In [2]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import os
from datetime import datetime
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import OneHotEncoder, StandardScaler
from sklearn.metrics import confusion_matrix
import seaborn as sns
from tqdm import tqdm
import librosa
```

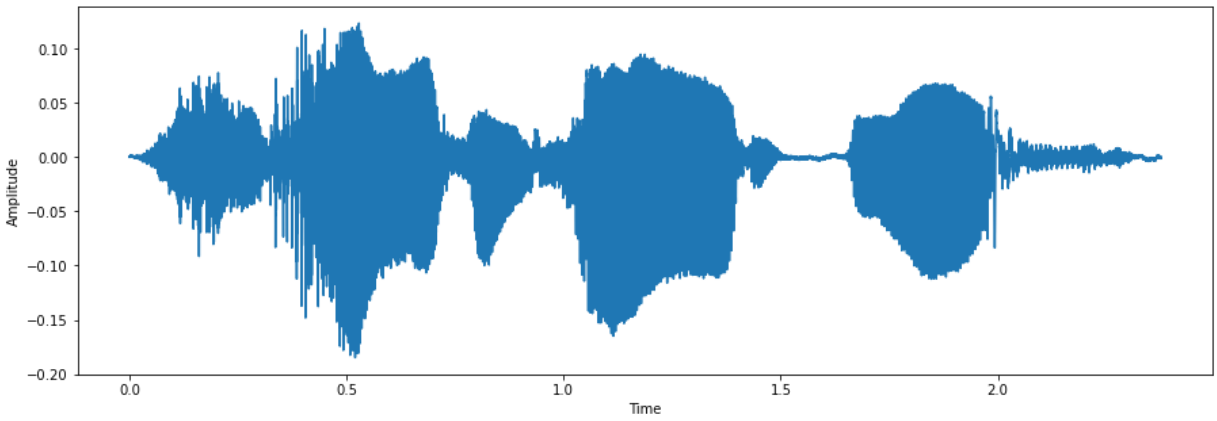
In [3]:
```
filepaths = []
labels = []

for dirpath, dirnames, filenames in os.walk('C:\\Users\\prajw\\TESS Toronto emotiona
    for filename in filenames:
        filepath = os.path.join(dirpath, filename)
        filepaths.append(filepath)
        parts = filename.split('_')
        label = parts[-1].split('.')[0].lower()
        labels.append(label)
```

In [4]:
```
len(filepaths)
```

Out[4]:
```
2800
```

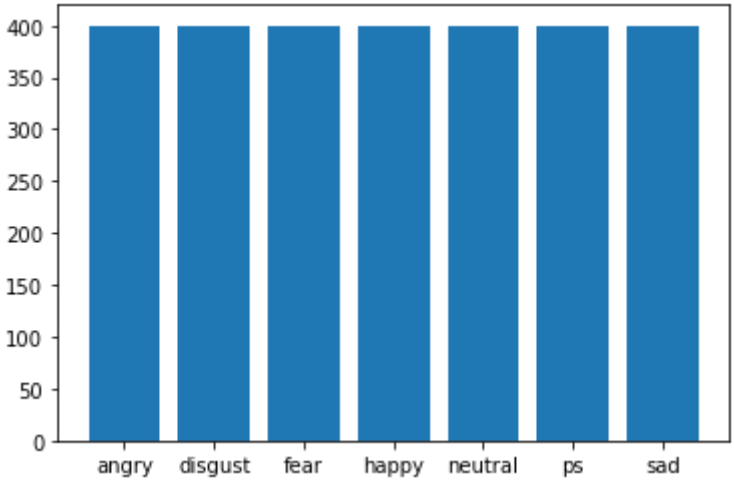
In [5]:
```
audio, sample_rate = librosa.load(filepath, sr=None, mono=True)

plt.figure(figsize=(15, 5))
plt.plot(np.linspace(0, len(audio) / sample_rate, len(audio)), audio)
plt.xlabel('Time')
plt.ylabel('Amplitude')
```

Out[5]:
```
Text(0, 0.5, 'Amplitude')
```



In [6]:
```
unique, unique_counts = np.unique(labels, return_counts=True)
plt.bar(unique, unique_counts)
```

Out[6]:
```
<BarContainer object of 7 artists>
```



In [7]:
```
df = pd.DataFrame()
df['filepath'] = filepaths
df['label'] = labels

df.head()
```

Out[7]:

	filepath	label
0	C:\Users\prajw\TESS Toronto emotional speech s...	angry
1	C:\Users\prajw\TESS Toronto emotional speech s...	angry
2	C:\Users\prajw\TESS Toronto emotional speech s...	angry
3	C:\Users\prajw\TESS Toronto emotional speech s...	angry
4	C:\Users\prajw\TESS Toronto emotional speech s...	angry

In [8]:
```
def feature_extractor(filepath):
    audio, sample_rate = librosa.load(filepath, sr=22050, mono=True)
    mfcc_feature = librosa.feature.mfcc(y=audio, sr=sample_rate, n_mfcc=40)
    return np.mean(mfcc_feature, axis=1)

feature_extractor(filepath).shape
```

Out[8]:
```
(40,)
```

In [ ]:
```
mfcc_features = df['filepath'].apply(lambda filepath: feature_extractor(filepath))
mfcc_features
```

In [ ]:
```
X = np.array(mfcc_features.to_list())
X = np.expand_dims(X, axis=-1)
X
```

In [ ]:
```
one_hot_encoder = OneHotEncoder(sparse=False)
y = one_hot_encoder.fit_transform(df[['label']])
y
```

In [ ]:
```
class_names = one_hot_encoder.categories_ [0]
class_names
```

In [ ]:
```
X_train_full, X_test, y_train_full, y_test = train_test_split(
    X, y, test_size=0.1, random_state=16529, shuffle=True, stratify=y)

X_train_full.shape, X_test.shape, y_train_full.shape, y_test.shape
```

In [ ]:
```
X_train, X_valid, y_train, y_valid = train_test_split(
    X_train_full, y_train_full, test_size=0.1, random_state=16529, shuffle=True, str

X_train.shape, X_valid.shape, y_train.shape, y_valid.shape
```

In [ ]:
```
!pip install tensorflow
```

In [ ]:
```
import tensorflow as tf
from tensorflow import keras
```

In [ ]:
```
keras.backend.clear_session()
tf.random.set_seed(42)
np.random.seed(42)

model = keras.models.Sequential()
model.add(keras.layers.LSTM(512, dropout=0.3, recurrent_dropout=0.0, return_sequence
model.add(keras.layers.LSTM(256, dropout=0.3, recurrent_dropout=0.0, return_sequence
model.add(keras.layers.LSTM(128, dropout=0.3, recurrent_dropout=0.0, return_sequence
model.add(keras.layers.Dense(7, activation='softmax'))

model.summary()
```

In [ ]:
```
model.compile(loss='categorical_crossentropy', optimizer='adam', metrics=['accuracy'
```

In [16]:
```
start_time = datetime.now()

early_stopping_cb = keras.callbacks.EarlyStopping(
    monitor='val_loss', min_delta=0, patience=30, verbose=1, mode='min', restore_bes

history = model.fit(
    x=X_train,
    y=y_train,
    batch_size=32,
    epochs=1000,
    verbose='auto',
    callbacks=[early_stopping_cb],
    validation_split=0.0,
    validation_data=(X_valid, y_valid),
    shuffle=True,)

end_time = datetime.now()
duration = end_time - start_time

print('Training completed in time:', duration)
```

```
Epoch 1/1000
71/71 [==============================] - 29s 341ms/step - loss: 0.8208 - accuracy:
0.6808 - val_loss: 0.3490 - val_accuracy: 0.8810
Epoch 2/1000
71/71 [==============================] - 21s 289ms/step - loss: 0.4992 - accuracy:
0.8148 - val_loss: 0.2973 - val_accuracy: 0.8889
```

```
Epoch 3/1000
71/71 [==============================] - 21s 297ms/step - loss: 0.4550 - accuracy:
0.8289 - val_loss: 0.1275 - val_accuracy: 0.9802
Epoch 4/1000
71/71 [==============================] - 21s 302ms/step - loss: 0.4223 - accuracy:
0.8399 - val_loss: 0.4302 - val_accuracy: 0.8214
Epoch 5/1000
71/71 [==============================] - 22s 305ms/step - loss: 0.4182 - accuracy:
0.8439 - val_loss: 0.2552 - val_accuracy: 0.9325
Epoch 6/1000
71/71 [==============================] - 21s 296ms/step - loss: 0.3485 - accuracy:
0.8792 - val_loss: 0.2860 - val_accuracy: 0.8730
Epoch 7/1000
71/71 [==============================] - 22s 311ms/step - loss: 0.3027 - accuracy:
0.8871 - val_loss: 0.4439 - val_accuracy: 0.8254
Epoch 8/1000
71/71 [==============================] - 22s 307ms/step - loss: 0.3141 - accuracy:
0.8898 - val_loss: 0.1629 - val_accuracy: 0.9405
Epoch 9/1000
71/71 [==============================] - 21s 300ms/step - loss: 0.2491 - accuracy:
0.9101 - val_loss: 0.1637 - val_accuracy: 0.9444
Epoch 10/1000
71/71 [==============================] - 21s 300ms/step - loss: 0.2128 - accuracy:
0.9277 - val_loss: 0.1461 - val_accuracy: 0.9524
Epoch 11/1000
71/71 [==============================] - 21s 302ms/step - loss: 0.2528 - accuracy:
0.9127 - val_loss: 0.2529 - val_accuracy: 0.9087
Epoch 12/1000
71/71 [==============================] - 21s 301ms/step - loss: 0.2289 - accuracy:
0.9078 - val_loss: 0.1707 - val_accuracy: 0.9405
Epoch 13/1000
71/71 [==============================] - 21s 300ms/step - loss: 0.1814 - accuracy:
0.9396 - val_loss: 0.1783 - val_accuracy: 0.9444
Epoch 14/1000
71/71 [==============================] - 22s 304ms/step - loss: 0.1908 - accuracy:
0.9383 - val_loss: 0.2320 - val_accuracy: 0.9206
Epoch 15/1000
71/71 [==============================] - 22s 304ms/step - loss: 0.1930 - accuracy:
0.9347 - val_loss: 0.2837 - val_accuracy: 0.9127
Epoch 16/1000
71/71 [==============================] - 21s 301ms/step - loss: 0.1963 - accuracy:
0.9365 - val_loss: 0.2678 - val_accuracy: 0.9048
Epoch 17/1000
71/71 [==============================] - 21s 301ms/step - loss: 0.1667 - accuracy:
0.9440 - val_loss: 0.1947 - val_accuracy: 0.9286
Epoch 18/1000
71/71 [==============================] - 21s 302ms/step - loss: 0.2003 - accuracy:
0.9299 - val_loss: 0.0998 - val_accuracy: 0.9722
Epoch 19/1000
71/71 [==============================] - 21s 302ms/step - loss: 0.1985 - accuracy:
0.9308 - val_loss: 0.1783 - val_accuracy: 0.9246
Epoch 20/1000
71/71 [==============================] - 21s 300ms/step - loss: 0.1478 - accuracy:
0.9475 - val_loss: 0.1866 - val_accuracy: 0.9524
Epoch 21/1000
71/71 [==============================] - 21s 299ms/step - loss: 0.1739 - accuracy:
0.9369 - val_loss: 0.1293 - val_accuracy: 0.9603
Epoch 22/1000
71/71 [==============================] - 21s 297ms/step - loss: 0.1680 - accuracy:
0.9427 - val_loss: 0.2113 - val_accuracy: 0.9167
Epoch 23/1000
71/71 [==============================] - 21s 299ms/step - loss: 0.1543 - accuracy:
0.9418 - val_loss: 0.1697 - val_accuracy: 0.9127
Epoch 24/1000
71/71 [==============================] - 21s 298ms/step - loss: 0.1443 - accuracy:
```

```
0.9458 - val_loss: 0.1350 - val_accuracy: 0.9484
Epoch 25/1000
71/71 [==============================] - 21s 299ms/step - loss: 0.1619 - accuracy:
0.9436 - val_loss: 0.1737 - val_accuracy: 0.9444
Epoch 26/1000
71/71 [==============================] - 21s 295ms/step - loss: 0.1441 - accuracy:
0.9515 - val_loss: 0.1440 - val_accuracy: 0.9405
Epoch 27/1000
71/71 [==============================] - 21s 297ms/step - loss: 0.1488 - accuracy:
0.9493 - val_loss: 0.1752 - val_accuracy: 0.9365
Epoch 28/1000
71/71 [==============================] - 21s 296ms/step - loss: 0.1408 - accuracy:
0.9489 - val_loss: 0.1384 - val_accuracy: 0.9603
Epoch 29/1000
71/71 [==============================] - 21s 297ms/step - loss: 0.1511 - accuracy:
0.9489 - val_loss: 0.2514 - val_accuracy: 0.9246
Epoch 30/1000
71/71 [==============================] - 21s 298ms/step - loss: 0.1249 - accuracy:
0.9599 - val_loss: 0.2686 - val_accuracy: 0.9167
Epoch 31/1000
71/71 [==============================] - 21s 298ms/step - loss: 0.1356 - accuracy:
0.9563 - val_loss: 0.0740 - val_accuracy: 0.9762
Epoch 32/1000
71/71 [==============================] - 21s 299ms/step - loss: 0.1179 - accuracy:
0.9559 - val_loss: 0.1803 - val_accuracy: 0.9286
Epoch 33/1000
71/71 [==============================] - 21s 300ms/step - loss: 0.1216 - accuracy:
0.9546 - val_loss: 0.0931 - val_accuracy: 0.9643
Epoch 34/1000
71/71 [==============================] - 21s 295ms/step - loss: 0.1358 - accuracy:
0.9541 - val_loss: 0.0517 - val_accuracy: 0.9881
Epoch 35/1000
71/71 [==============================] - 21s 292ms/step - loss: 0.1431 - accuracy:
0.9550 - val_loss: 0.1170 - val_accuracy: 0.9563
Epoch 36/1000
71/71 [==============================] - 21s 292ms/step - loss: 0.1143 - accuracy:
0.9586 - val_loss: 0.1244 - val_accuracy: 0.9563
Epoch 37/1000
71/71 [==============================] - 21s 292ms/step - loss: 0.1200 - accuracy:
0.9572 - val_loss: 0.1271 - val_accuracy: 0.9603
Epoch 38/1000
71/71 [==============================] - 21s 293ms/step - loss: 0.1056 - accuracy:
0.9643 - val_loss: 0.0717 - val_accuracy: 0.9802
Epoch 39/1000
71/71 [==============================] - 21s 298ms/step - loss: 0.0948 - accuracy:
0.9643 - val_loss: 0.2158 - val_accuracy: 0.9365
Epoch 40/1000
71/71 [==============================] - 21s 293ms/step - loss: 0.1031 - accuracy:
0.9669 - val_loss: 0.1190 - val_accuracy: 0.9524
Epoch 41/1000
71/71 [==============================] - 21s 291ms/step - loss: 0.1030 - accuracy:
0.9634 - val_loss: 0.1209 - val_accuracy: 0.9643
Epoch 42/1000
71/71 [==============================] - 21s 291ms/step - loss: 0.0979 - accuracy:
0.9647 - val_loss: 0.0766 - val_accuracy: 0.9762
Epoch 43/1000
71/71 [==============================] - 21s 303ms/step - loss: 0.0840 - accuracy:
0.9674 - val_loss: 0.1528 - val_accuracy: 0.9444
Epoch 44/1000
71/71 [==============================] - 20s 288ms/step - loss: 0.0707 - accuracy:
0.9775 - val_loss: 0.1300 - val_accuracy: 0.9603
Epoch 45/1000
71/71 [==============================] - 20s 285ms/step - loss: 0.0873 - accuracy:
0.9744 - val_loss: 0.0791 - val_accuracy: 0.9683
Epoch 46/1000
```

```
71/71 [==============================] - 21s 298ms/step - loss: 0.1017 - accuracy:
0.9687 - val_loss: 0.1611 - val_accuracy: 0.9405
Epoch 47/1000
71/71 [==============================] - 20s 284ms/step - loss: 0.0987 - accuracy:
0.9669 - val_loss: 0.1248 - val_accuracy: 0.9603
Epoch 48/1000
71/71 [==============================] - 20s 283ms/step - loss: 0.0859 - accuracy:
0.9727 - val_loss: 0.1941 - val_accuracy: 0.9405
Epoch 49/1000
71/71 [==============================] - 20s 281ms/step - loss: 0.0995 - accuracy:
0.9669 - val_loss: 0.0655 - val_accuracy: 0.9722
Epoch 50/1000
71/71 [==============================] - 20s 283ms/step - loss: 0.0756 - accuracy:
0.9740 - val_loss: 0.0591 - val_accuracy: 0.9762
Epoch 51/1000
71/71 [==============================] - 20s 282ms/step - loss: 0.1068 - accuracy:
0.9625 - val_loss: 0.1632 - val_accuracy: 0.9444
Epoch 52/1000
71/71 [==============================] - 20s 283ms/step - loss: 0.0972 - accuracy:
0.9665 - val_loss: 0.0612 - val_accuracy: 0.9802
Epoch 53/1000
71/71 [==============================] - 20s 281ms/step - loss: 0.0748 - accuracy:
0.9740 - val_loss: 0.1533 - val_accuracy: 0.9444
Epoch 54/1000
71/71 [==============================] - 20s 281ms/step - loss: 0.0753 - accuracy:
0.9749 - val_loss: 0.1824 - val_accuracy: 0.9444
Epoch 55/1000
71/71 [==============================] - 20s 282ms/step - loss: 0.0863 - accuracy:
0.9709 - val_loss: 0.1735 - val_accuracy: 0.9365
Epoch 56/1000
71/71 [==============================] - 20s 283ms/step - loss: 0.0649 - accuracy:
0.9744 - val_loss: 0.0717 - val_accuracy: 0.9802
Epoch 57/1000
71/71 [==============================] - 20s 281ms/step - loss: 0.0685 - accuracy:
0.9797 - val_loss: 0.0403 - val_accuracy: 0.9881
Epoch 58/1000
71/71 [==============================] - 20s 282ms/step - loss: 0.0642 - accuracy:
0.9784 - val_loss: 0.0698 - val_accuracy: 0.9841
Epoch 59/1000
71/71 [==============================] - 20s 289ms/step - loss: 0.0704 - accuracy:
0.9762 - val_loss: 0.0634 - val_accuracy: 0.9841
Epoch 60/1000
71/71 [==============================] - 21s 293ms/step - loss: 0.0955 - accuracy:
0.9665 - val_loss: 0.0413 - val_accuracy: 0.9881
Epoch 61/1000
71/71 [==============================] - 21s 295ms/step - loss: 0.0934 - accuracy:
0.9705 - val_loss: 0.0487 - val_accuracy: 0.9881
Epoch 62/1000
71/71 [==============================] - 21s 294ms/step - loss: 0.0716 - accuracy:
0.9749 - val_loss: 0.1003 - val_accuracy: 0.9722
Epoch 63/1000
71/71 [==============================] - 21s 290ms/step - loss: 0.0908 - accuracy:
0.9722 - val_loss: 0.1093 - val_accuracy: 0.9603
Epoch 64/1000
71/71 [==============================] - 21s 290ms/step - loss: 0.0704 - accuracy:
0.9797 - val_loss: 0.0849 - val_accuracy: 0.9762
Epoch 65/1000
71/71 [==============================] - 21s 291ms/step - loss: 0.0837 - accuracy:
0.9740 - val_loss: 0.1645 - val_accuracy: 0.9563
Epoch 66/1000
71/71 [==============================] - 21s 291ms/step - loss: 0.0731 - accuracy:
0.9771 - val_loss: 0.2658 - val_accuracy: 0.9167
Epoch 67/1000
71/71 [==============================] - 21s 291ms/step - loss: 0.0552 - accuracy:
0.9824 - val_loss: 0.0845 - val_accuracy: 0.9762
```

