Capstone

Toxicity Modeling

##

1. IMPORTS & SETUP

##

In [3]:
```
import pandas as pd
import numpy as np
import ast

# For modeling
from sklearn.model_selection import train_test_split
from sklearn.linear_model import LogisticRegression
from sklearn.ensemble import RandomForestClassifier
from sklearn.svm import SVC
from xgboost import XGBClassifier
from sklearn.preprocessing import StandardScaler
from sklearn.metrics import classification_report, confusion_matrix, roc_auc_score, roc_curve
from sklearn.feature_extraction.text import TfidfVectorizer
from scipy.sparse import hstack, csr_matrix
from imblearn.over_sampling import SMOTE
import matplotlib.pyplot as plt
```

##

2. LOAD DATASET AND CLEAN THE DATASET

##

In [5]:
```
df = pd.read_csv("C:/Users/annaj/Desktop/Python/Capstone/toxicity_w_bert_and_correct_labels.csv")
```

In [6]:
```
pd.set_option('display.max_columns', None)
df
```

Out[6]:

	Unnamed: 0	index	unique_id	comment_text	toxic	severe_toxic	obscene	threat	insult	identity_hate	sentiment_score	toxic_word_count	
0	0	0	00001cee341fdb12	yo bitch ja rule is more succesful then you wi...	1	0	1	0	1	0	-0.051786	5	0.1590
1	1	1	0000247867823ef7	from rfc the title is fine as it is, imo.	0	0	0	0	0	0	0.416667	0	[('trust
2	2	2	00013b17ad220c46	" sources * zawe ashton on lapland / "	0	0	0	0	0	0	0.000000	0	[('fe 0
3	3	3	00017563c3f7919a	if you have a look back at the source, the inf...	0	0	0	0	0	0	0.000000	0	0.6666
4	4	4	00017695ad8997eb	i do not anonymously edit articles at all.	0	0	0	0	0	0	0.000000	0	[('fe 0
...	...	...	...	...	...	...	...	...	...	...	...	...	
153159	153159	153159	fffcd0960ee309b5	. i totally agree, this stuff is nothing but...	0	0	0	0	0	0	0.000000	0	
153160	153160	153160	fffd7a9a6eb32c16	throw from out field to home plate. does ...	0	0	0	0	0	0	0.325000	0	[('fe 0
153161	153161	153161	fffda9e8d6fafa9e	" okinotorishima categories i see your...	0	0	0	0	0	0	0.100000	0	
153162	153162	153162	fffe8f1340a79fc2	" ""one of the founding nations of the eu ...	0	0	0	0	0	0	0.047917	0	
153163	153163	153163	ffffce3fb183ee80	" stop already. your bullshit is not welcome...	1	0	0	0	1	0	0.025000	0	0.16666

153164 rows × 28 columns

In [7]:
```
# Check for missing values in each DataFrame
df.isnull().sum()
```

Out[7]:
```
Unnamed: 0            0
index                 0
unique_id             0
comment_text          9
toxic                 0
severe_toxic          0
obscene               0
threat                0
insult                0
identity_hate         0
sentiment_score       0
toxic_word_count      0
emotions              0
anger                 0
disgust               0
anticipation          0
fear                  0
surprise              0
positive              0
joy                   0
sadness               0
negative              0
trust                 0
anticipation.1        0
left_vocab_count      0
right_vocab_count     0
Text Length           0
bert_embedding       72
dtype: int64
```

In [8]:
```
# Handle missing values
df.dropna(inplace=True)
df.isnull().sum().sum()
```

Out[8]:
```
0
```

In [9]:
```
# Drop unnecessary columns
df.drop(columns=['Unnamed: 0', 'index', 'unique_id'], inplace=True)
```

