## My Details

**Name** : `Rohan Ingle`

**PRN** : `22070126047`

**Batch** : `AIML A2 (2022-2026)`

## GitHub Link : https://github.com/Rohan-ingle/Natural-Language-Processing

## Importing Required Libraries

In [2]:

```python
import warnings

import re
import pandas as pd
import cudf
import cupy as cp

from sklearn.model_selection import GridSearchCV
from sklearn.linear_model import LogisticRegression
from sklearn.feature_extraction.text import CountVectorizer, TfidfVectorizer
from sklearn.ensemble import RandomForestClassifier
from sklearn.svm import SVC
from sklearn.preprocessing import LabelEncoder
from sklearn.metrics import classification_report, confusion_matrix

from scipy.sparse import csr_matrix
from cuml.svm import SVC as cuSVC
from cuml.ensemble import RandomForestClassifier as cuRF

import nltk
from nltk.corpus import stopwords
from nltk.tokenize import word_tokenize
from nltk.stem import WordNetLemmatizer

import seaborn as sns
import matplotlib.pyplot as plt



warnings.filterwarnings("ignore")
```

In [2]:

```python
nltk.download('all')
```

```
[nltk_data] Downloading collection 'all'
[nltk_data]    |
[nltk_data]    | Downloading package abc to
[nltk_data]    |     /home/speedindeed1/nltk_data...
[nltk_data]    |   Package abc is already up-to-date!
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```

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[nltk_data]    | Downloading package webtext to
[nltk_data]    |     /home/speedindeed1/nltk_data...
[nltk_data]    |   Package webtext is already up-to-date!
[nltk_data]    | Downloading package wmt15_eval to
[nltk_data]    |     /home/speedindeed1/nltk_data...
[nltk_data]    |   Package wmt15_eval is already up-to-date!
[nltk_data]    | Downloading package word2vec_sample to
[nltk_data]    |     /home/speedindeed1/nltk_data...
[nltk_data]    |   Package word2vec_sample is already up-to-date!
[nltk_data]    | Downloading package wordnet to
[nltk_data]    |     /home/speedindeed1/nltk_data...
[nltk_data]    |   Package wordnet is already up-to-date!
[nltk_data]    | Downloading package wordnet2021 to
[nltk_data]    |     /home/speedindeed1/nltk_data...
[nltk_data]    |   Package wordnet2021 is already up-to-date!
[nltk_data]    | Downloading package wordnet2022 to
[nltk_data]    |     /home/speedindeed1/nltk_data...
[nltk_data]    |   Package wordnet2022 is already up-to-date!
[nltk_data]    | Downloading package wordnet31 to
[nltk_data]    |     /home/speedindeed1/nltk_data...
[nltk_data]    |   Package wordnet31 is already up-to-date!
[nltk_data]    | Downloading package wordnet_ic to
[nltk_data]    |     /home/speedindeed1/nltk_data...
[nltk_data]    |   Package wordnet_ic is already up-to-date!
[nltk_data]    | Downloading package words to
[nltk_data]    |     /home/speedindeed1/nltk_data...
[nltk_data]    |   Package words is already up-to-date!
```

```
[nltk_data]    | Downloading package ycoe to
[nltk_data]    |     /home/speedindeed1/nltk_data...
[nltk_data]    |   Package ycoe is already up-to-date!
[nltk_data]    |
[nltk_data]  Done downloading collection all
```

Out[2]:
```
True
```

## Loading Datasets into a `DataFrame`

In [3]:
```python
train = pd.read_csv('train.csv')
test = pd.read_csv('test.csv')
```

**Baisc Preprocessing**

- Lets select only necessary features

In [4]:
```python
train["Genre"].unique()
```

Out[4]:
```
array(['Rock', 'Metal', 'Pop', 'Indie', 'R&B', 'Folk', 'Electronic',
       'Jazz', 'Hip-Hop', 'Country'], dtype=object)
```

In [5]:
```python
test["Genre"].unique()
```

Out[5]:
```
array(['Hip-Hop', 'Indie', 'Metal', 'Pop', 'Country', 'Jazz', 'Rock',
       'R&B', 'Electronic', 'Folk'], dtype=object)
```

