GRU, BiGRU, CNN_for multiclassification

March 11, 2025

[1]:
```
#GRU Model



import pandas as pd
import numpy as np
import re
from nltk.stem import WordNetLemmatizer
from sklearn.model_selection import KFold
from tensorflow.keras.preprocessing.text import Tokenizer  # Updated import
from tensorflow.keras.preprocessing.sequence import pad_sequences  # Updated␣
 ↪import
from tensorflow.keras.models import Sequential  # Updated import
from tensorflow.keras.layers import Embedding, GRU, Dropout, Dense  # Updated␣
 ↪import
from tensorflow.keras.optimizers import Adam  # Updated import
from sklearn.metrics import confusion_matrix, classification_report
import matplotlib.pyplot as plt
import seaborn as sns
from imblearn.over_sampling import RandomOverSampler


# 1. Load and Preprocess the dataset
#df = pd.read_csv('Amazon_Dataset_LD.csv', encoding='latin1')
df = pd.read_csv('accessibilityissues_multi.csv', encoding='latin1')
print(df.head())

print(df.head())

print(df.head())
lemmatizer = WordNetLemmatizer()

def clean_text(text):
    text = text.lower()
    text = re.sub(r'[^\w\s]', '', text)
    text = re.sub(r'\d+', '', text)
    tokens = text.split()
```

```
    tokens = [lemmatizer.lemmatize(token) for token in tokens]
    return ' '.join(tokens)

df['Review'] = df['Review'].apply(clean_text)

tokenizer = Tokenizer()
tokenizer.fit_on_texts(df['Review'])
X = tokenizer.texts_to_sequences(df['Review'])
vocab_size = len(tokenizer.word_index) + 1
maxlen = 100
X = pad_sequences(X, padding='post', maxlen=maxlen)
y_dict = {'Navigation and Interaction Problems (NAV)': 0, 'Input and Control␣
 ↪Issues (INPUT)': 1, 'Compatibility with Assistive Technologies (CAT)': 2,␣
 ↪'UI Accessibility Issues (UI)': 3, 'Audio and Visual Accessibility issues␣
 ↪(AUDIOVISUAL)': 4}
y = df['Assessability Issue Type'].map(y_dict)
y = pd.get_dummies(df['Assessability Issue Type']).values

# 2. Oversample to balance classes
oversampler = RandomOverSampler(random_state=42)
X_resampled, y_resampled = oversampler.fit_resample(X, y)

# 3. Define the GRU model
def create_model():
    model = Sequential()
    model.add(Embedding(input_dim=vocab_size, output_dim=100,␣
 ↪input_length=maxlen))
    model.add(GRU(64))
    model.add(Dropout(0.2))
    model.add(Dense(5, activation='softmax'))
    model.compile(optimizer=Adam(learning_rate=0.001),␣
 ↪loss='categorical_crossentropy', metrics=['accuracy'])
    return model

# 4. K-Fold Cross-Validation
n_folds = 5
kfold = KFold(n_splits=n_folds, shuffle=True)
fold_no = 1
acc_per_fold = []

# Lists to store average accuracies across folds
avg_train_acc = []
avg_val_acc = []

for train, test in kfold.split(X_resampled, y_resampled):
    model = create_model()
```

```
    history = model.fit(X_resampled[train], y_resampled[train],␣
 ↪validation_split=0.1, epochs=10, batch_size=32, verbose=0)

    avg_train_acc.append(history.history['accuracy'])
    avg_val_acc.append(history.history['val_accuracy'])

    scores = model.evaluate(X_resampled[test], y_resampled[test], verbose=0)
    acc_per_fold.append(scores[1] * 100)
    fold_no += 1

# 5. Performance Metrics
print(f'> Average Accuracy across {n_folds}-folds: {np.mean(acc_per_fold):.2f}%␣
 ↪(+/- {np.std(acc_per_fold):.2f}%)')

# Average Training and Validation Accuracy for 5 folds
plt.plot(np.mean(avg_train_acc, axis=0), label='Average Training Accuracy')
plt.plot(np.mean(avg_val_acc, axis=0), label='Average Validation Accuracy')
plt.title('Average Training and Validation Accuracy across 5 folds')
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.legend()
plt.show()

# Confusion Matrix
y_pred = model.predict(X_resampled)
y_pred_classes = np.argmax(y_pred, axis=1)
y_true_classes = np.argmax(y_resampled, axis=1)
cm = confusion_matrix(y_true_classes, y_pred_classes)
sns.heatmap(cm, annot=True, fmt='g')
plt.show()

# Classification Report
print(classification_report(y_true_classes, y_pred_classes,␣
 ↪target_names=list(y_dict.keys())))
```

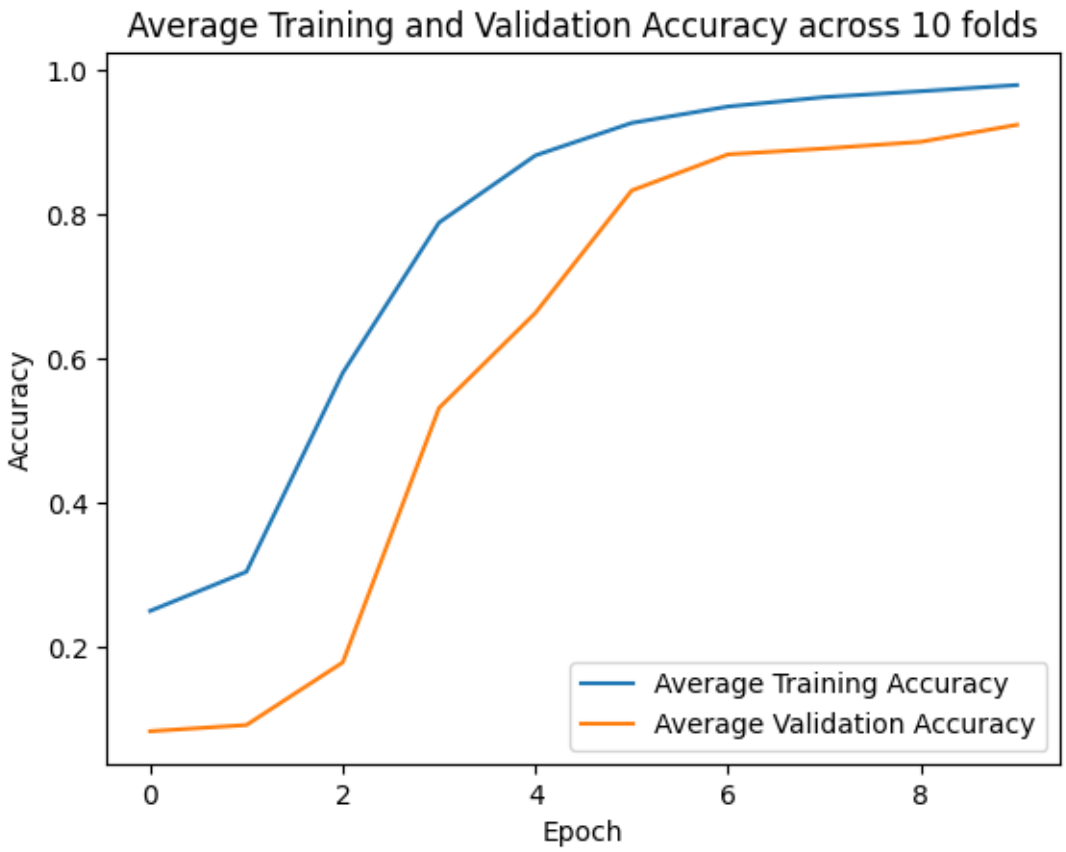
```
   Unnamed: 0       userName                                              Title  \
0         NaN      AllykatTX      LYSN allows unchecked bullying & harassment
1         NaN    starry_sara           Filled with toxic and abusive comments
2         NaN        dayflan                                Toxic communities
3         NaN   myhomiejesus                                  HonestlyÃ¢â ¬Ã¦
4         NaN  @junmyeonsoup  Despicable, toxic community for artist and fans

                                          Review  Rating  \
0  When I originally joined the LYSN app I expect…       1
1  Even though the companyÃ¢â ¬â ¢s policy states…       1
2  At first, I was excited about downloading the …       1
3  I see a lot of 5 star reviews of people saying…       1
```

```
4  I expected this app to be a good time for me t…       1

                                     cleaned_Review Have assessablity Issue  \
0  when i originally joined the lysn app i expect…                       Yes
1  even though the company s policy state they wi…                       Yes
2  at first i wa excited about downloading the ap…                       Yes
3  i see a lot of star review of people saying th…                       Yes
4  i expected this app to be a good time for me t…                       Yes

                   Assessability Issue Type
0  Navigation and Interaction Problems (NAV)
1  Navigation and Interaction Problems (NAV)
2  Navigation and Interaction Problems (NAV)
3           Input and Control Issues (INPUT)
4  Navigation and Interaction Problems (NAV)
   Unnamed: 0       userName                                          Title  \
0         NaN      AllykatTX      LYSN allows unchecked bullying & harassment
1         NaN    starry_sara           Filled with toxic and abusive comments
2         NaN        dayflan                                 Toxic communities
3         NaN   myhomiejesus                                   HonestlyÃ¢â ¬Â¦
4         NaN  @junmyeonsoup  Despicable, toxic community for artist and fans

                                          Review  Rating  \
0  When I originally joined the LYSN app I expect…       1
1  Even though the companyÃ¢â ¬â ¢s policy states…       1
2  At first, I was excited about downloading the …       1
3  I see a lot of 5 star reviews of people saying…       1
4  I expected this app to be a good time for me t…       1

                                     cleaned_Review Have assessablity Issue  \
0  when i originally joined the lysn app i expect…                       Yes
1  even though the company s policy state they wi…                       Yes
2  at first i wa excited about downloading the ap…                       Yes
3  i see a lot of star review of people saying th…                       Yes
4  i expected this app to be a good time for me t…                       Yes

                   Assessability Issue Type
0  Navigation and Interaction Problems (NAV)
1  Navigation and Interaction Problems (NAV)
2  Navigation and Interaction Problems (NAV)
3           Input and Control Issues (INPUT)
4  Navigation and Interaction Problems (NAV)
   Unnamed: 0       userName                                          Title  \
0         NaN      AllykatTX      LYSN allows unchecked bullying & harassment
1         NaN    starry_sara           Filled with toxic and abusive comments
2         NaN        dayflan                                 Toxic communities
3         NaN   myhomiejesus                                   HonestlyÃ¢â ¬Â¦
4         NaN  @junmyeonsoup  Despicable, toxic community for artist and fans
```

