20000
10000




```
for model_name, model in models:
    if 'Decision Tree' in model_name or 'Random Forest' in model_name:
        importances = model.feature_importances_
        feature_names = X.columns
        indices = np.argsort(importances)[::-1]

        plt.figure(figsize=(10, 6))
        plt.title(f'Feature Importance for {model_name}')
        plt.bar(range(X.shape[1]), importances[indices],
align='center')
        plt.xticks(range(X.shape[1]), [feature_names[i] for i in
indices], rotation=90)
        plt.xlim([-1, X.shape[1]])
        plt.show
```



Visualize learning curves for each model

```
from sklearn.model_selection import learning_curve

for model_name, model in models:
    train_sizes, train_scores, test_scores = learning_curve(model,
X_train, y_train, cv=5, scoring='accuracy')
    train_scores_mean = np.mean(train_scores, axis=1)
    test_scores_mean = np.mean(test_scores, axis=1)

    plt.figure(figsize=(8, 6))
    plt.title(f'Learning Curve for {model_name}')
    plt.xlabel("Training examples")
    plt.ylabel("Score")
    plt.grid()
    plt.plot(train_sizes, train_scores_mean, 'o-', label="Training
```

```
score")
    plt.plot(train_sizes, test_scores_mean, 'o-', label="Cross-
validation score")
    plt.legend(loc="best")
    plt.show()