**Lets rename `Hip-Hop` to `HH` for simplicity**

In [4]:
```python
train['Genre'] = train['Genre'].str.replace('Hip-Hop', 'HH')
test['Genre'] = test['Genre'].str.replace('Hip-Hop', 'HH')
```

In [7]:
```python
train["Genre"].unique()
```

Out[7]:
```
array(['Rock', 'Metal', 'Pop', 'Indie', 'R&B', 'Folk', 'Electronic',
       'Jazz', 'HH', 'Country'], dtype=object)
```

In [8]:
```python
test["Genre"].unique()
```

Out[8]:
```
array(['HH', 'Indie', 'Metal', 'Pop', 'Country', 'Jazz', 'Rock', 'R&B',
       'Electronic', 'Folk'], dtype=object)
```

**Here we will only select `English` i.e. `'en'` songs only**

In [5]:
```python
genre = ['Rock', 'Jazz', 'HH', 'Metal', 'Country']
train = train[(train['Genre'].isin(genre)) & (train['Language'] == 'en')]
```

In [10]:
```python
train.describe()
```

Out[10]:

| | Artist | Song | Genre | Language | Lyrics |
|---|---|---|---|---|---|
| **count** | 143720 | 143719 | 143720 | 143720 | 143720 |
| **unique** | 6193 | 86662 | 5 | 1 | 127917 |
| **top** | elvis presley | home | Rock | en | My heart is sad and lonely\nFor you I sigh, fo... |
| **freq** | 1598 | 87 | 107145 | 143720 | 83 |

**Get insights on duplicated values**

In [6]:
```python
duplicates = train[train['Lyrics'].duplicated(keep=False)].sort_values(by='Lyrics')
```

In [12]:
```python
duplicates
```

Out[12]:

| | Artist | Song | Genre | Language | Lyrics |
|---|---|---|---|---|---|
| **12587** | cowboy junkies | take me | Rock | en | \n\nwhere the thunder meets the light\nTake me... |
| **12469** | cowboy junkies | take me | Rock | en | \n\nwhere the thunder meets the light\nTake me... |
| **30** | 12 stones | back up | Rock | en | \nI hear the words you say to me\nI see the wa... |
| **9** | 12 stones | back up | Rock | en | \nI hear the words you say to me\nI see the wa... |
| **245656** | george strait | lovesick blues | Rock | en | \nI'm in love,\nI'm in love,\nI'm in love with... |
| **...** | ... | ... | ... | ... | ... |
| **22528** | george michael | you've changed | Rock | en | you've changed\nthat sparkle in your eyes has ... |
| **9402** | bush | dead meat | Rock | en | your dead meat\nyour dead meat\nyour dead meat... |
| **9431** | bush | dead meat | Rock | en | your dead meat\nyour dead meat\nyour dead meat... |
| **11969** | coheed and cambria | a favor house atlantic | Metal | en | your eyes tell the stories of a day you wish y... |
| **11963** | coheed and cambria | a favor house atlantic | Metal | en | your eyes tell the stories of a day you wish y... |

26207 rows × 5 columns

In [13]:

```
duplicates_by_genre = train[train.duplicated(subset=['Lyrics', 'Genre'], keep=False)]

duplicate_counts_by_genre = duplicates_by_genre.groupby('Genre').size()

print(duplicate_counts_by_genre)
```

```
Genre
Jazz      6020
Metal     2495
Rock     16985
dtype: int64
```

In [14]:

```
train["Genre"].unique()
```

Out[14]:

```
array(['Rock', 'Metal', 'Jazz', 'HH', 'Country'], dtype=object)
```

In [15]:

```
test["Genre"].unique()
```

Out[15]:

```
array(['HH', 'Indie', 'Metal', 'Pop', 'Country', 'Jazz', 'Rock', 'R&B',
       'Electronic', 'Folk'], dtype=object)
```

In [16]:

```
test.describe()
```

Out[16]:

| | Song year | Track_id |
|---|---|---|
| **count** | 7935.000000 | 7935.000000 |
| **mean** | 2007.943793 | 13262.260744 |
| **std** | 5.201110 | 7612.173049 |
| **min** | 1970.000000 | 3.000000 |
| **25%** | 2006.000000 | 6708.500000 |
| **50%** | 2007.000000 | 13169.000000 |
| **75%** | 2011.000000 | 19840.000000 |
| **max** | 2016.000000 | 26446.000000 |