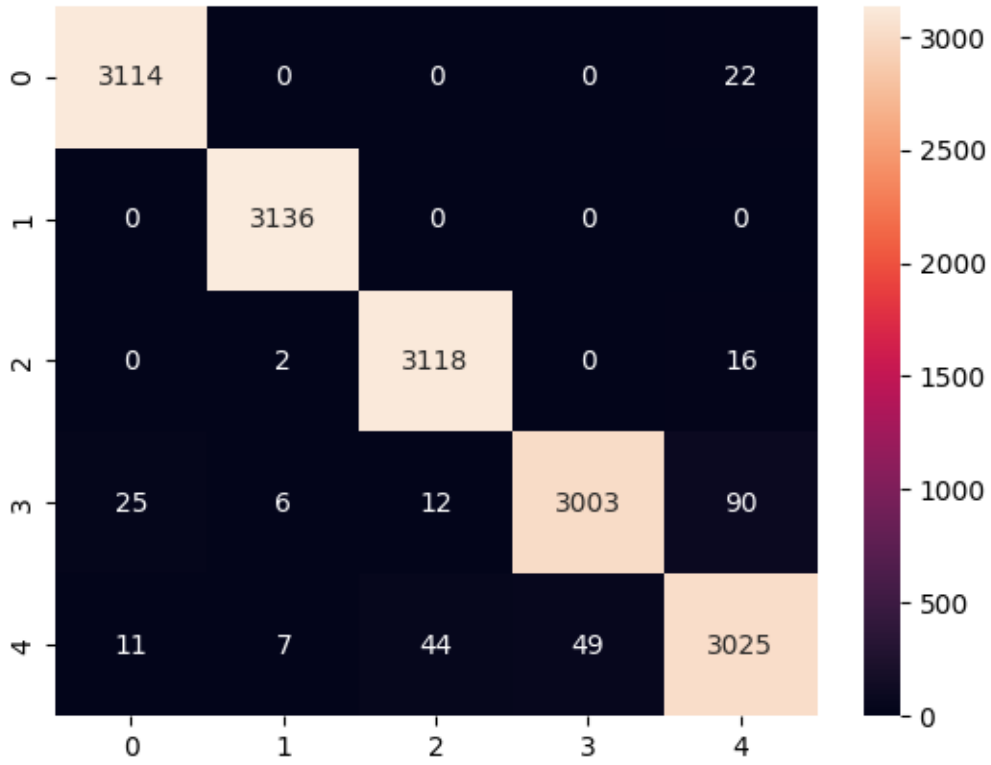
```
                                              Review  Rating  \
0  When I originally joined the LYSN app I expect…       1
1  Even though the companyÃ¢â ¬â ¢s policy states…       1
2  At first, I was excited about downloading the …       1
3  I see a lot of 5 star reviews of people saying…       1
4  I expected this app to be a good time for me t…       1

                                     cleaned_Review Have assessablity Issue  \
0  when i originally joined the lysn app i expect…                      Yes
1  even though the company s policy state they wi…                      Yes
2  at first i wa excited about downloading the ap…                      Yes
3  i see a lot of star review of people saying th…                      Yes
4  i expected this app to be a good time for me t…                      Yes

                   Assessability Issue Type
0  Navigation and Interaction Problems (NAV)
1  Navigation and Interaction Problems (NAV)
2  Navigation and Interaction Problems (NAV)
3           Input and Control Issues (INPUT)
4  Navigation and Interaction Problems (NAV)
```

```
/Users/nekdilkhan/miniforge3/lib/python3.12/site-
packages/keras/src/layers/core/embedding.py:90: UserWarning: Argument
`input_length` is deprecated. Just remove it.
  warnings.warn(
```

```
> Average Accuracy across 5-folds: 93.65% (+/- 3.07%)
```




```
490/490                 4s 9ms/step
```



	precision	recall	f1-score	support
Navigation and Interaction Problems (NAV)	0.99	0.99	0.99	3136
Input and Control Issues (INPUT)	1.00	1.00	1.00	3136
Compatibility with Assistive Technologies (CAT)	0.98	0.99	0.99	3136
UI Accessibility Issues (UI)	0.98	0.96	0.97	3136
Audio and Visual Accessibility issues (AUDIOVISUAL)	0.96	0.96	0.96	3136
accuracy			0.98	15680
macro avg	0.98	0.98	0.98	15680
weighted avg	0.98	0.98	0.98	15680