```
Epoch 68/1000
71/71 [==============================] - 21s 292ms/step - loss: 0.0746 - accuracy:
0.9744 - val_loss: 0.1581 - val_accuracy: 0.9484
Epoch 69/1000
71/71 [==============================] - 21s 293ms/step - loss: 0.0634 - accuracy:
0.9797 - val_loss: 0.0580 - val_accuracy: 0.9841
Epoch 70/1000
71/71 [==============================] - 21s 290ms/step - loss: 0.0584 - accuracy:
0.9828 - val_loss: 0.1318 - val_accuracy: 0.9484
Epoch 71/1000
71/71 [==============================] - 21s 294ms/step - loss: 0.0676 - accuracy:
0.9802 - val_loss: 0.1134 - val_accuracy: 0.9683
Epoch 72/1000
71/71 [==============================] - 21s 295ms/step - loss: 0.0540 - accuracy:
0.9841 - val_loss: 0.0669 - val_accuracy: 0.9762
Epoch 73/1000
71/71 [==============================] - 21s 298ms/step - loss: 0.0565 - accuracy:
0.9810 - val_loss: 0.1232 - val_accuracy: 0.9683
Epoch 74/1000
71/71 [==============================] - 21s 293ms/step - loss: 0.0588 - accuracy:
0.9806 - val_loss: 0.0981 - val_accuracy: 0.9683
Epoch 75/1000
71/71 [==============================] - 21s 292ms/step - loss: 0.0687 - accuracy:
0.9780 - val_loss: 0.0582 - val_accuracy: 0.9841
Epoch 76/1000
71/71 [==============================] - 21s 293ms/step - loss: 0.0620 - accuracy:
0.9788 - val_loss: 0.1737 - val_accuracy: 0.9325
Epoch 77/1000
71/71 [==============================] - 21s 292ms/step - loss: 0.0604 - accuracy:
0.9797 - val_loss: 0.0547 - val_accuracy: 0.9802
Epoch 78/1000
71/71 [==============================] - 20s 284ms/step - loss: 0.0563 - accuracy:
0.9806 - val_loss: 0.0780 - val_accuracy: 0.9603
Epoch 79/1000
71/71 [==============================] - 20s 285ms/step - loss: 0.0450 - accuracy:
0.9837 - val_loss: 0.1699 - val_accuracy: 0.9484
Epoch 80/1000
71/71 [==============================] - 20s 286ms/step - loss: 0.0721 - accuracy:
0.9718 - val_loss: 0.0720 - val_accuracy: 0.9722
Epoch 81/1000
71/71 [==============================] - 20s 284ms/step - loss: 0.0632 - accuracy:
0.9780 - val_loss: 0.0721 - val_accuracy: 0.9762
Epoch 82/1000
71/71 [==============================] - 20s 285ms/step - loss: 0.0670 - accuracy:
0.9757 - val_loss: 0.0519 - val_accuracy: 0.9802
Epoch 83/1000
71/71 [==============================] - 20s 284ms/step - loss: 0.0598 - accuracy:
0.9788 - val_loss: 0.1404 - val_accuracy: 0.9524
Epoch 84/1000
71/71 [==============================] - 20s 287ms/step - loss: 0.0557 - accuracy:
0.9806 - val_loss: 0.1819 - val_accuracy: 0.9325
Epoch 85/1000
71/71 [==============================] - 20s 287ms/step - loss: 0.0673 - accuracy:
0.9780 - val_loss: 0.0497 - val_accuracy: 0.9841
Epoch 86/1000
71/71 [==============================] - 20s 284ms/step - loss: 0.0433 - accuracy:
0.9859 - val_loss: 0.1786 - val_accuracy: 0.9484
Epoch 87/1000
71/71 [==============================] - ETA: 0s - loss: 0.0563 - accuracy: 0.9828Re
storing model weights from the end of the best epoch: 57.
71/71 [==============================] - 20s 285ms/step - loss: 0.0563 - accuracy:
0.9828 - val_loss: 0.0984 - val_accuracy: 0.9683
Epoch 87: early stopping
Training completed in time: 0:30:17.639995
```

In [19]:
```
results = model.evaluate(X_test, y_test, verbose=0)