**lets define our `stop_words` and `lemmatizer`**

In [7]:

```
stop_words = set(stopwords.words('english'))
lemmatizer = WordNetLemmatizer()
```

**Here we will make a preprocessing function to clean the lyrics string and also tokenize it**

In [8]:

```
def text_cleaner(text):
    text = re.sub(r'\@w+|\#','', text)
    text = re.sub(r'[^A-Za-z\s]', '', text)
    text = text.lower()
    tokens = word_tokenize(text)
    tokens = [lemmatizer.lemmatize(word) for word in tokens if word not in stop_words]
    return ' '.join(tokens)
```

In [9]:

```
train['Lyrics'] = train['Lyrics'].apply(text_cleaner)
```

In [10]:

```
test = test[(test['Genre'].isin(genre))]
test['Lyrics'] = test['Lyrics'].apply(text_cleaner)
```

**Lets check how it affected `Lyrics` column**

In [21]:
```
train.head()
```

Out[21]:

| | Artist | Song | Genre | Language | Lyrics |
|---|---|---|---|---|---|
| **0** | 12 stones | world so cold | Rock | en | start pain followed hate fueled endless questi... |
| **1** | 12 stones | broken | Rock | en | freedom alone alone patiently waiting phone ho... |
| **2** | 12 stones | 3 leaf loser | Rock | en | biting hand feed lying voice inside reach beg ... |
| **3** | 12 stones | anthem for the underdog | Rock | en | say know cant imagine wait across line thought... |
| **4** | 12 stones | adrenaline | Rock | en | heart beating faster cant control feeling anym... |

In [22]:
```
test.head()
```

Out[22]:

| | Song | Song year | Artist | Genre | Lyrics | Track_id |
|---|---|---|---|---|---|---|
| **0** | craftsmanship | 2005 | buck-65 | HH | folk spend day daydreaming finding clue whole ... | 8294 |
| **2** | riot | 2013 | bullet-for-my-valentine | Metal | ready time war well break fucking door smash w... | 3301 |
| **4** | believe-in-a-dollar | 2012 | cassidy | HH | believe magic young girl heart music free when... | 16797 |
| **5** | mama-bake-a-pie-daddy-kill-a-chicken | 2007 | bobby-bare | Country | people starin wheel ramp toward plane war ive ... | 1251 |
| **6** | thinking-about-you | 2007 | bill-monroe | Country | sigh hour away think love yesterday know shes ... | 25217 |

**Now we are going to encode our dataset, define vectorizers and models and transform data by vectorizing it**

- We will use `fit_transform` on training dataset and `transform` on testing

In [11]:
```
encode_label = LabelEncoder()
train['Genre'] = encode_label.fit_transform(train['Genre'])
test['Genre'] = encode_label.transform(test['Genre'])
```

In [12]:
```
countVec = CountVectorizer(max_features=50000)
tfidfVec = TfidfVectorizer(max_features=50000)
```

In [13]:
```
X_train_countVec = countVec.fit_transform(train['Lyrics'])
X_test_countVec = countVec.transform(test['Lyrics'])

X_train_tfidfVec = tfidfVec.fit_transform(train['Lyrics'])
X_test_tfidfVec = tfidfVec.transform(test['Lyrics'])
```

In [14]:
```
y_train = train['Genre']
y_test = test['Genre']
```

## Training

**We will make a function to train models**

In [15]:
```
def train(model, X_train, X_test, y_train, y_test, model_name, vectorizer):
    model.fit(X_train, y_train)
    y_pred = model.predict(X_test)

    print(f"\nClassification Report for {model_name} with {vectorizer}:")
    print(classification_report(y_test, y_pred, target_names=encode_label.classes_))

    cm = confusion_matrix(y_test, y_pred)
    sns.heatmap(cm, annot=True, fmt='d', cmap='Blues', xticklabels=encode_label.classes_, yticklabels=encode_la
    plt.title(f'Confusion Matrix for {model_name} with {vectorizer}')
    plt.xlabel('Predicted')
    plt.ylabel('True')
    plt.show()
```

In [28]:
```
lr = LogisticRegression(class_weight='balanced', max_iter=10000)
```