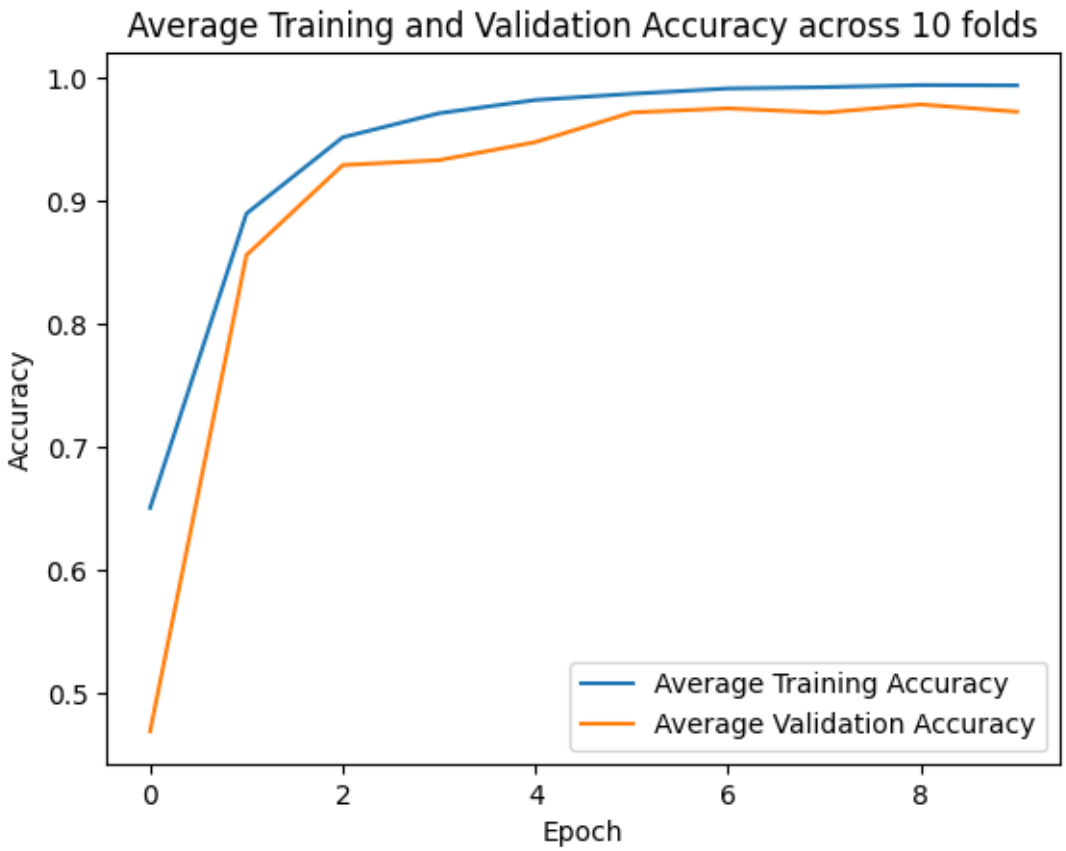
[2]:
```
# BiGRU Model

import pandas as pd
import numpy as np
import re
from nltk.stem import WordNetLemmatizer
from sklearn.model_selection import KFold
from tensorflow.keras.preprocessing.text import Tokenizer
from tensorflow.keras.preprocessing.sequence import pad_sequences
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Embedding, Bidirectional, GRU, Dropout,␣
 ↪Dense
from tensorflow.keras.optimizers import Adam
from sklearn.metrics import confusion_matrix, classification_report
import matplotlib.pyplot as plt
import seaborn as sns
from imblearn.over_sampling import RandomOverSampler
# 1. Load and Preprocess the dataset
#df = pd.read_csv('Amazon_Dataset_LD.csv', encoding='latin1')
df = pd.read_csv('accessibilityissues_multi.csv', encoding='latin1')
lemmatizer = WordNetLemmatizer()

def clean_text(text):
    text = text.lower()
    text = re.sub(r'[^\w\s]', '', text)
    text = re.sub(r'\d+', '', text)
    tokens = text.split()
    tokens = [lemmatizer.lemmatize(token) for token in tokens]
    return ' '.join(tokens)

df['Review'] = df['Review'].apply(clean_text)

tokenizer = Tokenizer()
tokenizer.fit_on_texts(df['Review'])
X = tokenizer.texts_to_sequences(df['Review'])
vocab_size = len(tokenizer.word_index) + 1
maxlen = 100
X = pad_sequences(X, padding='post', maxlen=maxlen)
y_dict = {'Navigation and Interaction Problems (NAV)': 0, 'Input and Control␣
 ↪Issues (INPUT)': 1, 'Compatibility with Assistive Technologies (CAT)': 2,␣
 ↪'UI Accessibility Issues (UI)': 3, 'Audio and Visual Accessibility issues␣
 ↪(AUDIOVISUAL)': 4}
y = df['Assessability Issue Type'].map(y_dict)
y = pd.get_dummies(df['Assessability Issue Type']).values

# 2. Oversample to balance classes
oversampler = RandomOverSampler(random_state=42)
```

```
X_resampled, y_resampled = oversampler.fit_resample(X, y)

# 3. Define the BiGRU model
def create_bigru_model():
    model = Sequential()
    model.add(Embedding(input_dim=vocab_size, output_dim=100,␣
 ↪input_length=maxlen))
    model.add(Bidirectional(GRU(64, return_sequences=True)))
    model.add(Dropout(0.2))
    model.add(Bidirectional(GRU(64)))
    model.add(Dropout(0.2))
    model.add(Dense(5, activation='softmax'))
    model.compile(optimizer=Adam(learning_rate=0.001),␣
 ↪loss='categorical_crossentropy', metrics=['accuracy'])
    return model

# 4. K-Fold Cross-Validation
n_folds = 5
kfold = KFold(n_splits=n_folds, shuffle=True)
fold_no = 1
acc_per_fold = []

# Lists to store average accuracies across folds
avg_train_acc = []
avg_val_acc = []

for train, test in kfold.split(X_resampled, y_resampled):
    model = create_bigru_model()
    history = model.fit(X_resampled[train], y_resampled[train],␣
 ↪validation_split=0.1, epochs=10, batch_size=32, verbose=0)

    avg_train_acc.append(history.history['accuracy'])
    avg_val_acc.append(history.history['val_accuracy'])

    scores = model.evaluate(X_resampled[test], y_resampled[test], verbose=0)
    acc_per_fold.append(scores[1] * 100)
    fold_no += 1

# 5. Performance Metrics
print(f'> Average Accuracy across {n_folds}-folds: {np.mean(acc_per_fold):.2f}%␣
 ↪(+/- {np.std(acc_per_fold):.2f}%)')

# Average Training and Validation Accuracy for 5 folds
plt.plot(np.mean(avg_train_acc, axis=0), label='Average Training Accuracy')
plt.plot(np.mean(avg_val_acc, axis=0), label='Average Validation Accuracy')
plt.title('Average Training and Validation Accuracy across 10 folds')
plt.xlabel('Epoch')
```

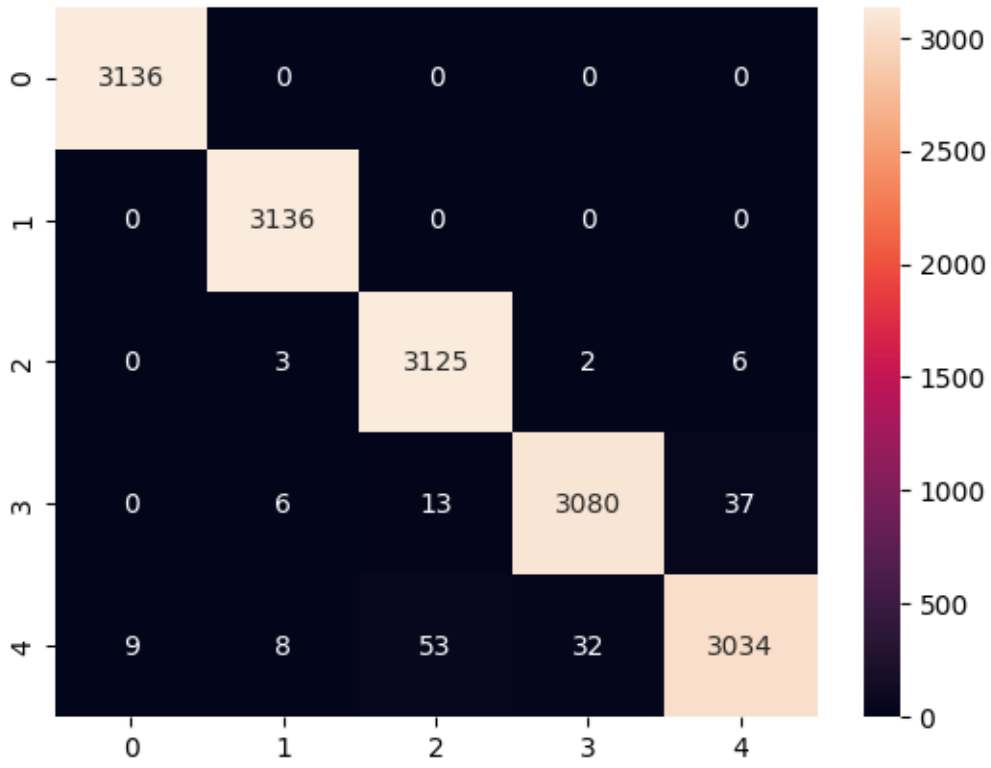
```
plt.ylabel('Accuracy')
plt.legend()
plt.show()

# Confusion Matrix
y_pred = model.predict(X_resampled)
y_pred_classes = np.argmax(y_pred, axis=1)
y_true_classes = np.argmax(y_resampled, axis=1)
cm = confusion_matrix(y_true_classes, y_pred_classes)
sns.heatmap(cm, annot=True, fmt='g')
plt.show()

# Classification Report
print(classification_report(y_true_classes, y_pred_classes,␣
 ↪target_names=list(y_dict.keys())))
```

```
/Users/nekdilkhan/miniforge3/lib/python3.12/site-
packages/keras/src/layers/core/embedding.py:90: UserWarning: Argument
`input_length` is deprecated. Just remove it.
  warnings.warn(
```

```
> Average Accuracy across 5-folds: 95.85% (+/- 0.53%)
```



```
490/490              19s 37ms/step
```



	precision	recall	f1-score	support
Navigation and Interaction Problems (NAV)	1.00	1.00	1.00	3136
Input and Control Issues (INPUT)	0.99	1.00	1.00	3136
Compatibility with Assistive Technologies (CAT)	0.98	1.00	0.99	3136
UI Accessibility Issues (UI)	0.99	0.98	0.99	3136
Audio and Visual Accessibility issues (AUDIOVISUAL)	0.99	0.97	0.98	3136
accuracy			0.99	15680
macro avg	0.99	0.99	0.99	15680
weighted avg	0.99	0.99		