In [10]:
```
print(f"Columns in df:")
print(df.columns.tolist())
```

```
Columns in df:
['comment_text', 'toxic', 'severe_toxic', 'obscene', 'threat', 'insult', 'identity_hate', 'sentiment_score', 'toxic_word_count', 'emotions', 'anger',
'disgust', 'anticipation', 'fear', 'surprise', 'positive', 'joy', 'sadness', 'negative', 'trust', 'anticipation.1', 'left_vocab_count', 'right_vocab_co
unt', 'Text Length', 'bert_embedding']
```

In [18]:
```
# Quick statistical summaries
print("Summary of df:")
```

```
display(df.describe())
```

Summary of df:

	toxic	severe_toxic	obscene	threat	insult	identity_hate	sentiment_score	toxic_word_count	anger	disgust	15
count	153083.000000	153083.000000	153083.000000	153083.000000	153083.00000	153083.000000	153083.000000	153083.000000	153083.000000	153083.000000	
mean	0.122123	0.003227	0.078755	0.001731	0.06341	0.009544	0.034947	0.608983	0.019143	0.020364	
std	0.327429	0.056715	0.269356	0.041570	0.24370	0.097226	0.263585	11.156536	0.073552	0.080076	
min	0.000000	0.000000	0.000000	0.000000	0.00000	0.000000	-1.000000	0.000000	0.000000	0.000000	
25%	0.000000	0.000000	0.000000	0.000000	0.00000	0.000000	-0.025591	0.000000	0.000000	0.000000	
50%	0.000000	0.000000	0.000000	0.000000	0.00000	0.000000	0.000000	0.000000	0.000000	0.000000	
75%	0.000000	0.000000	0.000000	0.000000	0.00000	0.000000	0.162500	0.000000	0.000000	0.000000	
max	1.000000	1.000000	1.000000	1.000000	1.00000	1.000000	1.000000	1000.000000	1.000000	1.000000	

Merge all toxicity labels into a single "toxic" column

In [21]:
```
# Merge all toxicity labels into a single "toxic" column
df['toxic'] = df[['toxic', 'severe_toxic', 'obscene', 'threat', 'insult', 'identity_hate']].max(axis=1)

# Drop the other columns as they are now merged
df.drop(columns=['severe_toxic', 'obscene', 'threat', 'insult', 'identity_hate'], inplace=True)

print("Updated Columns:", df.columns)
```

```
Updated Columns: Index(['comment_text', 'toxic', 'sentiment_score', 'toxic_word_count',
       'emotions', 'anger', 'disgust', 'anticipation', 'fear', 'surprise',
       'positive', 'joy', 'sadness', 'negative', 'trust', 'anticipation.1',
       'left_vocab_count', 'right_vocab_count', 'Text Length',
       'bert_embedding'],
      dtype='object')
```

##

3.1. CONVERT BERT EMBEDDINGS FROM STRING TO FLOATS [X_bert]

##

In [26]:
```
# 1) Convert BERT embeddings from string ("[0.12, -0.33, ...]") to a list of floats
df['bert_embedding'] = df['bert_embedding'].apply(ast.literal_eval)

# 2) Convert BERT embeddings into a NumPy array
```

```
X_bert = np.array(df['bert_embedding'].tolist())
print("BERT embedding shape:", X_bert.shape)
```

```
BERT embedding shape: (153083, 312)
```

Save this dataframe as a new csv file

In [25]:
```
# df.to_csv("toxicity_w_bert_Feb11.csv", index=False)
```

##

3.2. TF-IDF vectorization on comment_text and Combined with Bert Embedding [X_combined]

##

In [32]:
```
# 3) TF-IDF vectorization on comment_text
tfidf = TfidfVectorizer(max_features=5000, stop_words='english')
X_tfidf = tfidf.fit_transform(df['comment_text'].astype(str))
print("TF-IDF shape:", X_tfidf.shape)  # e.g. (num_samples, 5000)

# 4) Combine TF-IDF and BERT embeddings into one feature matrix
X_combined = hstack([X_tfidf, csr_matrix(X_bert)])
print("Combined feature shape:", X_combined.shape)
```

```
TF-IDF shape: (153083, 5000)
Combined feature shape: (153083, 5312)
```