```

```
/usr/local/lib/python3.10/dist-packages/sklearn/utils/
validation.py:1143: DataConversionWarning: A column-vector y was
passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.10/dist-packages/sklearn/utils/validation.py:11
43: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples, ), for
example using ravel().
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.10/dist-packages/sklearn/utils/validation.py:11
43: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples, ), for
example using ravel().
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.10/dist-packages/sklearn/utils/validation.py:11
43: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples, ), for
example using ravel().
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.10/dist-packages/sklearn/utils/validation.py:11
43: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples, ), for
example using ravel().
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.10/dist-packages/sklearn/utils/validation.py:11
43: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples, ), for
example using ravel().
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.10/dist-packages/sklearn/utils/validation.py:11
43: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples, ), for
example using ravel().
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.10/dist-packages/sklearn/utils/validation.py:11
43: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples, ), for
example using ravel().
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.10/dist-packages/sklearn/utils/validation.py:11
43: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples, ), for
example using ravel().
```

```
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.10/dist-packages/sklearn/utils/validation.py:11
43: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples, ), for
example using ravel().
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.10/dist-packages/sklearn/utils/validation.py:11
43: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples, ), for
example using ravel().
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.10/dist-packages/sklearn/utils/validation.py:11
43: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples, ), for
example using ravel().
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.10/dist-packages/sklearn/utils/validation.py:11
43: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples, ), for
example using ravel().
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.10/dist-packages/sklearn/utils/validation.py:11
43: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples, ), for
example using ravel().
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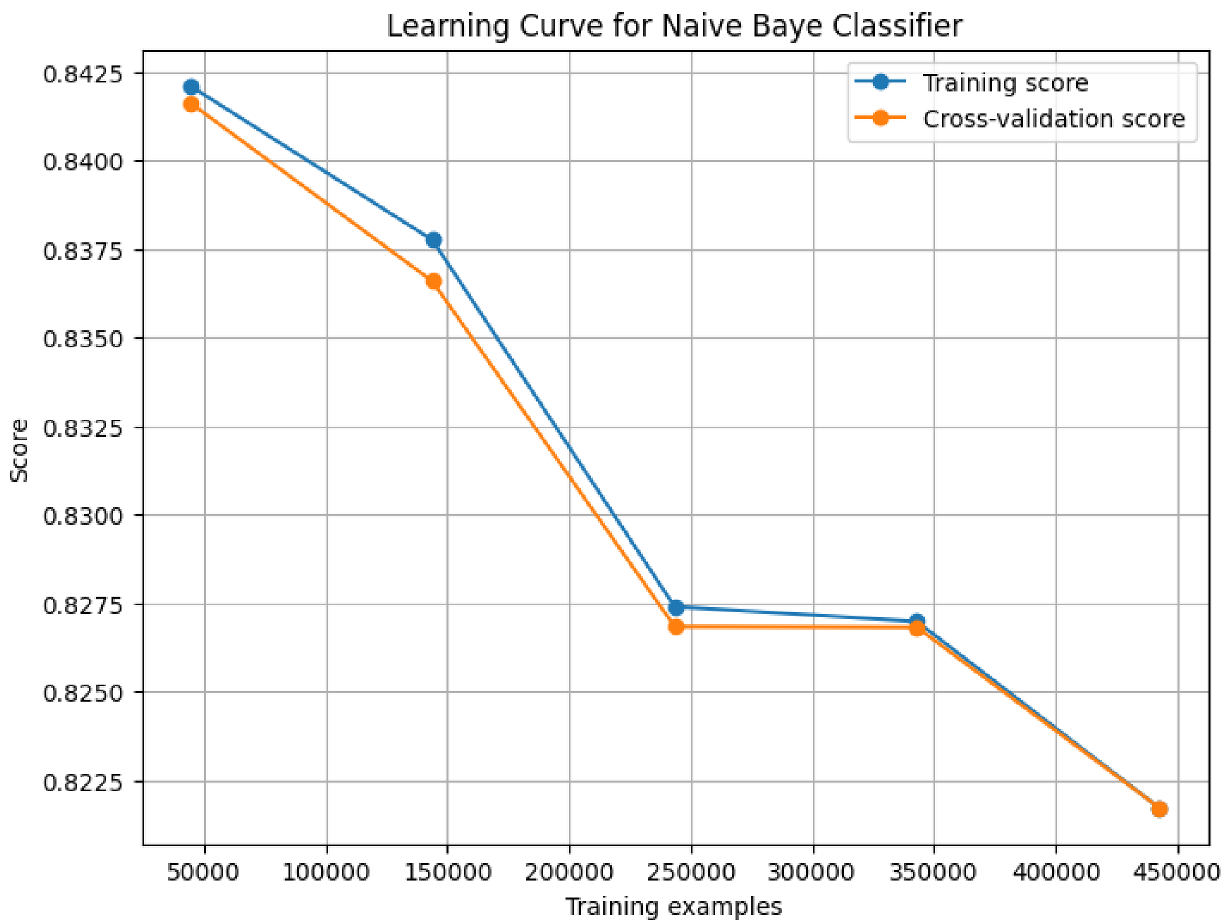


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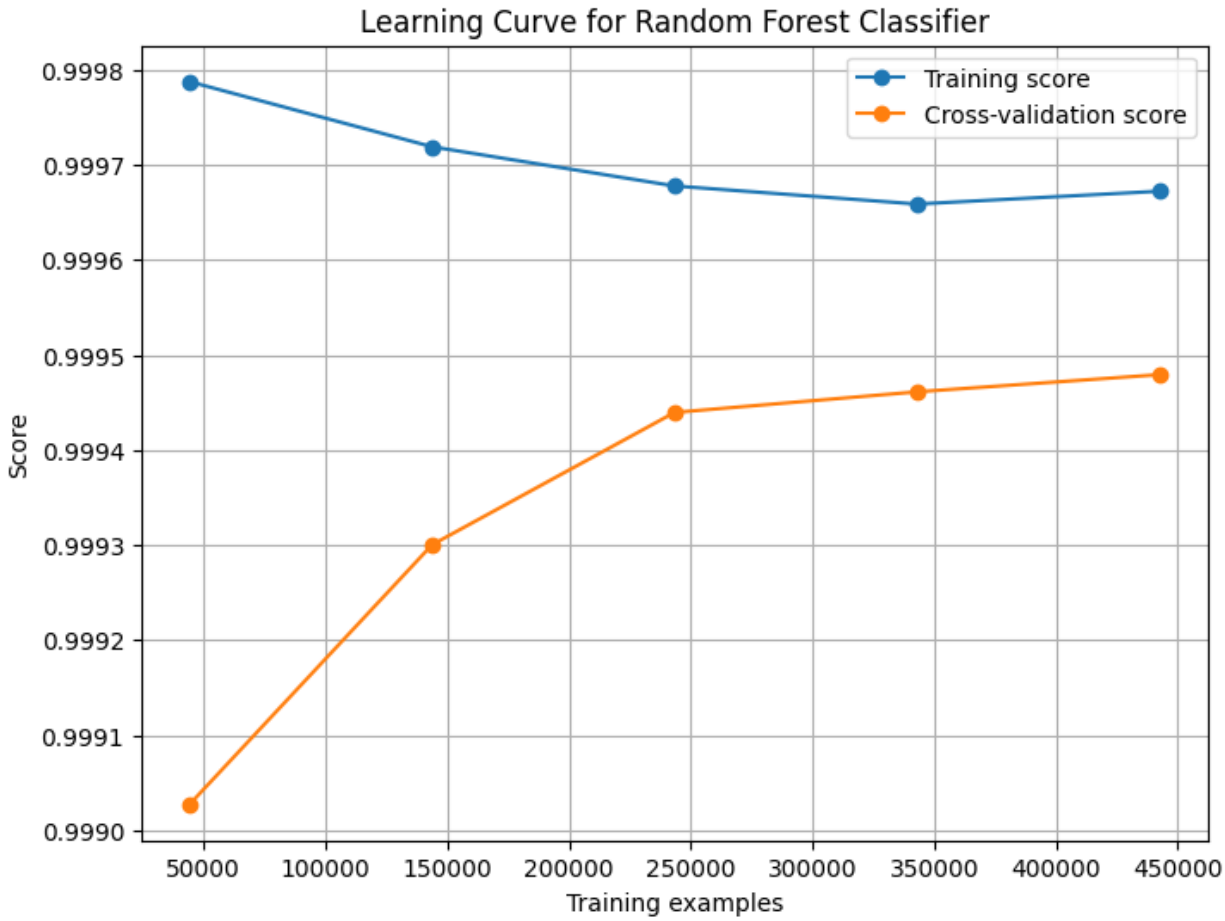


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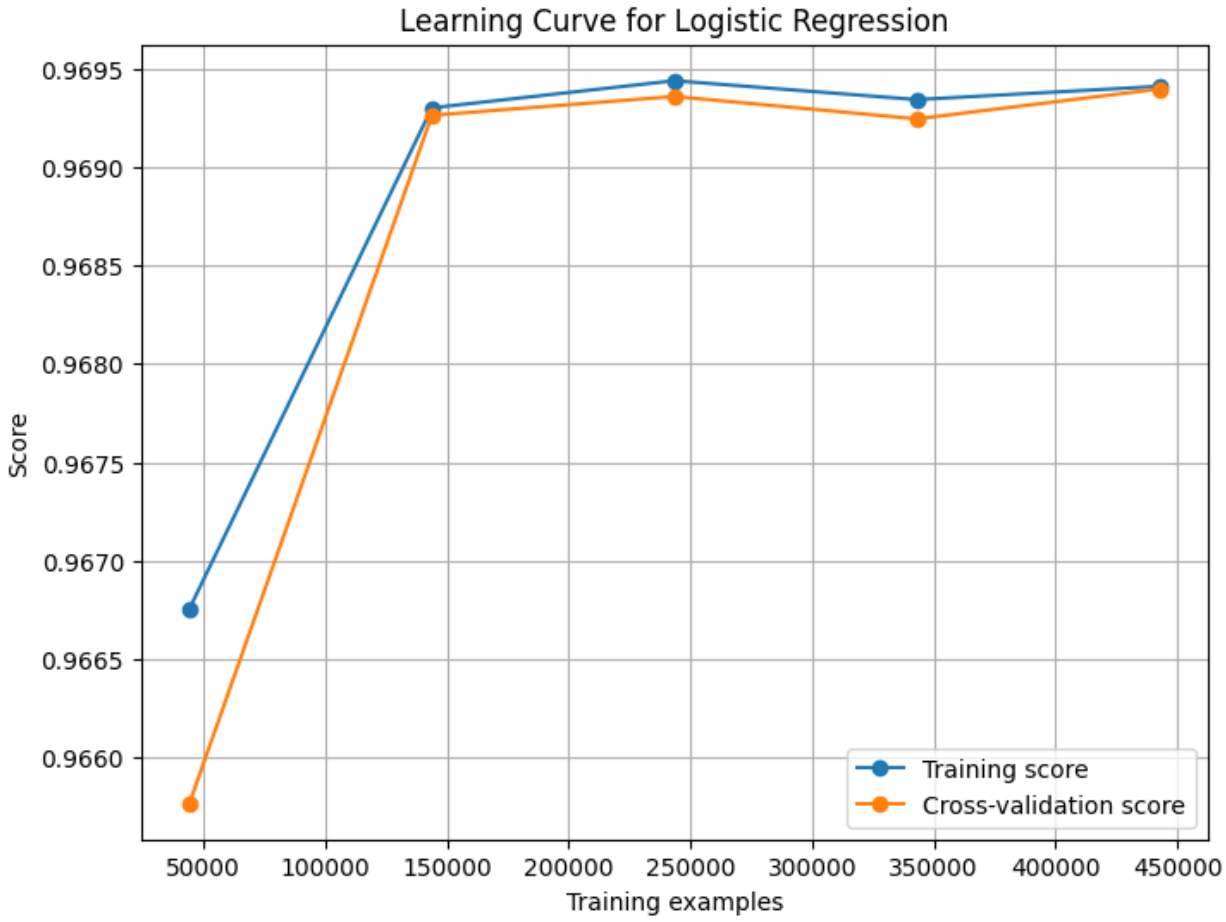


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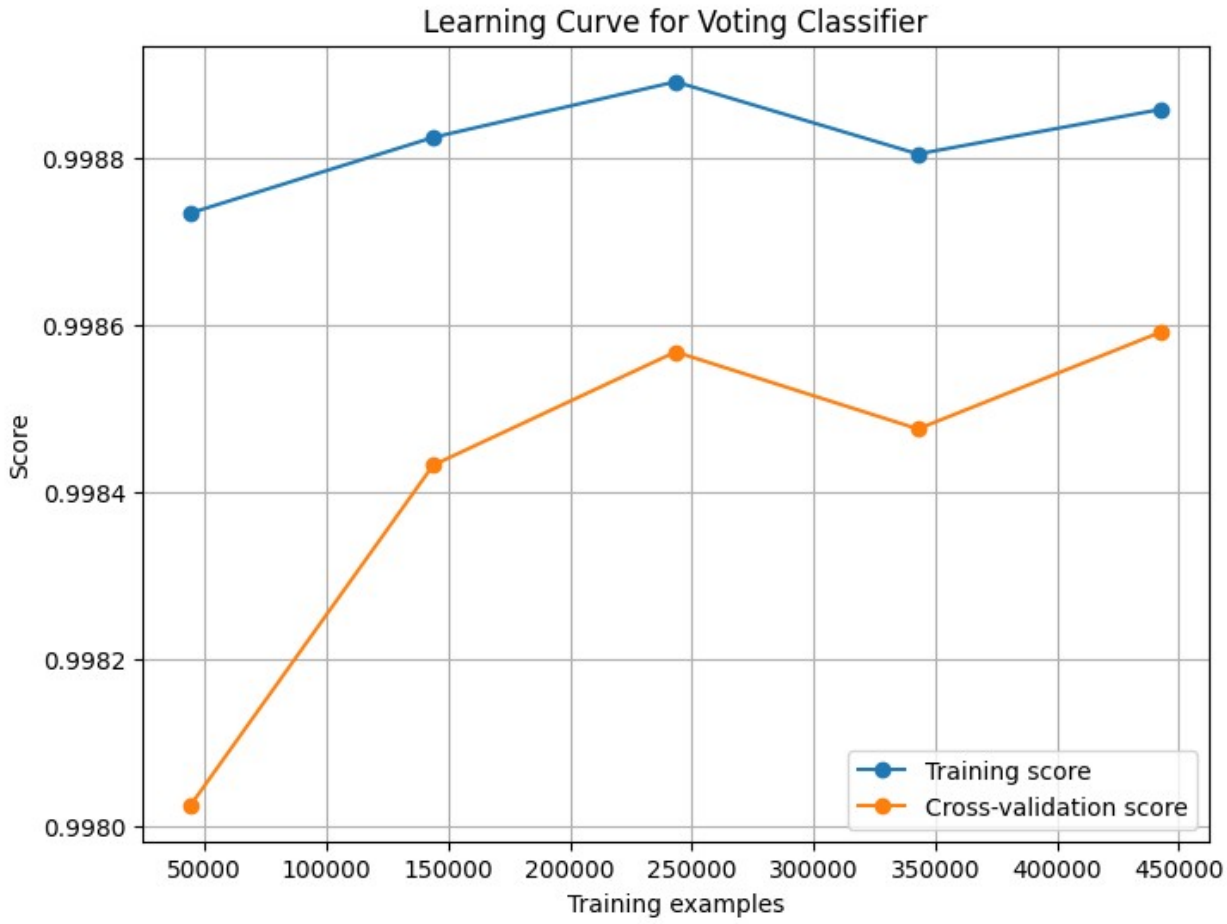

Create a grouped bar plot for comparing multiple metrics across models

```
metrics_to_compare = ['Train Accuracy', 'Test Accuracy', 'F1 Score',
'Precision', 'Recall']
model_names = results_df['Model']
num_models = len(models)

bar_width = 0.15

indices = np.arange(len(model_names))

colors = ['b', 'g', 'm', 'y','c']

plt.figure(figsize=(12, 6))

for i, metric in enumerate(metrics_to_compare):
    x_positions = [ind + i * bar_width for ind in indices]
```

```
    metric_values = results_df[metric]

    plt.bar(x_positions, metric_values, width=bar_width, label=metric,
color=colors[i])

plt.xlabel('Model')
plt.ylabel('Score')
plt.title('Model Comparison')
plt.xticks(indices + (bar_width * (num_models - 1)) / 2, model_names,
rotation=45)
plt.legend(loc='lower right')

plt.tight_layout()
plt.show()
```