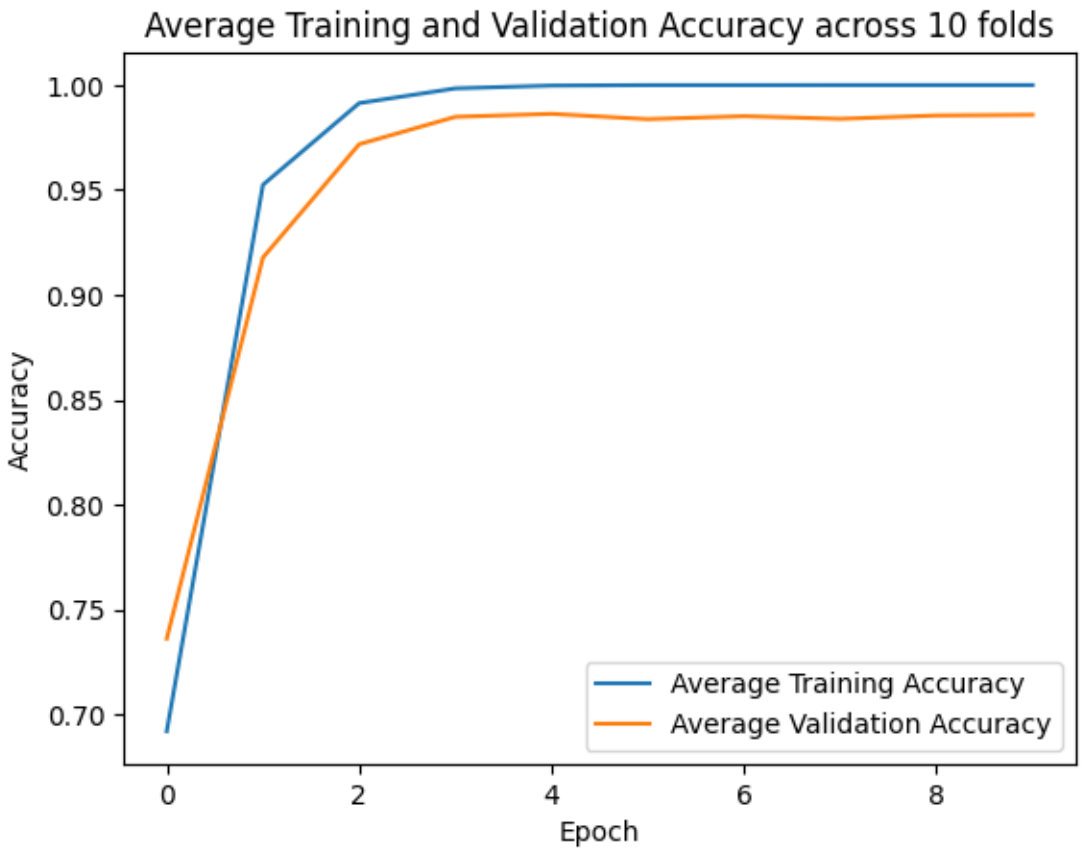
```
0.99      15680
```

[3]:
```
#CNN  Dataset , Oversampling ,


import pandas as pd
import numpy as np
import re
from nltk.stem import WordNetLemmatizer
from sklearn.model_selection import KFold
from tensorflow.keras.preprocessing.text import Tokenizer  # Updated import
from tensorflow.keras.preprocessing.sequence import pad_sequences  # Updated␣
 ↪import
from tensorflow.keras.models import Sequential  # Updated import
from tensorflow.keras.layers import Embedding, Conv1D, MaxPooling1D, Flatten,␣
 ↪Dropout, Dense  # Updated import
from tensorflow.keras.optimizers import Adam  # Updated import
from sklearn.metrics import confusion_matrix, classification_report
import matplotlib.pyplot as plt
import seaborn as sns
from imblearn.over_sampling import RandomOverSampler



# 3. Define the CNN model
def create_model():
    model = Sequential()
    model.add(Embedding(input_dim=vocab_size, output_dim=100,␣
 ↪input_length=maxlen))
    model.add(Conv1D(128, 5, activation='relu'))
    model.add(MaxPooling1D(pool_size=2))
    model.add(Flatten())
    model.add(Dropout(0.2))
    model.add(Dense(5, activation='softmax'))
    model.compile(optimizer=Adam(learning_rate=0.001),␣
 ↪loss='categorical_crossentropy', metrics=['accuracy'])
    return model

# 4. K-Fold Cross-Validation
n_folds = 5
kfold = KFold(n_splits=n_folds, shuffle=True)
fold_no = 1
acc_per_fold = []

# Lists to store average accuracies across folds
avg_train_acc = []
```

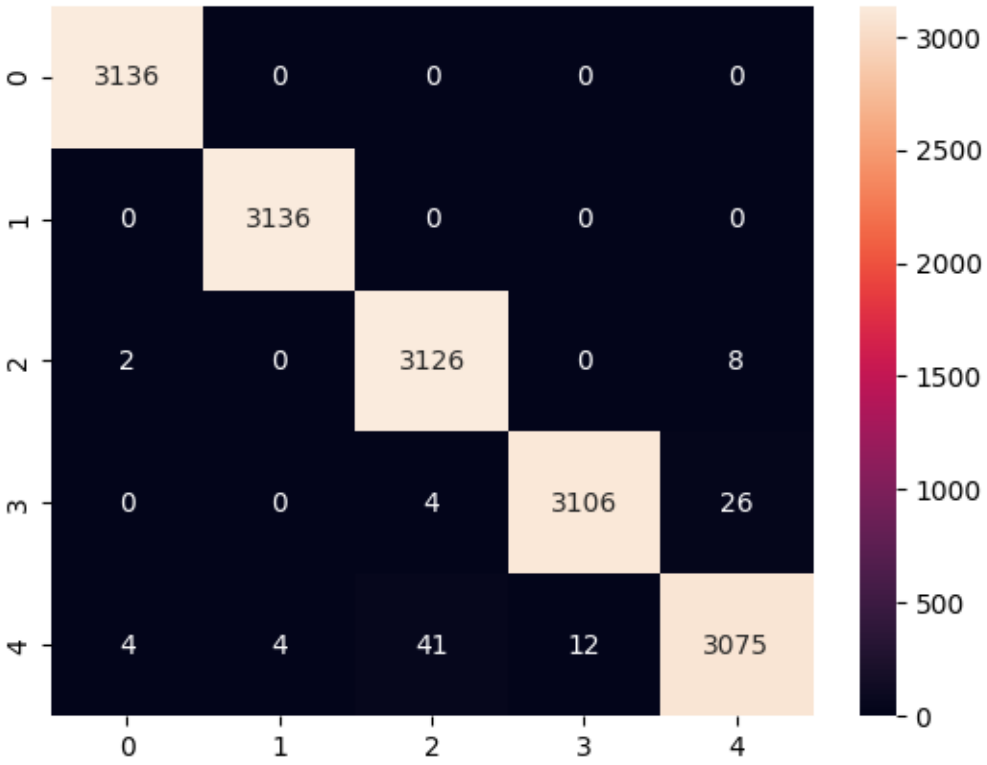
```
avg_val_acc = []

for train, test in kfold.split(X_resampled, y_resampled):
    model = create_model()
    history = model.fit(X_resampled[train], y_resampled[train],␣
 ↪validation_split=0.1, epochs=10, batch_size=32, verbose=0)

    avg_train_acc.append(history.history['accuracy'])
    avg_val_acc.append(history.history['val_accuracy'])

    scores = model.evaluate(X_resampled[test], y_resampled[test], verbose=0)
    acc_per_fold.append(scores[1] * 100)
    fold_no += 1

# 5. Performance Metrics
print(f'> Average Accuracy across {n_folds}-folds: {np.mean(acc_per_fold):.2f}%␣
 ↪(+/- {np.std(acc_per_fold):.2f}%)')

# Average Training and Validation Accuracy for 5 folds
plt.plot(np.mean(avg_train_acc, axis=0), label='Average Training Accuracy')
plt.plot(np.mean(avg_val_acc, axis=0), label='Average Validation Accuracy')
plt.title('Average Training and Validation Accuracy across 5 folds')
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.legend()
plt.show()

# Confusion Matrix
y_pred = model.predict(X_resampled)
y_pred_classes = np.argmax(y_pred, axis=1)
y_true_classes = np.argmax(y_resampled, axis=1)
cm = confusion_matrix(y_true_classes, y_pred_classes)
sns.heatmap(cm, annot=True, fmt='g')
plt.show()

# Classification Report
print(classification_report(y_true_classes, y_pred_classes,␣
 ↪target_names=list(y_dict.keys())))
```

```
/Users/nekdilkhan/miniforge3/lib/python3.12/site-
packages/keras/src/layers/core/embedding.py:90: UserWarning: Argument
`input_length` is deprecated. Just remove it.
  warnings.warn(
```

```
> Average Accuracy across 5-folds: 97.19% (+/- 0.41%)
```




```
490/490                2s 4ms/step
```