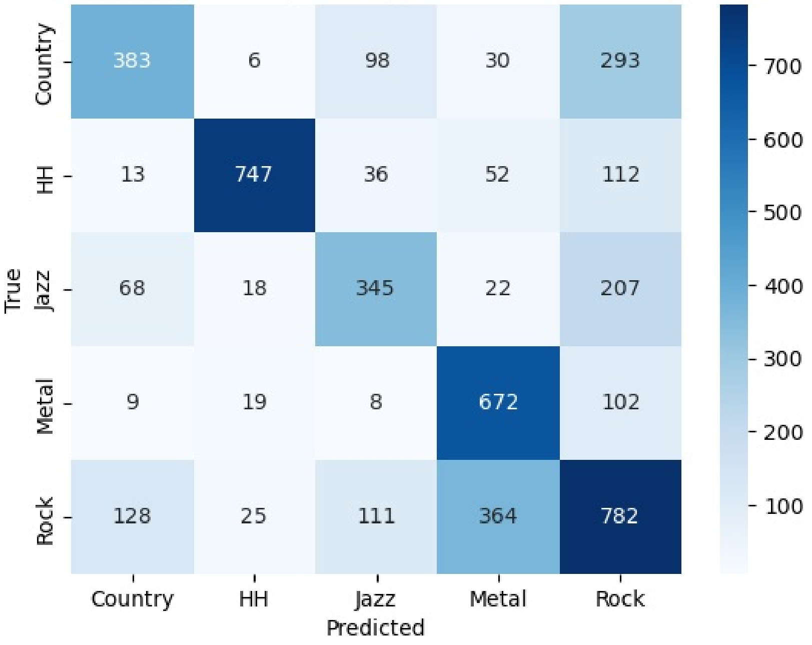
In [29]:
```
train(lr, X_train_tfidfVec, X_test_tfidfVec, y_train, y_test, 'logisticRegression','Tfidf Vectorizer')
```

```
Classification Report for logisticRegression with Tfidf Vectorizer:
              precision    recall  f1-score   support

     Country       0.64      0.47      0.54       810
          HH       0.92      0.78      0.84       960
        Jazz       0.58      0.52      0.55       660
       Metal       0.59      0.83      0.69       810
        Rock       0.52      0.55      0.54      1410

    accuracy                           0.63      4650
   macro avg       0.65      0.63      0.63      4650
weighted avg       0.64      0.63      0.63      4650
```

Confusion Matrix for logisticRegression with Tfidf Vectorizer



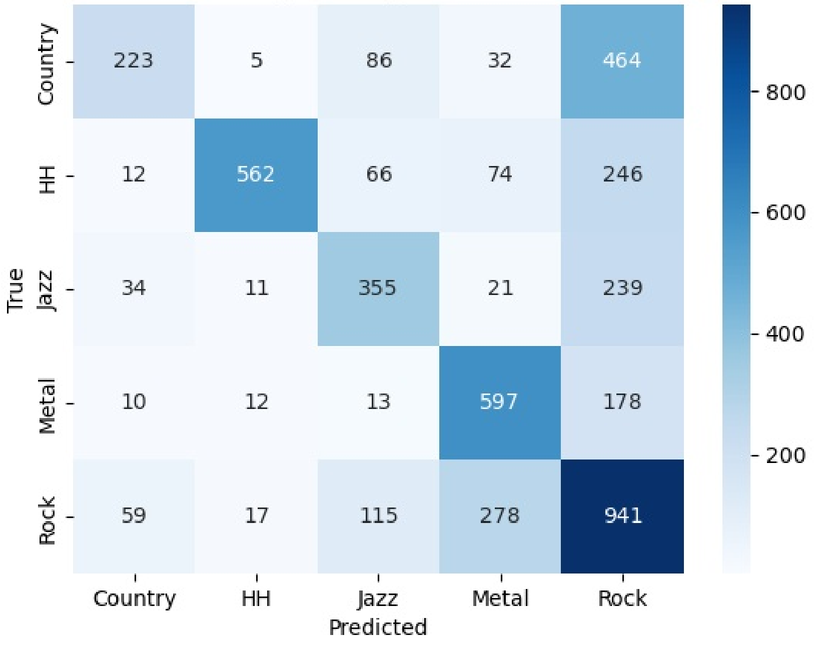
```
In [30]: train(lr, X_train_countVec, X_test_countVec, y_train, y_test,"Logistic Regression", 'Count Vectorizer')
```

```
Classification Report for Logistic Regression with Count Vectorizer:
              precision    recall  f1-score   support

     Country       0.66      0.28      0.39       810
          HH       0.93      0.59      0.72       960
        Jazz       0.56      0.54      0.55       660
       Metal       0.60      0.74      0.66       810
        Rock       0.46      0.67      0.54      1410

    accuracy                           0.58      4650
   macro avg       0.64      0.56      0.57      4650
weighted avg       0.63      0.58      0.57      4650
```