##

4. Feature Column and Target Column

##

In [60]:
```
target_col = 'toxic'
X = X_tfidf
# X = X_combined # combination of two columns => 'bert_embedding' + 'comment_text'
y = df[target_col].values
```

In [62]:
```
print(X.shape)
```

```
(153083, 5000)
```

##

5.1. Train, Validate and Test Split, TRAIN THE MODEL AND EVALUATE

##

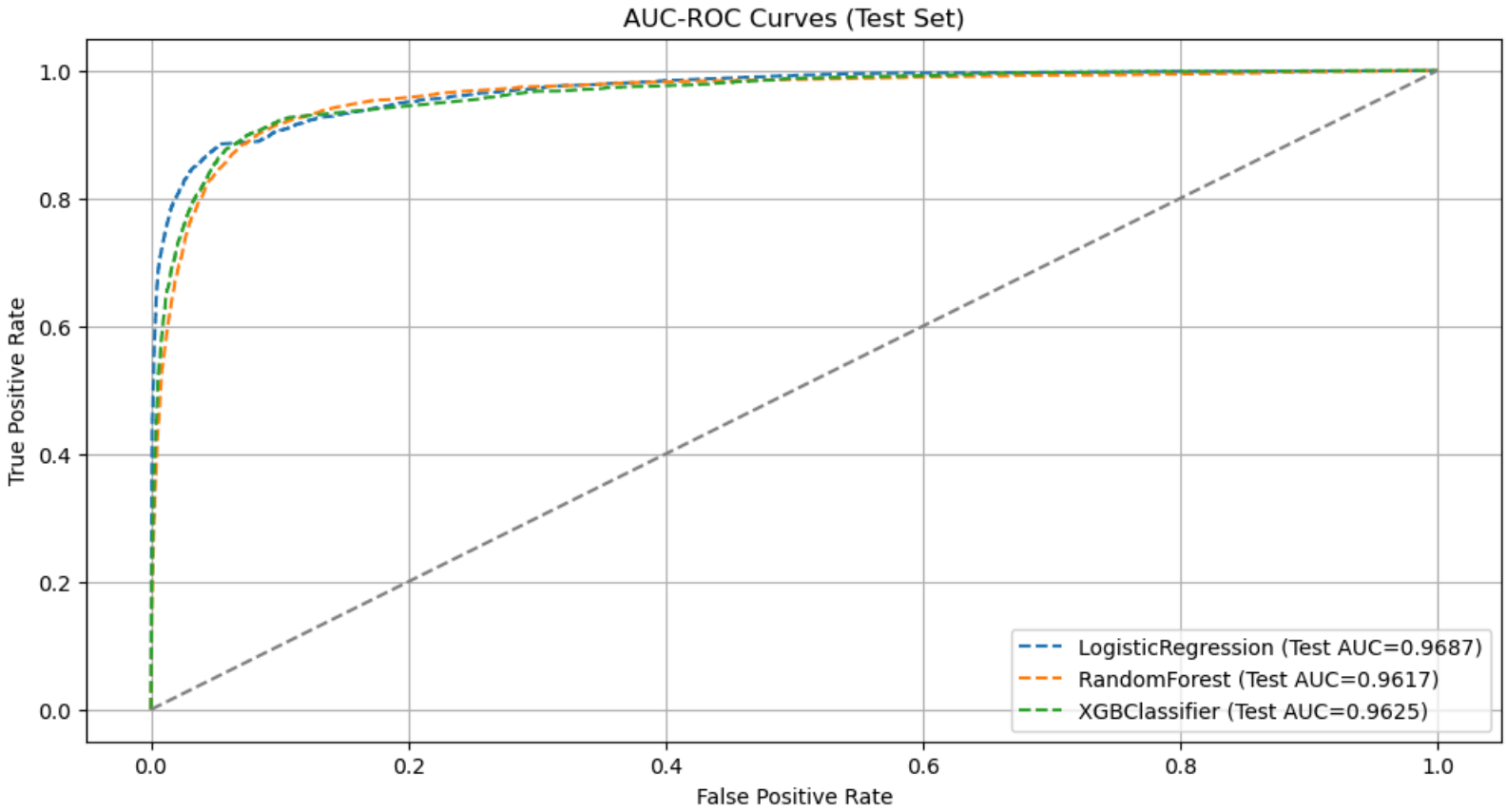
Train & Validation Sets

In [64]:
```
# Step 1: Split into Train (80%) and Test (20%)
X_train, X_test, y_train, y_test = train_test_split(
    X, y, test_size=0.2, random_state=42, stratify=y
)

# Step 2: Apply SMOTE on the training set
smote = SMOTE(random_state=42)
X_train_resampled, y_train_resampled = smote.fit_resample(X_train, y_train)

# Define models
models = {
    "LogisticRegression": LogisticRegression(
        random_state=42, max_iter=1000
    ),
    "RandomForest": RandomForestClassifier(
        n_estimators=100, random_state=42, bootstrap=True, n_jobs=-1
    ),
    "XGBClassifier": XGBClassifier(
        eval_metric='logloss', random_state=42, n_jobs=-1
    )
}

# Train and Evaluate Models on Test Set
plt.figure(figsize=(12, 6))

for model_name, model in models.items():
    print(f"=== Model: {model_name} ===")

    # Train model on resampled training set
    model.fit(X_train_resampled, y_train_resampled)

    # Predict on Test Set
    y_test_pred = model.predict(X_test)
    y_test_pred_proba = model.predict_proba(X_test)[:, 1]

    # Evaluation
    print(f"\nTest Set Metrics for {model_name}:")
    print(classification_report(y_test, y_test_pred))
    print("Confusion Matrix (Test Set):")
    print(confusion_matrix(y_test, y_test_pred))

    # AUC-ROC
    auc_roc_test = roc_auc_score(y_test, y_test_pred_proba)
```

```
    print(f"AUC-ROC Score (Test Set): {auc_roc_test:.4f}")

    # ROC Curve
    fpr_test, tpr_test, _ = roc_curve(y_test, y_test_pred_proba)
    plt.plot(fpr_test, tpr_test, linestyle="--", label=f"{model_name} (Test AUC={auc_roc_test:.4f})")