for name, value in zip(model.metrics_names, results):
    print(f"{name:10} {value:.4f}")
```

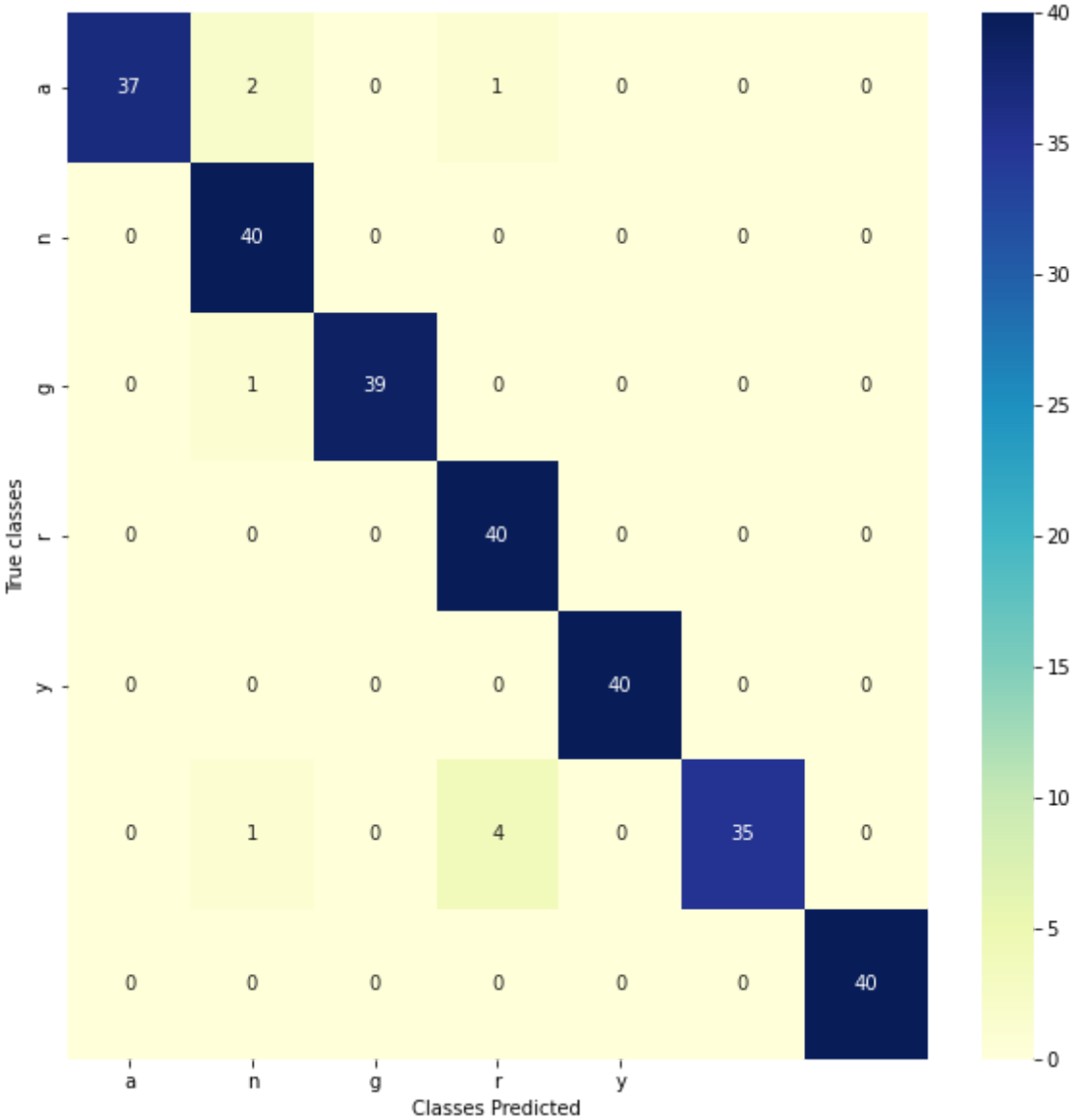
```
loss       0.0800
accuracy   0.9679
```

In [20]:
```
y_proba = model.predict(X_test)
y_pred = np.argmax(y_proba, axis=-1)
y_true = np.argmax(y_test, axis=-1)

np.mean(y_true == y_pred)
```

Out[20]:
```
0.9678571428571429
```

In [33]:
```
cm = confusion_matrix(y_true, y_pred)
plt.figure(figsize=(10, 10))
sns.heatmap(cm, annot=True, fmt='d',cmap='YlGnBu', xticklabels=class_names[0], ytick
plt.xlabel('Classes Predicted')
plt.ylabel('True classes')
```

Out[33]:
```
Text(69.0, 0.5, 'True classes')
```



In [ ]: