```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.model_selection import train_test_split, cross_val_score
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.preprocessing import LabelEncoder
from sklearn.linear_model import LogisticRegression
from sklearn.naive_bayes import MultinomialNB
from sklearn.ensemble import RandomForestClassifier
from sklearn.metrics import classification_report, confusion_matrix, accuracy_s
from sklearn.pipeline import make_pipeline
import joblib
import warnings
warnings.filterwarnings('ignore')
```

```
from google.colab import drive
drive.mount('/content/drive')
```

```
Mounted at /content/drive
```

Importing the Dependencies

Data Collection & Pre-Processing

```
# loading the data from csv file to a pandas Dataframe
raw_mail_data = pd.read_csv('/content/drive/MyDrive/Colab Notebooks/dataset/mai
```

```
print(raw_mail_data)
```

```
     Category                                            Message
0         ham  Go until jurong point, crazy.. Available only ...
1         ham                      Ok lar... Joking wif u oni...
2        spam  Free entry in 2 a wkly comp to win FA Cup fina...
3         ham  U dun say so early hor... U c already then say...
4         ham  Nah I don't think he goes to usf, he lives aro...
...       ...                                                ...
5567     spam  This is the 2nd time we have tried 2 contact u...
5568      ham              Will Ã¼ b going to esplanade fr home?
5569      ham  Pity, * was in mood for that. So...any other s...
5570      ham  The guy did some bitching but I acted like i'd...
5571      ham                        Rofl. Its true to its name

[5572 rows x 2 columns]
```

```
# replace the null values with a null string
mail_data = raw_mail_data.where((pd.notnull(raw_mail_data)),'')


# printing the first 5 rows of the dataframe
mail_data.head()
```

	Category	Message
0	ham	Go until jurong point, crazy.. Available only ...
1	ham	Ok lar... Joking wif u oni...
2	spam	Free entry in 2 a wkly comp to win FA Cup fina...
3	ham	U dun say so early hor... U c already then say...
4	ham	Nah I don't think he goes to usf, he lives aro...

Next steps: Generate code with mail_data | View recommended plots | New interactive sheet

```
# checking the number of rows and columns in the dataframe
mail_data.shape
```

```
(5572, 2)
```

Label Encoding

```
# Encode labels
label_encoder = LabelEncoder()
mail_data['Category'] = label_encoder.fit_transform(mail_data['Category'])  #
```

spam - 0

ham - 1

```
# separating the data as texts and label

X = mail_data['Message']

y = mail_data['Category']
```

```
print(X)
```

```
0       Go until jurong point, crazy.. Available only ...
1                           Ok lar... Joking wif u oni...
2       Free entry in 2 a wkly comp to win FA Cup fina...
3       U dun say so early hor... U c already then say...
4       Nah I don't think he goes to usf, he lives aro...
                              ...
5567    This is the 2nd time we have tried 2 contact u...
5568                Will Ã¼ b going to esplanade fr home?
5569    Pity, * was in mood for that. So...any other s...
5570    The guy did some bitching but I acted like i'd...
5571                            Rofl. Its true to its name
Name: Message, Length: 5572, dtype: object
```

```
print(y)
```

```
0       0
1       0
2       1
3       0
4       0
       ..
5567    1
5568    0
5569    0
5570    0
5571    0
Name: Category, Length: 5572, dtype: int64
```

Splitting the data into training data & test data

```
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, strati
```

```
print(X.shape)
print(X_train.shape)
print(X_test.shape)
```

```
(5572,)
(4457,)
(1115,)
```

Feature Extraction

```
# Vectorize text using TF-IDF
vectorizer = TfidfVectorizer(min_df=1, stop_words='english', lowercase=True)
X_train_tfidf = vectorizer.fit_transform(X_train)
X_test_tfidf = vectorizer.transform(X_test)

# Save vectorizer
joblib.dump(vectorizer, 'tfidf_vectorizer.pkl')
```

```
['tfidf_vectorizer.pkl']
```

```
# Initialize models
models = {
    'Logistic Regression': LogisticRegression(),
    'Naive Bayes': MultinomialNB(),
    'Random Forest': RandomForestClassifier(n_estimators=100, random_state=42)
}

results = {}
```

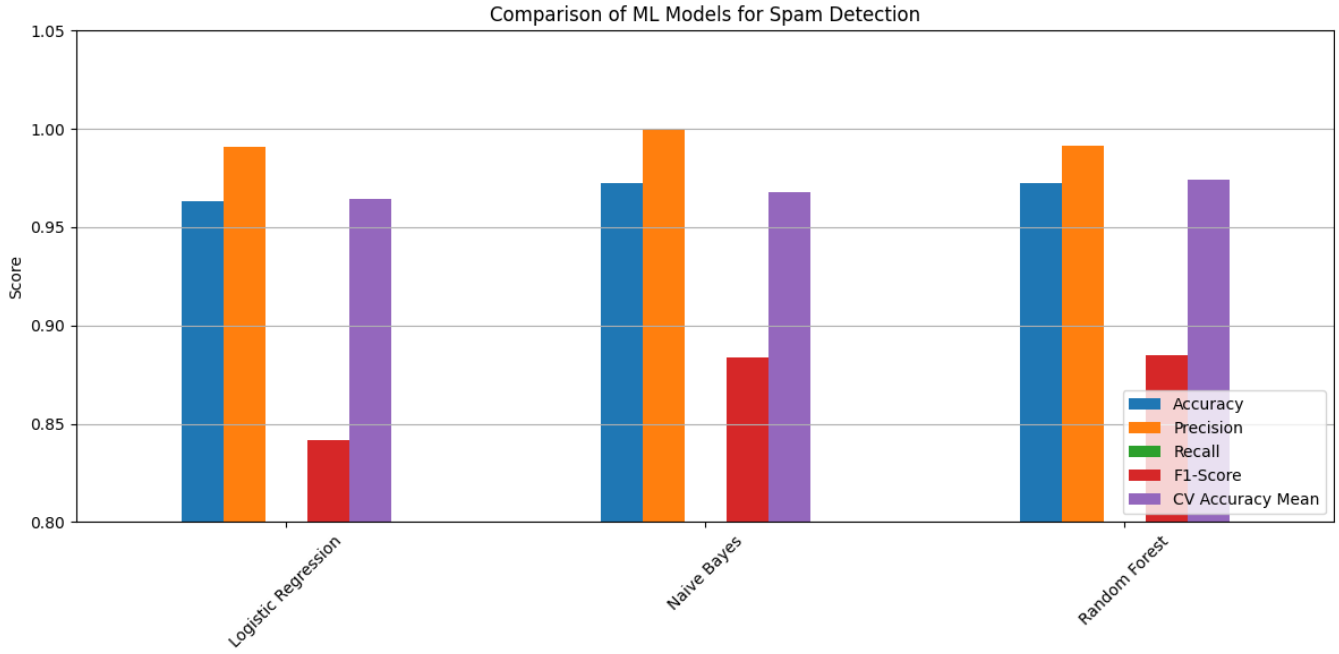
```
# Train, cross-validate and evaluate models
for name, model in models.items():
    model.fit(X_train_tfidf, y_train)
    y_pred = model.predict(X_test_tfidf)
    acc = accuracy_score(y_test, y_pred)
    report = classification_report(y_test, y_pred, output_dict=True)
    cm = confusion_matrix(y_test, y_pred)
    roc_auc = None
    if hasattr(model, "predict_proba"):
        y_scores = model.predict_proba(X_test_tfidf)[:, 1]
    else:
        y_scores = model.decision_function(X_test_tfidf)
    fpr, tpr, _ = roc_curve(y_test, y_scores)
    roc_auc = auc(fpr, tpr)

    # Cross-validation
    pipeline = make_pipeline(TfidfVectorizer(stop_words='english', lowercase=Tr
    cv_scores = cross_val_score(pipeline, X, y, cv=5, scoring='accuracy')

    results[name] = {
        'Model' : model,
        'Accuracy': acc,
        'Precision': report['1']['precision'],
        'Recall': report['1']['recall'],
        'F1-Score': report['1']['f1-score'],
        'Confusion Matrix': cm,
        'ROC AUC': roc_auc,
        'CV Accuracy Mean': cv_scores.mean(),
        'FPR': fpr,
        'TPR': tpr
    }


# Save models
for name, data in results.items():
    joblib.dump(data['Model'], f"{name.replace(' ', '_').lower()}_model.pkl")
```

```
# Display evaluation results
eval_df = pd.DataFrame({k: {
    'Accuracy': v['Accuracy'],
    'Precision': v['Precision'],
    'Recall': v['Recall'],
    'F1-Score': v['F1-Score'],
    'ROC AUC': v['ROC AUC'],
    'CV Accuracy Mean': v['CV Accuracy Mean']
} for k, v in results.items()}).T

print("Model Evaluation Comparison:")
print(eval_df)
```

```
Model Evaluation Comparison:
                     Accuracy  Precision    Recall  F1-Score   ROC AUC  \
Logistic Regression  0.963229   0.990909  0.731544  0.841699  0.991645
Naive Bayes          0.972197   1.000000  0.791946  0.883895  0.990520
Random Forest        0.972197   0.991667  0.798658  0.884758  0.988825

                     CV Accuracy Mean
Logistic Regression          0.964106
Naive Bayes                  0.968054
Random Forest                0.974154
```