    print("\n" + "-"*50 + "\n")

# Finalize Plot
plt.plot([0, 1], [0, 1], linestyle="--", color="gray")
plt.xlabel("False Positive Rate")
plt.ylabel("True Positive Rate")
plt.title("AUC-ROC Curves (Test Set)")
plt.legend()
plt.grid(True)
plt.show()
```

```
=== Model: LogisticRegression ===

Test Set Metrics for LogisticRegression:
              precision    recall  f1-score   support

           0       0.98      0.91      0.94     26825
           1       0.57      0.90      0.70      3792

    accuracy                           0.90     30617
   macro avg       0.78      0.90      0.82     30617
weighted avg       0.93      0.90      0.91     30617

Confusion Matrix (Test Set):
[[24279  2546]
 [  372  3420]]
AUC-ROC Score (Test Set): 0.9687

--------------------------------------------------

=== Model: RandomForest ===

Test Set Metrics for RandomForest:
              precision    recall  f1-score   support

           0       0.98      0.95      0.96     26825
           1       0.71      0.84      0.77      3792

    accuracy                           0.94     30617
   macro avg       0.84      0.89      0.86     30617
weighted avg       0.94      0.94      0.94     30617

Confusion Matrix (Test Set):
[[25504  1321]
 [  618  3174]]
AUC-ROC Score (Test Set): 0.9617

--------------------------------------------------

=== Model: XGBClassifier ===

Test Set Metrics for XGBClassifier:
              precision    recall  f1-score   support

           0       0.98      0.95      0.96     26825
           1       0.70      0.86      0.77      3792

    accuracy                           0.94     30617
   macro avg       0.84      0.91      0.87     30617
weighted avg       0.95      0.94      0.94     30617

Confusion Matrix (Test Set):
[[25408  1417]
```

```
 [  515  3277]]
AUC-ROC Score (Test Set): 0.9625

--------------------------------------------------
```