Confusion Matrix for Logistic Regression with Count Vectorizer



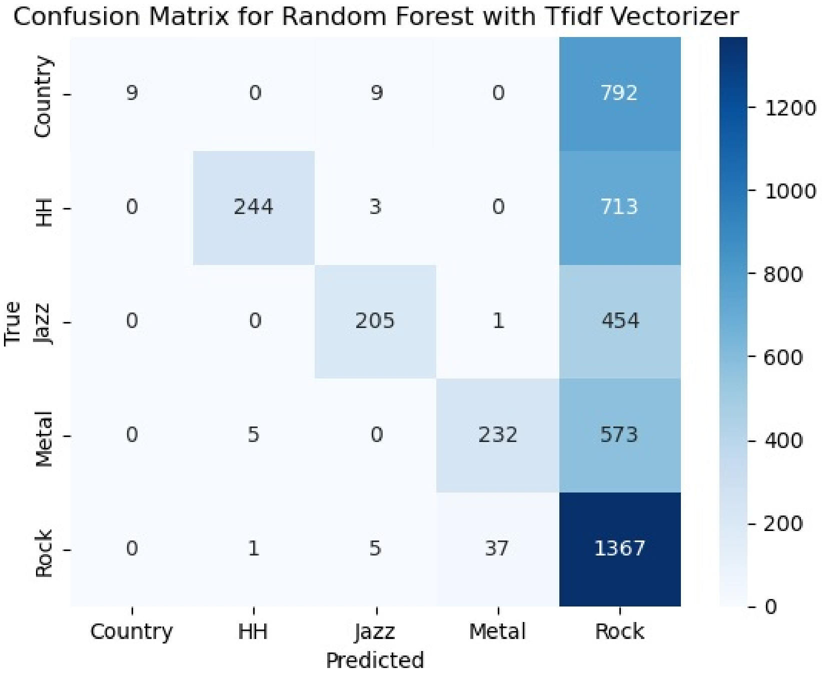
```
In [31]: rf = RandomForestClassifier(class_weight='balanced')
```

```
In [32]: train(rf, X_train_tfidfVec, X_test_tfidfVec, y_train, y_test,'Random Forest','Tfidf Vectorizer')
```

```
Classification Report for Random Forest with Tfidf Vectorizer:
              precision    recall  f1-score   support

     Country       1.00      0.01      0.02       810
          HH       0.98      0.25      0.40       960
        Jazz       0.92      0.31      0.46       660
       Metal       0.86      0.29      0.43       810
        Rock       0.35      0.97      0.51      1410

    accuracy                           0.44      4650
   macro avg       0.82      0.37      0.37      4650
weighted avg       0.76      0.44      0.38      4650
```