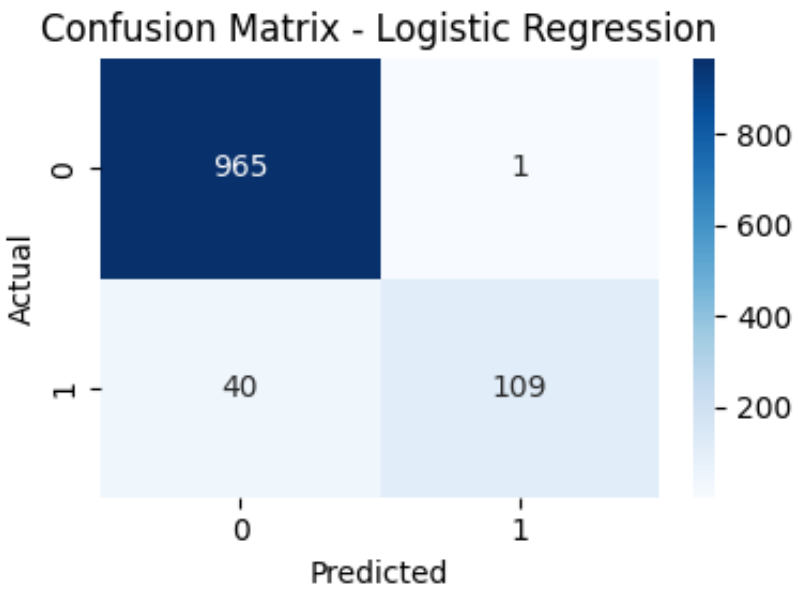
```
# Plot comparison
plt.figure(figsize=(10, 6))
eval_df[['Accuracy', 'Precision', 'Recall', 'F1-Score', 'CV Accuracy Mean']].pl
plt.title("Comparison of ML Models for Spam Detection")
plt.ylabel("Score")
plt.ylim(0.8, 1.05)
plt.xticks(rotation=45)
plt.grid(axis='y')
plt.legend(loc='lower right')
plt.tight_layout()
plt.show()
```

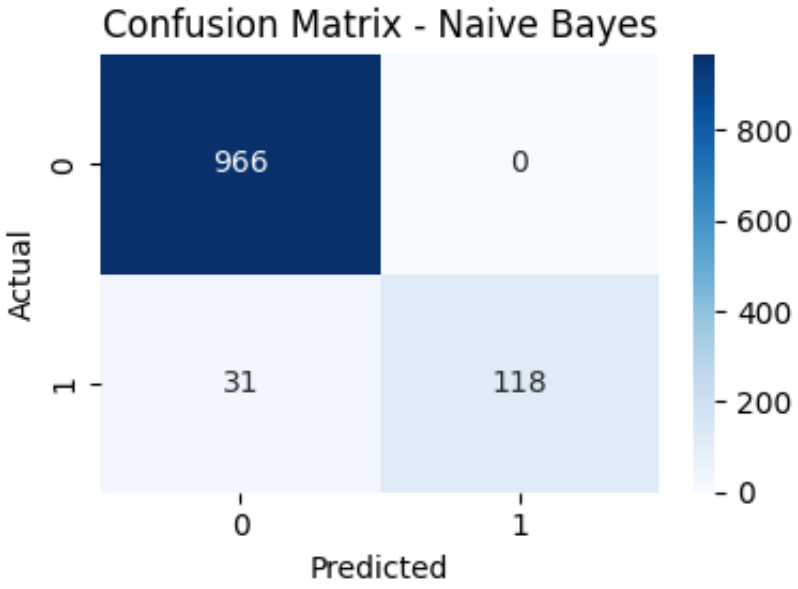
```
<Figure size 1000x600 with 0 Axes>
```

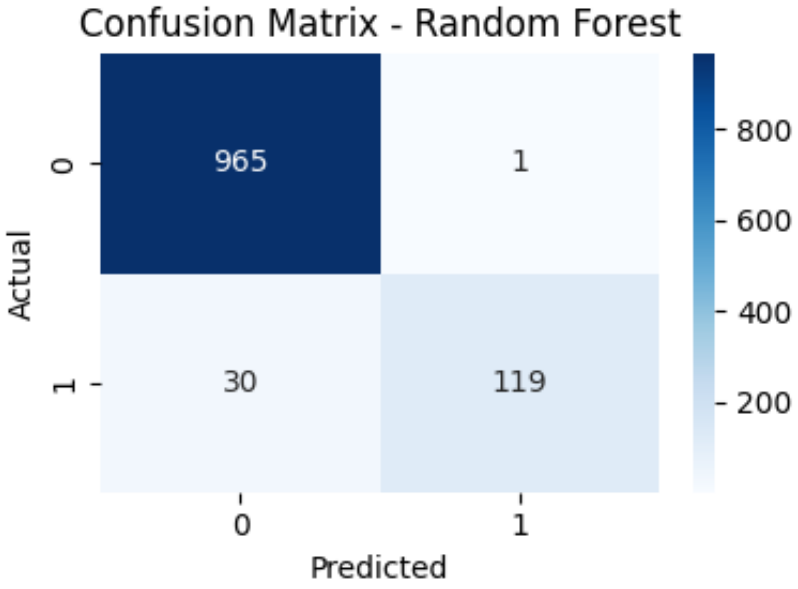



```
# Show confusion matrices
for name, metrics in results.items():
    plt.figure(figsize=(4, 3))
    sns.heatmap(metrics['Confusion Matrix'], annot=True, fmt='d', cmap='Blues')
    plt.title(f"Confusion Matrix - {name}")
    plt.xlabel("Predicted")
    plt.ylabel("Actual")
    plt.tight_layout()
```

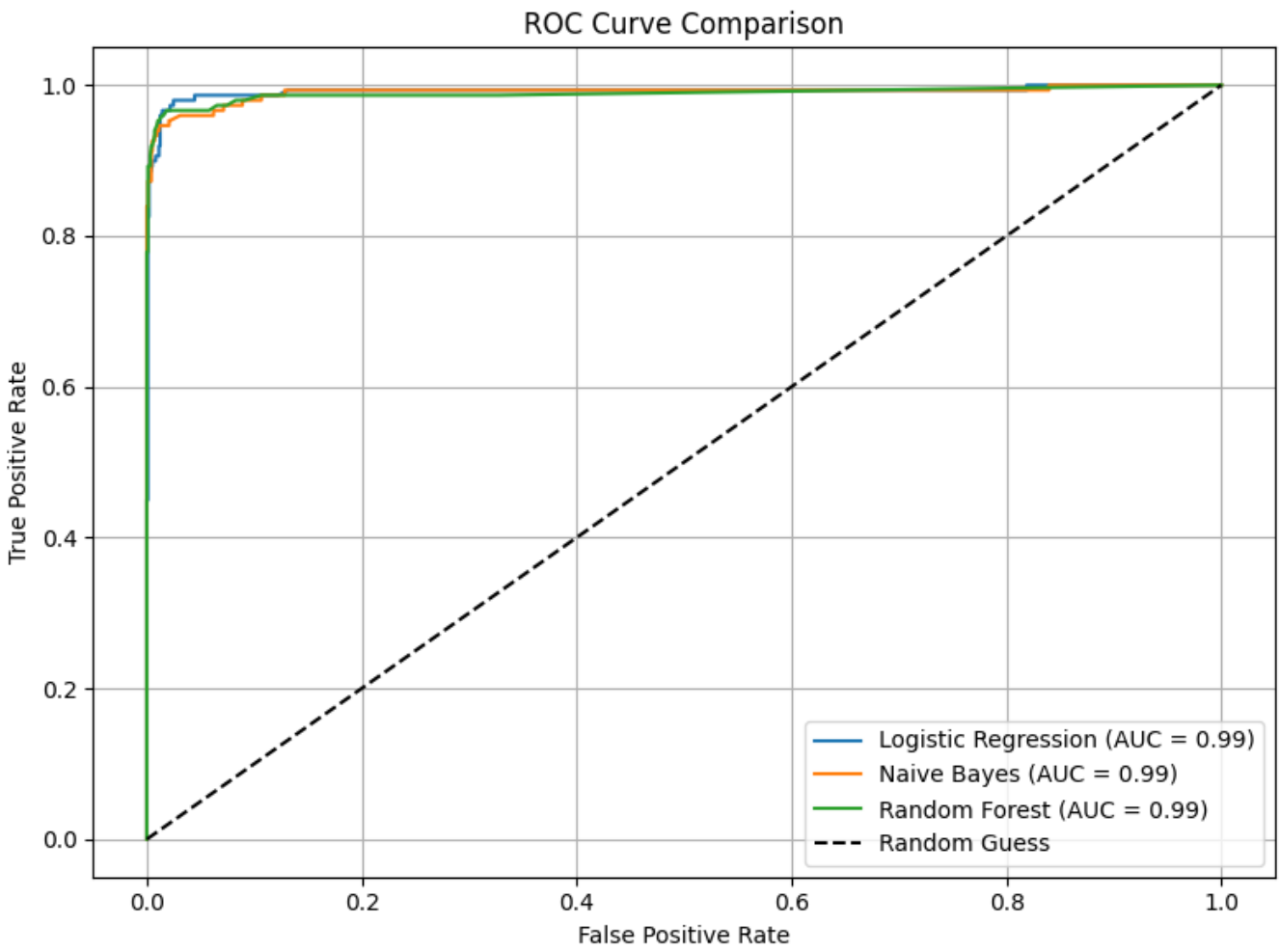
```
plt.show()
```


Confusion Matrix - Logistic Regression
965
1
40
109
Actual
Predicted
0
1
800
600
400
200


Confusion Matrix - Naive Bayes
966
0
31
118
Actual
Predicted
0
1
800
600
400
200
0


Confusion Matrix - Random Forest
965
1
30
119
Actual
Predicted
0
1
800
600
400
200

```
# Plot ROC Curves
plt.figure(figsize=(8, 6))
for name, metrics in results.items():
    plt.plot(metrics['FPR'], metrics['TPR'], label=f"{name} (AUC = {metrics['RO

plt.plot([0, 1], [0, 1], 'k--', label="Random Guess")
plt.xlabel("False Positive Rate")
plt.ylabel("True Positive Rate")
plt.title("ROC Curve Comparison")
plt.legend()
plt.grid(True)
plt.tight_layout()
plt.show()
```



```
# Support for real-time prediction
def predict_email_category(model_path, vectorizer_path, new_message):
    model = joblib.load(model_path)
    vectorizer = joblib.load(vectorizer_path)
    new_vector = vectorizer.transform([new_message])
    prediction = model.predict(new_vector)
    category = "Spam" if prediction[0] == 1 else "Ham"
    return category

# Example usage
example_text = "Congratulations! You've won a $1000 Walmart gift card. Go to h
predicted_label = predict_email_category("./logistic_regression_model.pkl", "t
print(f"Predicted label: {predicted_label}")
```

```
Predicted label: Spam
```