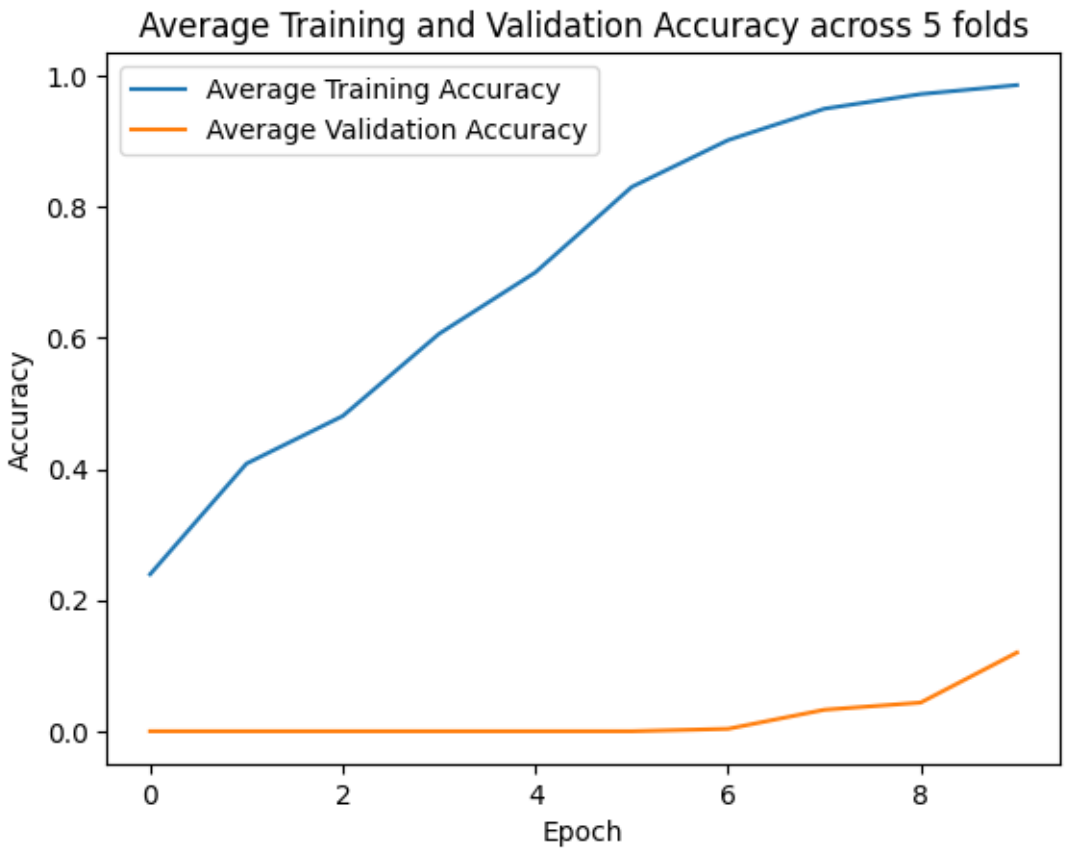
	precision	recall	f1-score	support
Navigation and Interaction Problems (NAV)	1.00	1.00	1.00	3136
Input and Control Issues (INPUT)	1.00	1.00	1.00	3136
Compatibility with Assistive Technologies (CAT)	0.99	1.00	0.99	3136
UI Accessibility Issues (UI)	1.00	0.99	0.99	3136
Audio and Visual Accessibility issues (AUDIOVISUAL)	0.99	0.98	0.98	3136
accuracy			0.99	15680
macro avg	0.99	0.99	0.99	15680
weighted avg	0.99	0.99	0.99	15680

[4]:
```
#CNN manual annoated dataset dataset, undersampling

import pandas as pd
import numpy as np
import re
from nltk.stem import WordNetLemmatizer
from sklearn.model_selection import KFold
from tensorflow.keras.preprocessing.text import Tokenizer  # Updated import
from tensorflow.keras.preprocessing.sequence import pad_sequences  # Updated␣
 ↪import
from tensorflow.keras.models import Sequential  # Updated import
from tensorflow.keras.layers import Embedding, Conv1D, MaxPooling1D, Flatten,␣
 ↪Dropout, Dense  # Updated import
from tensorflow.keras.optimizers import Adam  # Updated import
from sklearn.metrics import confusion_matrix, classification_report
import matplotlib.pyplot as plt
import seaborn as sns
from imblearn.under_sampling import RandomUnderSampler


# 2. Undersample to balance classes
undersampler = RandomUnderSampler(random_state=42)
X_resampled, y_resampled = undersampler.fit_resample(X, y)

# 3. Define the CNN model
def create_model():
    model = Sequential()
    model.add(Embedding(input_dim=vocab_size, output_dim=100,␣
 ↪input_length=maxlen))
    model.add(Conv1D(128, 5, activation='relu'))
    model.add(MaxPooling1D(pool_size=2))
    model.add(Flatten())
    model.add(Dropout(0.2))
    model.add(Dense(5, activation='softmax'))
    model.compile(optimizer=Adam(learning_rate=0.001),␣
 ↪loss='categorical_crossentropy', metrics=['accuracy'])
    return model

# 4. K-Fold Cross-Validation
n_folds = 5
kfold = KFold(n_splits=n_folds, shuffle=True)
fold_no = 1
acc_per_fold = []

# Lists to store average accuracies across folds
avg_train_acc = []
avg_val_acc = []
```

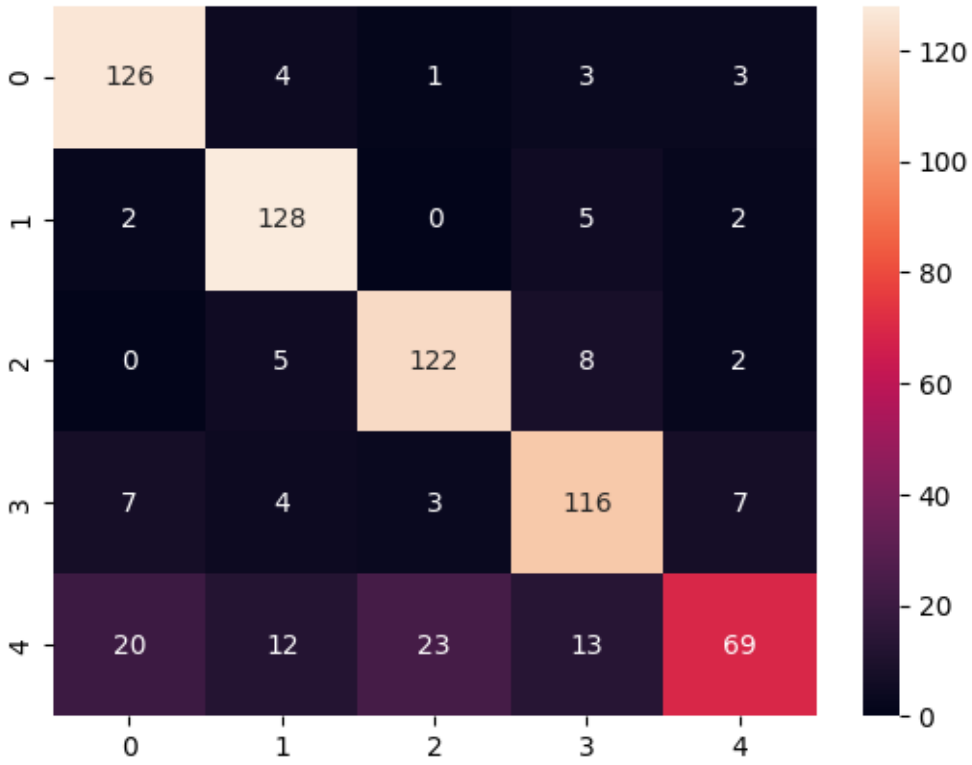
```
for train, test in kfold.split(X_resampled, y_resampled):
    model = create_model()
    history = model.fit(X_resampled[train], y_resampled[train],␣
 ↪validation_split=0.1, epochs=10, batch_size=32, verbose=0)

    avg_train_acc.append(history.history['accuracy'])
    avg_val_acc.append(history.history['val_accuracy'])

    scores = model.evaluate(X_resampled[test], y_resampled[test], verbose=0)
    acc_per_fold.append(scores[1] * 100)
    fold_no += 1

# 5. Performance Metrics
print(f'> Average Accuracy across {n_folds}-folds: {np.mean(acc_per_fold):.2f}%␣
 ↪(+/- {np.std(acc_per_fold):.2f}%)')

# Average Training and Validation Accuracy for 5 folds
plt.plot(np.mean(avg_train_acc, axis=0), label='Average Training Accuracy')
plt.plot(np.mean(avg_val_acc, axis=0), label='Average Validation Accuracy')
plt.title('Average Training and Validation Accuracy across 5 folds')
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.legend()
plt.show()

# Confusion Matrix
y_pred = model.predict(X_resampled)
y_pred_classes = np.argmax(y_pred, axis=1)
y_true_classes = np.argmax(y_resampled, axis=1)
cm = confusion_matrix(y_true_classes, y_pred_classes)
sns.heatmap(cm, annot=True, fmt='g')
plt.show()

# Classification Report
print(classification_report(y_true_classes, y_pred_classes,␣
 ↪target_names=list(y_dict.keys())))
```

```
/Users/nekdilkhan/miniforge3/lib/python3.12/site-
packages/keras/src/layers/core/embedding.py:90: UserWarning: Argument
`input_length` is deprecated. Just remove it.
  warnings.warn(
```

```
> Average Accuracy across 5-folds: 47.59% (+/- 2.37%)
```




```
22/22                0s 11ms/step
```



	precision	recall	f1-score	support
Navigation and Interaction Problems (NAV)	0.81	0.92	0.86	137
Input and Control Issues (INPUT)	0.84	0.93	0.88	137
Compatibility with Assistive Technologies (CAT)	0.82	0.89	0.85	137
UI Accessibility Issues (UI)	0.80	0.85	0.82	137
Audio and Visual Accessibility issues (AUDIOVISUAL)	0.83	0.50	0.63	137
accuracy			0.82	685
macro avg	0.82	0.82	0.81	685
weighted avg	0.82	0.82	0.81	685