5.2. PREDICT ON TEST SET AND EVALUATE

TEST set

In [66]:
```
# === Evaluate Best Model on the Test Set ===
print("=== Final Test Evaluation for Best Model ===")
best_model = models["RandomForest"]
print(f"Model: {best_model.__class__.__name__}")
```

```
=== Final Test Evaluation for Best Model ===
Model: RandomForestClassifier
```

In [52]:
```
"""
# Predict on Test Set
y_test_pred = best_model.predict(X_test)
y_test_pred_proba = best_model.predict_proba(X_test)[:, 1]

# Print Test Metrics
print(classification_report(y_test, y_test_pred))
print("Confusion Matrix (Test Set):")
print(confusion_matrix(y_test, y_test_pred))

# Compute AUC-ROC
auc_roc_test = roc_auc_score(y_test, y_test_pred_proba)
print(f"AUC-ROC Score (Test Set): {auc_roc_test:.4f}")

# Plot ROC Curve
fpr_test, tpr_test, _ = roc_curve(y_test, y_test_pred_proba)
plt.figure(figsize=(8, 6))
plt.plot(fpr_test, tpr_test, label=f"{best_model.__class__.__name__} (AUC={auc_roc_test:.4f})")
plt.plot([0, 1], [0, 1], linestyle="--", color="gray")  # Diagonal reference line
plt.xlabel("False Positive Rate")
plt.ylabel("True Positive Rate")
plt.title("AUC-ROC Curve (Test Set)")
plt.legend()
plt.grid(True)
plt.show()
"""
```

Out[52]:
```
'\n# Predict on Test Set\ny_test_pred = best_model.predict(X_test)\ny_test_pred_proba = best_model.predict_proba(X_test)[:, 1]\n\n# Print Test Metric
s\nprint(classification_report(y_test, y_test_pred))\nprint("Confusion Matrix (Test Set):")\nprint(confusion_matrix(y_test, y_test_pred))\n\n# Comput
e AUC-ROC\nauc_roc_test = roc_auc_score(y_test, y_test_pred_proba)\nprint(f"AUC-ROC Score (Test Set): {auc_roc_test:.4f}")\n\n# Plot ROC Curve\nfpr_t
est, tpr_test, _ = roc_curve(y_test, y_test_pred_proba)\nplt.figure(figsize=(8, 6))\nplt.plot(fpr_test, tpr_test, label=f"{best_model.__class__.__nam
e__} (AUC={auc_roc_test:.4f})")\nplt.plot([0, 1], [0, 1], linestyle="--", color="gray")  # Diagonal reference line\nplt.xlabel("False Positive Rate")
\nplt.ylabel("True Positive Rate")\nplt.title("AUC-ROC Curve (Test Set)")\nplt.legend()\nplt.grid(True)\nplt.show()\n'
```

Saving Model

In [70]:
```
import zipfile
import joblib
# Save the trained logistic regression model
joblib.dump(models["RandomForest"], "toxicity_model.pkl")
print("RandomForest model saved as 'toxicity_model.pkl'")

# Save the TF-IDF vectorizer used during training
joblib.dump(tfidf, "Preprocessing.pkl")
print("TF-IDF vectorizer saved as 'Preprocessing.pkl'")


# Define filenames
model_filename = "toxicity_model.pkl"
vectorizer_filename = "Preprocessing.pkl"
```

```
zip_filename = "toxicity_model_pack.zip"

# Create zip file
with zipfile.ZipFile(zip_filename, 'w') as zipf:
    zipf.write(model_filename)
    zipf.write(vectorizer_filename)

print(f"Created zip file: {zip_filename}")
```

```
RandomForest model saved as 'toxicity_model.pkl'
TF-IDF vectorizer saved as 'Preprocessing.pkl'
Created zip file: toxicity_model_pack.zip
```

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