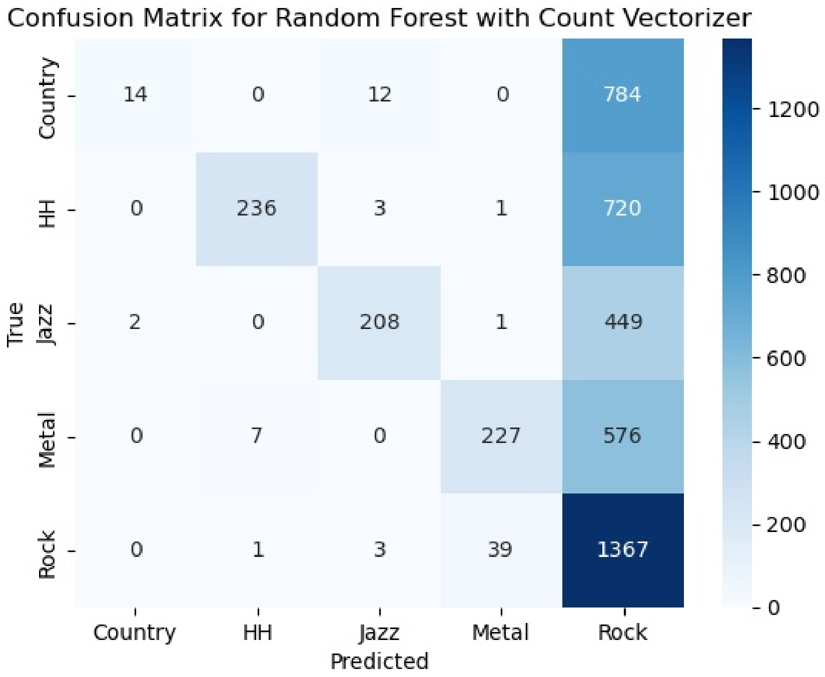

Confusion Matrix for Random Forest with Tfidf Vectorizer

```
In [33]: train(rf, X_train_countVec, X_test_countVec, y_train, y_test,'Random Forest','Count Vectorizer')
```

```
Classification Report for Random Forest with Count Vectorizer:
              precision    recall  f1-score   support

     Country       0.88      0.02      0.03       810
          HH       0.97      0.25      0.39       960
        Jazz       0.92      0.32      0.47       660
       Metal       0.85      0.28      0.42       810
        Rock       0.35      0.97      0.52      1410

    accuracy                           0.44      4650
   macro avg       0.79      0.37      0.37      4650
weighted avg       0.74      0.44      0.38      4650
```


Confusion Matrix for Random Forest with Count Vectorizer

## Using cuML to train SVC on GPU to improve training time

**But first we need to convert data to support cuML library and models**

- Converting to csr_matrix ensures that sparse data, like word vectors from CountVectorizer or TF-IDF, is stored efficiently by keeping only non-zero values. This reduces memory usage and speeds up operations on large datasets.
- Switching to float32 cuts memory usage in half compared to float64. This format is more compatible with GPU-accelerated libraries like CuPy, offering a good balance between precision and performance.
- CuPy allows data to be processed on NVIDIA GPUs, speeding up computation for large datasets and complex operations. By converting to CuPy's sparse format, you take full advantage of parallel GPU processing for faster model training.

In [16]:
```
X_train_count_float32_csrMatrix = csr_matrix(X_train_countVec, dtype=cp.float32)
X_test_count_float32_csrMatrix = csr_matrix(X_test_countVec, dtype=cp.float32)
```

In [ ]:
```
X_train_tfidf_float32_csrMatrix = csr_matrix(X_train_tfidfVec, dtype=cp.float32)
X_test_tfidf_float32_csrMatrix = csr_matrix(X_test_tfidfVec, dtype=cp.float32)
```

In [ ]:
```
X_train_count_cupy = cp.sparse.csr_matrix(X_train_count_float32_csrMatrix)
X_test_count_cupy = cp.sparse.csr_matrix(X_test_count_float32_csrMatrix)
```

In [ ]:
```
X_train_tfidf_cupy = cp.sparse.csr_matrix(X_train_tfidf_float32_csrMatrix)
X_test_tfidf_cupy = cp.sparse.csr_matrix(X_test_tfidf_float32_csrMatrix)
```

In [ ]:
```
y_train_cupy = cp.array(y_train.to_numpy(), dtype=cp.int32)
y_test_cupy = cp.array(y_test.to_numpy(), dtype=cp.int32)
```

**Here we will make a function to train SVC models using cuML**

In [17]:

```
def cuML_train(model, X_train, X_test, y_train, y_test, model_name, vectorizer_name):
    model.fit(X_train, y_train)
    y_pred = model.predict(X_test)

    print(f"\nClassification Report for {model_name} with {vectorizer_name}:")
    print(classification_report(cp.asnumpy(y_test), cp.asnumpy(y_pred), target_names=encode_label.classes_))

    confusionMatrix = confusion_matrix(cp.asnumpy(y_test), cp.asnumpy(y_pred))
    sns.heatmap(confusionMatrix, annot=True, fmt='d', cmap='Blues', xticklabels=encode_label.classes_, yticklabe
    plt.title(f'Confusion Matrix for {model_name} with {vectorizer_name}')
    plt.xlabel('Predicted')
    plt.ylabel('True')
    plt.show()
```

**Defining model**

In [18]:

```
SVC_cuML = cuSVC(kernel = "rbf", probability=True, class_weight='balanced')
```

In [37]:

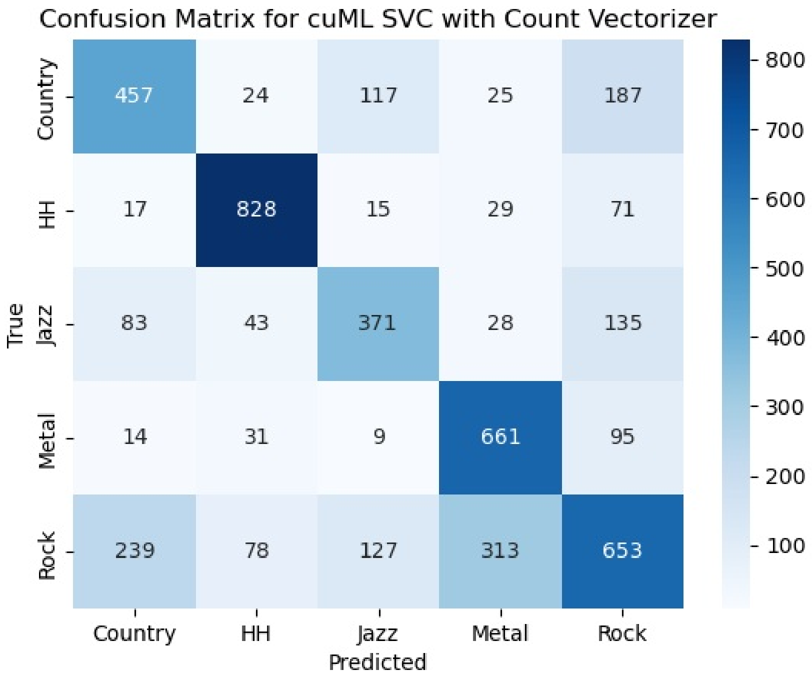
```
cuML_train(SVC_cuML, X_train_count_cupy, X_test_count_cupy, y_train_cupy, y_test_cupy, 'cuML SVC', 'Count Vecto
```

```
[W] [05:00:58.749077] Sample weights are currently ignored for multi class classification
[W] [05:02:38.408955] Sample weights are currently ignored for multi class classification
[W] [05:04:18.159253] Sample weights are currently ignored for multi class classification
[W] [05:05:58.520177] Sample weights are currently ignored for multi class classification
[W] [05:07:37.618347] Sample weights are currently ignored for multi class classification

Classification Report for cuML SVC with Count Vectorizer:
              precision    recall  f1-score   support

     Country       0.56      0.56      0.56       810
          HH       0.82      0.86      0.84       960
        Jazz       0.58      0.56      0.57       660
       Metal       0.63      0.82      0.71       810
        Rock       0.57      0.46      0.51      1410

    accuracy                           0.64      4650
   macro avg       0.63      0.65      0.64      4650
weighted avg       0.63      0.64      0.63      4650
```


Confusion Matrix for cuML SVC with Count Vectorizer

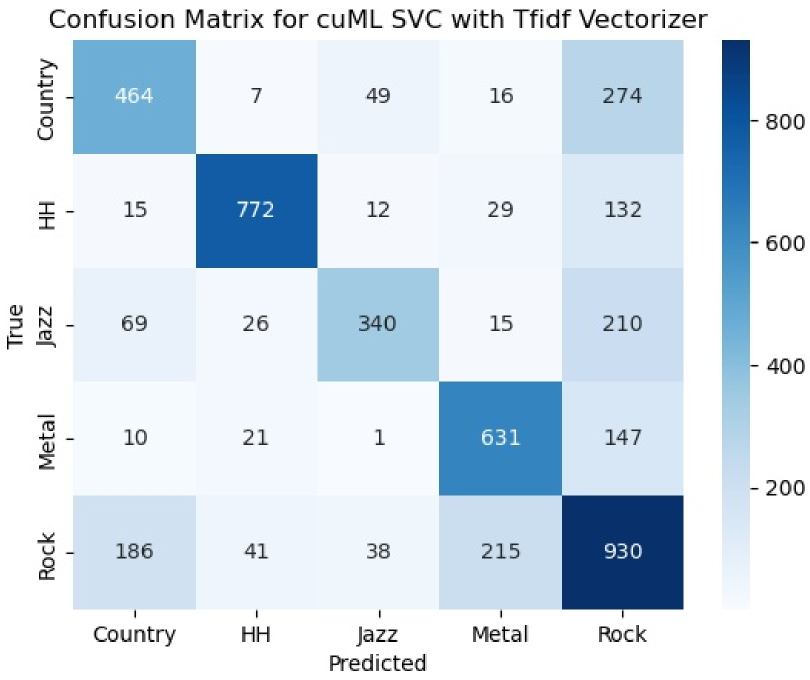
In [19]:

```
cuML_train(SVC_cuML, X_train_tfidf_cupy, X_test_tfidf_cupy, y_train_cupy, y_test_cupy, 'cuML SVC', 'Tfidf Vecto
[W] [14:12:26.733111] Sample weights are currently ignored for multi class classification
[W] [14:14:20.595877] Sample weights are currently ignored for multi class classification
[W] [14:16:15.122395] Sample weights are currently ignored for multi class classification
[W] [14:18:06.489816] Sample weights are currently ignored for multi class classification
[W] [15:32:02.664048] Sample weights are currently ignored for multi class classification

Classification Report for cuML SVC with Tfidf Vectorizer:
              precision    recall  f1-score   support

     Country       0.62      0.57      0.60       810
          HH       0.89      0.80      0.85       960
        Jazz       0.77      0.52      0.62       660
       Metal       0.70      0.78      0.74       810
        Rock       0.55      0.66      0.60      1410

    accuracy                           0.67      4650
   macro avg       0.71      0.67      0.68      4650
weighted avg       0.69      0.67      0.68      4650
```



## Insights

### 1. Logistic Regression with Count Vectorizer and Tf-idf Vectorizer:

#### Count Vectorizer:

- **Precision, recall, and F1-scores** are low for several classes, especially for "Country" and "Rock" genres, indicating difficulty in predicting these classes.
- **Confusion Matrix** shows a significant amount of misclassification for these classes. For example, many "Country" predictions are classified as "Rock."

#### Tf-idf Vectorizer:

- **Slight improvement in performance** over Count Vectorizer, especially for "Rock" and "Jazz."
- **Confusion Matrix** shows fewer misclassifications for some classes (e.g., "Rock"), but the model still struggles with distinguishing "Country" and "Jazz."

### 2. Random Forest with Count Vectorizer and Tf-idf Vectorizer:

#### Count Vectorizer:

- **Overall performance is poor**, particularly for "Country" and "Jazz."
- **Confusion Matrix** indicates the model is skewed towards predicting "Rock," with many other classes misclassified as "Rock."

#### Tf-idf Vectorizer:

- **Similar issues as Count Vectorizer**, though there is a slight improvement in performance metrics.
- **Confusion Matrix** shows improvement in predicting "HH" and "Jazz," but "Country" is still largely misclassified as "Rock."

## 3. cuML SVC with Count Vectorizer and Tf-idf Vectorizer (GPU-accelerated):

### Count Vectorizer:

- **Significant improvement in performance**, especially in recall and F1-scores for most classes compared to previous models.
- **Confusion Matrix** shows better prediction of "HH" and "Jazz" with fewer misclassifications.

### Tf-idf Vectorizer:

- **Best performance among all models**, with higher precision and recall scores across all classes.
- **Confusion Matrix** reflects fewer misclassifications, particularly for "Rock" and "Jazz," making this model the most accurate.

## Key Insights:

- **Tf-idf Vectorizer** generally performs better than **Count Vectorizer** across all models.
- **cuML SVC** offers the best performance due to GPU acceleration, providing faster and more accurate predictions compared to Logistic Regression and Random Forest.
- There is still room for improvement in distinguishing between certain genres like "Country" and "Rock."