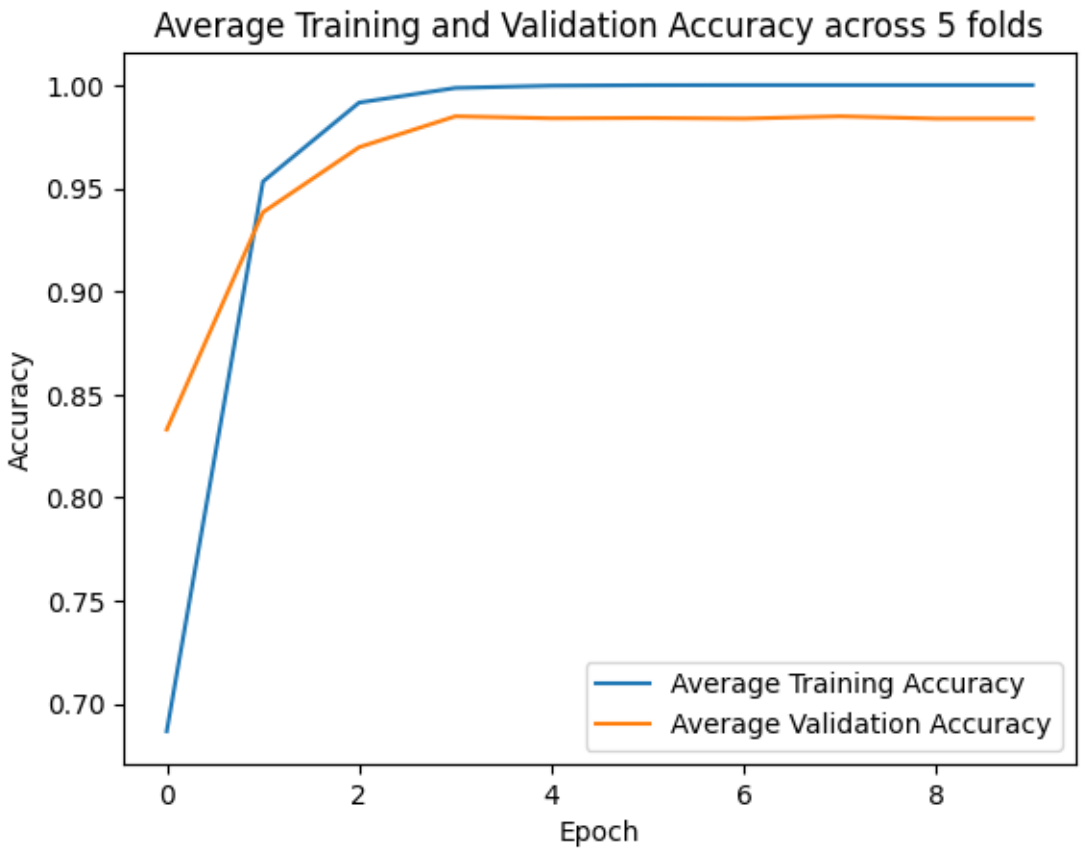
[5]:
```
import pandas as pd
import numpy as np
import re
from nltk.stem import WordNetLemmatizer
from sklearn.model_selection import KFold
from tensorflow.keras.preprocessing.text import Tokenizer
from tensorflow.keras.preprocessing.sequence import pad_sequences
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Embedding, Conv1D, MaxPooling1D, Flatten,␣
 ↪Dropout, Dense
from tensorflow.keras.optimizers import Adam
from sklearn.metrics import confusion_matrix, classification_report
import matplotlib.pyplot as plt
import seaborn as sns
from imblearn.over_sampling import RandomOverSampler
from sklearn.preprocessing import label_binarize  # Correct import
from sklearn.metrics import roc_curve, auc


# 2. Oversample to balance classes
oversampler = RandomOverSampler(random_state=42)
X_resampled, y_resampled = oversampler.fit_resample(X, y)

# 3. Define the CNN model
def create_model():
    model = Sequential()
    model.add(Embedding(input_dim=vocab_size, output_dim=100,␣
 ↪input_length=maxlen))
    model.add(Conv1D(128, 5, activation='relu'))
    model.add(MaxPooling1D(pool_size=2))
    model.add(Flatten())
    model.add(Dropout(0.2))
    model.add(Dense(5, activation='softmax'))
    model.compile(optimizer=Adam(learning_rate=0.001),␣
 ↪loss='categorical_crossentropy', metrics=['accuracy'])
    return model

# 4. K-Fold Cross-Validation
n_folds = 5
kfold = KFold(n_splits=n_folds, shuffle=True)
fold_no = 1
acc_per_fold = []

# Lists to store average accuracies across folds
avg_train_acc = []
avg_val_acc = []
```

```
for train, test in kfold.split(X_resampled, y_resampled):
    model = create_model()
    history = model.fit(X_resampled[train], y_resampled[train],␣
 ↪validation_split=0.1, epochs=10, batch_size=32, verbose=0)

    avg_train_acc.append(history.history['accuracy'])
    avg_val_acc.append(history.history['val_accuracy'])

    scores = model.evaluate(X_resampled[test], y_resampled[test], verbose=0)
    acc_per_fold.append(scores[1] * 100)
    fold_no += 1

# 5. Performance Metrics
print(f'> Average Accuracy across {n_folds}-folds: {np.mean(acc_per_fold):.2f}%␣
 ↪(+/- {np.std(acc_per_fold):.2f}%)')

# Average Training and Validation Accuracy for 5 folds
plt.plot(np.mean(avg_train_acc, axis=0), label='Average Training Accuracy')
plt.plot(np.mean(avg_val_acc, axis=0), label='Average Validation Accuracy')
plt.title('Average Training and Validation Accuracy across 5 folds')
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.legend()
plt.show()

# 6. ROC curve
y_pred = model.predict(X_resampled)
y_true_classes = np.argmax(y_resampled, axis=1)
y_pred_probs = model.predict(X_resampled)

# Binarize the true labels for ROC
y_true_binarized = label_binarize(y_true_classes, classes=[0, 1, 2, 3, 4, 5, 6,␣
 ↪7])

# Initialize variables to store fpr, tpr, and auc for each class
fpr = dict()
tpr = dict()
roc_auc = dict()

# Calculate ROC curve and AUC for each class
for i in range(5):
    fpr[i], tpr[i], _ = roc_curve(y_true_binarized[:, i], y_pred_probs[:, i])
    roc_auc[i] = auc(fpr[i], tpr[i])

# Plot ROC curves for each class
plt.figure()
colors = ['red', 'blue', 'green', 'orange', 'purple']
```

```
for i, color in zip(range(5), colors):
    plt.plot(fpr[i], tpr[i], color=color, lw=2, label=f'ROC curve (class {i})␣
 ↪(area = {roc_auc[i]:.2f})')

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 Multiclass')
plt.legend(loc='lower right')
plt.show()


# 7. Confusion Matrix
y_pred_classes = np.argmax(y_pred, axis=1)
cm = confusion_matrix(y_true_classes, y_pred_classes)
sns.heatmap(cm, annot=True, fmt='g')
plt.show()

# 8. Classification Report
print(classification_report(y_true_classes, y_pred_classes,␣
 ↪target_names=list(y_dict.keys())))
```

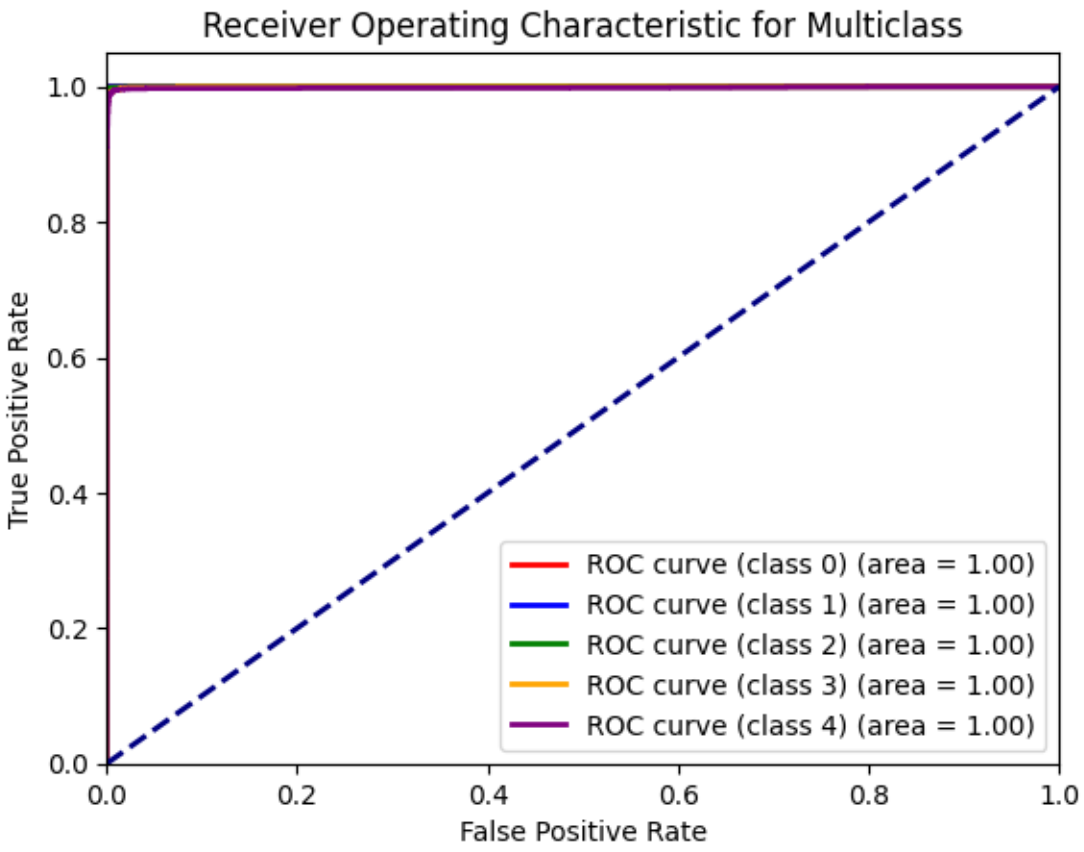
```
/Users/nekdilkhan/miniforge3/lib/python3.12/site-
packages/keras/src/layers/core/embedding.py:90: UserWarning: Argument
`input_length` is deprecated. Just remove it.
  warnings.warn(
```

```
> Average Accuracy across 5-folds: 97.16% (+/- 0.12%)
```

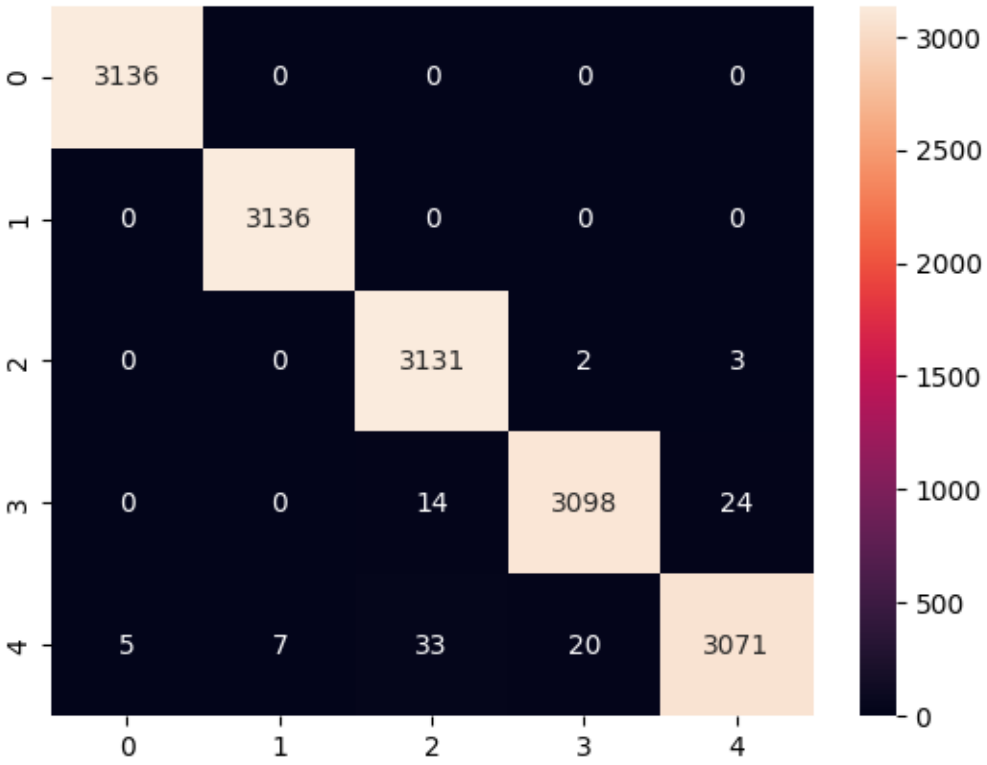



```
490/490              2s 4ms/step
490/490              2s 4ms/step
```

[6]:


Receiver Operating Characteristic for Multiclass
True Positive Rate
False Positive Rate
0.0
0.2
0.4
0.6
0.8
1.0
ROC curve (class 0) (area = 1.00)
ROC curve (class 1) (area = 1.00)
ROC curve (class 2) (area = 1.00)
ROC curve (class 3) (area = 1.00)
ROC curve (class 4) (area = 1.00)

[7]:



[8]:

```
                                                    precision    recall
f1-score   support

          Navigation and Interaction Problems (NAV)       1.00      1.00
1.00      3136
                   Input and Control Issues (INPUT)       1.00      1.00
1.00      3136
    Compatibility with Assistive Technologies (CAT)       0.99      1.00
0.99      3136
                      UI Accessibility Issues (UI)       0.99      0.99
0.99      3136
Audio and Visual Accessibility issues (AUDIOVISUAL)       0.99      0.98
0.99      3136

                                          accuracy
0.99     15680
                                         macro avg       0.99      0.99
0.99     15680
                                      weighted avg       0.99      0.99
0.99     15680
```

[9]:
```
import pandas as pd
import numpy as np
import re
from nltk.stem import WordNetLemmatizer
from sklearn.model_selection import KFold
from tensorflow.keras.preprocessing.text import Tokenizer
from tensorflow.keras.preprocessing.sequence import pad_sequences
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Embedding, Conv1D, MaxPooling1D, Flatten,␣
 ↪Dropout, Dense
from tensorflow.keras.optimizers import Adam
from sklearn.metrics import confusion_matrix, classification_report
import matplotlib.pyplot as plt
import seaborn as sns
from imblearn.over_sampling import RandomOverSampler
from sklearn.preprocessing import label_binarize
from sklearn.metrics import roc_curve, auc


# Assuming X and y are defined already, and data preprocessing is done
# Example: X = ... , y = ...

# 2. Oversample to balance classes
oversampler = RandomOverSampler(random_state=42)
X_resampled, y_resampled = oversampler.fit_resample(X, y)

# 3. Define the CNN model
def create_model():
    model = Sequential()
    model.add(Embedding(input_dim=vocab_size, output_dim=100,␣
 ↪input_length=maxlen))
    model.add(Conv1D(128, 5, activation='relu'))
    model.add(MaxPooling1D(pool_size=2))
    model.add(Flatten())
    model.add(Dropout(0.2))
    model.add(Dense(5, activation='softmax'))
    model.compile(optimizer=Adam(learning_rate=0.001),␣
 ↪loss='categorical_crossentropy', metrics=['accuracy'])
    return model

# 4. K-Fold Cross-Validation
n_folds = 5
kfold = KFold(n_splits=n_folds, shuffle=True)
fold_no = 1
acc_per_fold = []
```

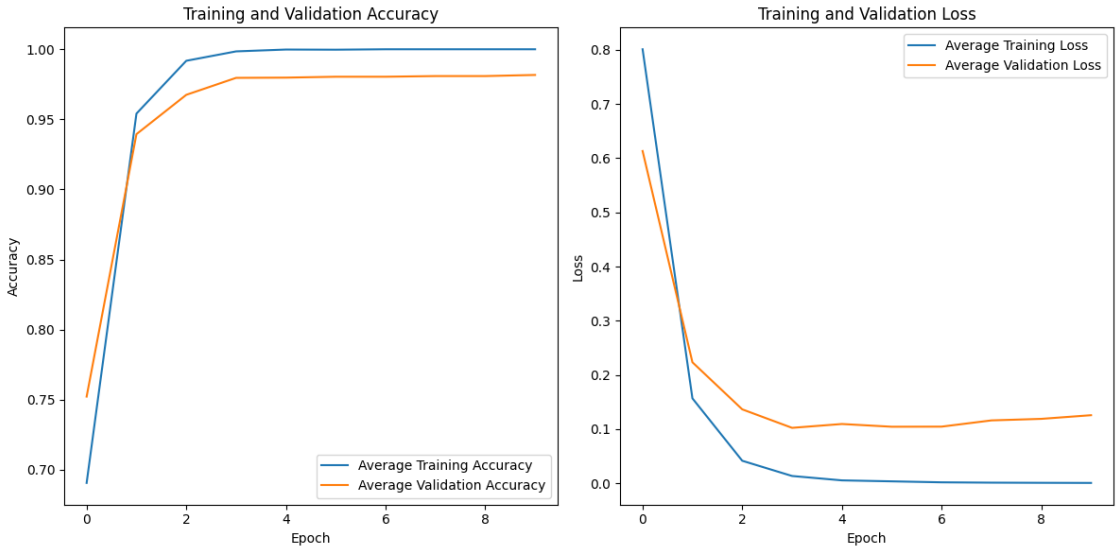
```
# Lists to store average accuracies and losses across folds
avg_train_acc = []
avg_val_acc = []
avg_train_loss = []
avg_val_loss = []

for train, test in kfold.split(X_resampled, y_resampled):
    model = create_model()
    history = model.fit(X_resampled[train], y_resampled[train],␣
 ↪validation_split=0.1, epochs=10, batch_size=32, verbose=0)

    avg_train_acc.append(history.history['accuracy'])
    avg_val_acc.append(history.history['val_accuracy'])
    avg_train_loss.append(history.history['loss'])
    avg_val_loss.append(history.history['val_loss'])

    scores = model.evaluate(X_resampled[test], y_resampled[test], verbose=0)
    acc_per_fold.append(scores[1] * 100)
    fold_no += 1

# 5. Performance Metrics
print(f'> Average Accuracy across {n_folds}-folds: {np.mean(acc_per_fold):.2f}%␣
 ↪(+/- {np.std(acc_per_fold):.2f}%)')

# 6. Plotting Training and Validation Accuracy and Loss in the same graph
def plot_history():
    plt.figure(figsize=(12, 6))

    # Plot for model accuracy
    plt.subplot(1, 2, 1)
    plt.plot(np.mean(avg_train_acc, axis=0), label='Average Training Accuracy')
    plt.plot(np.mean(avg_val_acc, axis=0), label='Average Validation Accuracy')
    plt.title('Training and Validation Accuracy')
    plt.xlabel('Epoch')
    plt.ylabel('Accuracy')
    plt.legend()

    # Plot for model loss
    plt.subplot(1, 2, 2)
    plt.plot(np.mean(avg_train_loss, axis=0), label='Average Training Loss')
    plt.plot(np.mean(avg_val_loss, axis=0), label='Average Validation Loss')
    plt.title('Training and Validation Loss')
    plt.xlabel('Epoch')
    plt.ylabel('Loss')
    plt.legend()
```

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

# Plot the results
plot_history()

# 7. ROC curve
y_pred = model.predict(X_resampled)
y_true_classes = np.argmax(y_resampled, axis=1)
y_pred_probs = model.predict(X_resampled)

# Binarize the true labels for ROC
y_true_binarized = label_binarize(y_true_classes, classes=[0, 1, 2, 3, 4, 5, 6,␣
 ↪7])

# Initialize variables to store fpr, tpr, and auc for each class
fpr = dict()
tpr = dict()
roc_auc = dict()

# Calculate ROC curve and AUC for each class
for i in range(5):
    fpr[i], tpr[i], _ = roc_curve(y_true_binarized[:, i], y_pred_probs[:, i])
    roc_auc[i] = auc(fpr[i], tpr[i])

# Plot ROC curves for each class
plt.figure()
colors = ['red', 'blue', 'green', 'orange', 'purple']
for i, color in zip(range(5), colors):
    plt.plot(fpr[i], tpr[i], color=color, lw=2, label=f'ROC curve (class {i})␣
 ↪(area = {roc_auc[i]:.2f})')

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 Multiclass')
plt.legend(loc='lower right')
plt.show()

# 8. Confusion Matrix
y_pred_classes = np.argmax(y_pred, axis=1)
cm = confusion_matrix(y_true_classes, y_pred_classes)
sns.heatmap(cm, annot=True, fmt='g')
plt.title('Confusion Matrix')
plt.show()
```

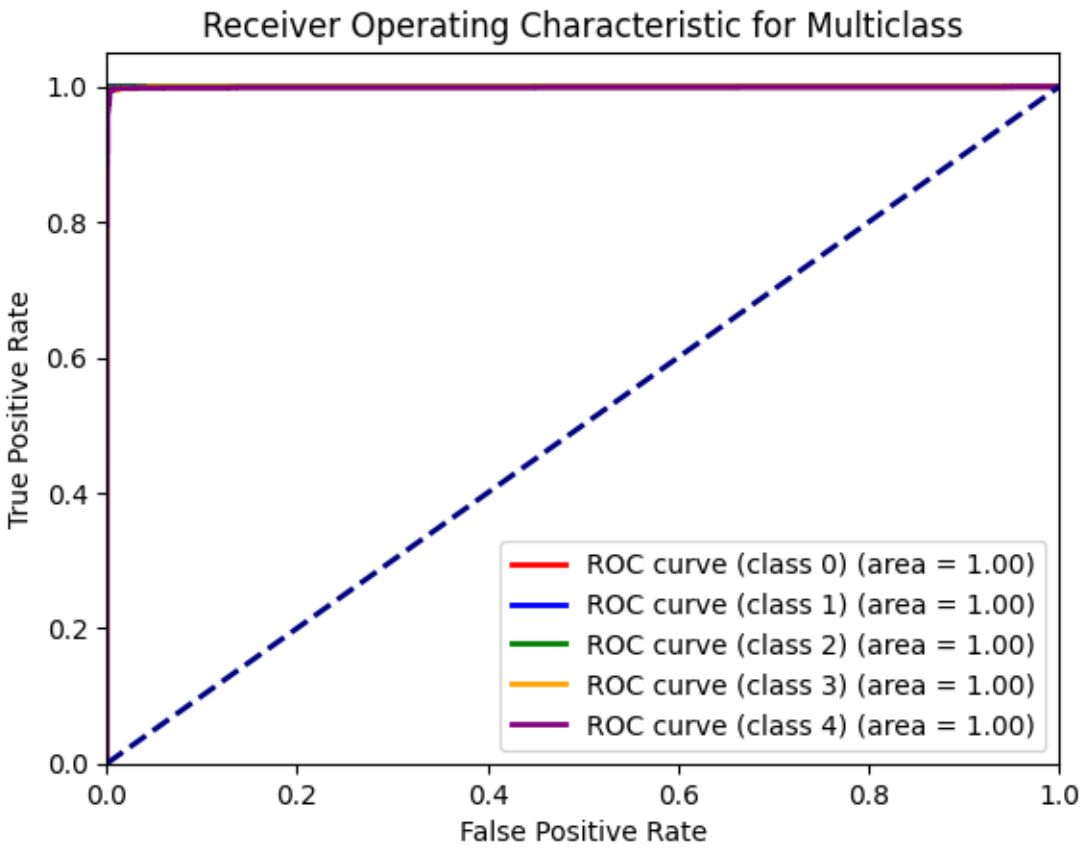
```
# 9. Classification Report
print(classification_report(y_true_classes, y_pred_classes,␣
  ↪target_names=[f"Class {i}" for i in range(5)]))
```

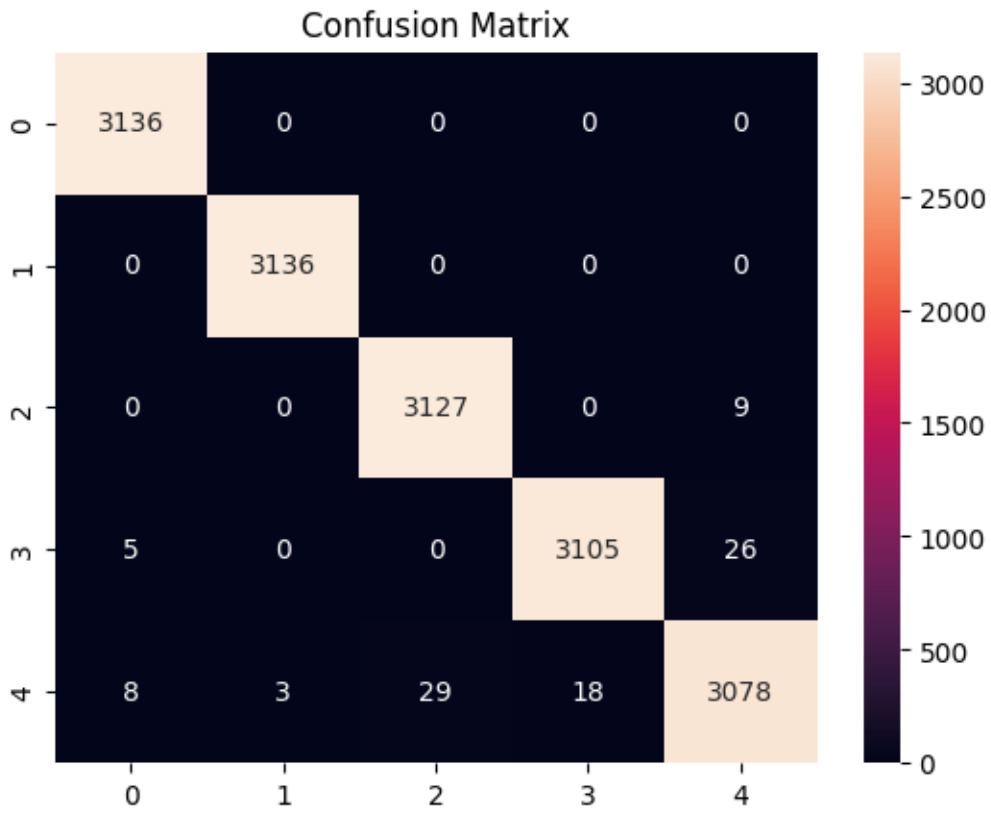
```
/Users/nekdilkhan/miniforge3/lib/python3.12/site-
packages/keras/src/layers/core/embedding.py:90: UserWarning: Argument
`input_length` is deprecated. Just remove it.
  warnings.warn(
```

```
> Average Accuracy across 5-folds: 96.94% (+/- 0.41%)
```




```
490/490                2s 4ms/step
490/490                2s 4ms/step
```


Receiver Operating Characteristic for Multiclass
True Positive Rate
False Positive Rate
0.0
0.2
0.4
0.6
0.8
1.0
ROC curve (class 0) (area = 1.00)
ROC curve (class 1) (area = 1.00)
ROC curve (class 2) (area = 1.00)
ROC curve (class 3) (area = 1.00)
ROC curve (class 4) (area = 1.00)



	precision	recall	f1-score	support
Class 0	1.00	1.00	1.00	3136
Class 1	1.00	1.00	1.00	3136
Class 2	0.99	1.00	0.99	3136
Class 3	0.99	0.99	0.99	3136
Class 4	0.99	0.98	0.99	3136
accuracy			0.99	15680
macro avg	0.99	0.99	0.99	15680
weighted avg	0.99	0.99	0.99	15680

[ ]: