English Accent Detection: A Comparison of Audio, Spectrogram and Text Classification Method using Transformers

Colab Link: https://colab.research.google.com/drive/1V59vfCSLv6DxCXBrqy1M9k081DuEAcjB?usp=sharing

Candidate Numbers: 31948, 24692, 24155

Date: 29 April 2024

Audio Array Classification

In [35]:

```
%%capture
! pip install datasets evaluate
! pip install accelerate
! pip install wandb
```

In [2]:

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

```
Drive already mounted at /content/drive; to attempt to forcibly remount, call drive.mount(
"/content/drive", force_remount=True).
```

In [37]:

```
import pandas as pd
import numpy as np
import os
```

In [ ]:

```
from datasets import Dataset, Audio, load_dataset
from sklearn.model_selection import train_test_split
import pyarrow.parquet as pq
from transformers import Wav2Vec2Processor
import random
from sklearn.utils.class_weight import compute_class_weight
```

In [5]:

```
from transformers import AutoModelForAudioClassification, TrainingArguments, Trainer, Aut
oFeatureExtractor
import evaluate
from datasets import Dataset, Audio
import torch
```

In [6]:

```
from transformers import EarlyStoppingCallback, IntervalStrategy
```

In [7]:

```
from datasets import load_from_disk
```

In [8]:

```
import wandb
wandb.login()
wandb.init(project="accents_classification")
```

```
wandb: Logging into wandb.ai. (Learn how to deploy a W&B server locally: https://wandb.me/
wandb-server)
wandb: You can find your API key in your browser here: https://wandb.ai/authorize
wandb: Paste an API key from your profile and hit enter, or press ctrl+c to quit:
```

```
 ..........
```

```
wandb: Appending key for api.wandb.ai to your netrc file: /root/.netrc
wandb: Currently logged in as: yiwe (yiweizhou). Use `wandb login --relogin` to force relo
gin
```

Tracking run with wandb version 0.16.6

Run data is saved locally in `/content/wandb/run-20240428_211525-5bhqlbh6`

Syncing run [revived-bee-5](https://wandb.ai/yiweizhou/accents_classification/runs/5bhqlbh6) to [Weights & Biases](https://wandb.ai) ([docs](https://wandb.me/run))

View project at https://wandb.ai/yiweizhou/accents_classification

View run at https://wandb.ai/yiweizhou/accents_classification/runs/5bhqlbh6

Out[8]:

Display W&B run

In [ ]:

```
# Change directory to data location
os.chdir("/content/drive/My Drive/ST311")
```

In [ ]:

```
# Load data
df0 = pq.read_table(source= '0000.parquet').to_pandas()
df1 = pq.read_table(source= '0001.parquet').to_pandas()
df2 = pq.read_table(source= '0002.parquet').to_pandas()
df3 = pq.read_table(source= '0003.parquet').to_pandas()
df4 = pq.read_table(source= '0004.parquet').to_pandas()
df5 = pq.read_table(source= '0005.parquet').to_pandas()
df6 = pq.read_table(source= '0006.parquet').to_pandas()
df7 = pq.read_table(source= '0007.parquet').to_pandas()
data = pd.concat([df0,df1,df2,df3,df4,df5,df6,df7])
data.reset_index(drop=True, inplace=True)
```

In [ ]:

```
data = data.drop(['path'], axis=1)
data = data.drop(['up_votes'], axis=1)
data = data.drop(['down_votes'], axis=1)
data = data.drop(['age'], axis=1)
data = data.drop(['gender'], axis=1)

#train test split
train_data, test_data = train_test_split(data, test_size=0.2, random_state=42)
```

In [ ]:

```
data.value_counts()
```

In [14]:

```
print(len(data), len(train_data), len(test_data))
```

```
7678 6142 1536
```

In [ ]:

```
test_data.iloc[1529]
```

Out[ ]:

```
accents                                      United States English
accents                                        United States English
sentence                                      They are on the ground.
audio        {'array': [2.2737367544323206e-12, 9.094947017...
Name: 7482, dtype: object
```

In [ ]:

```
test_data['accents'].value_counts()
```

Out[ ]:

```
accents
United States English                                    670
India and South Asia (India, Pakistan, Sri Lanka)        225
England English                                          203
Filipino                                                 136
Australian English                                       135
Canadian English                                         100
Irish English                                             39
Scottish English                                          28
Name: count, dtype: int64
```

In [ ]:

```
train_data['accents'].value_counts()
```

Out[ ]:

```
accents
United States English                                    2577
India and South Asia (India, Pakistan, Sri Lanka)         963
England English                                           891
Australian English                                        528
Filipino                                                  471
Canadian English                                          395
Irish English                                             226
Scottish English                                           91
Name: count, dtype: int64
```

In [ ]:

```
test_data.iloc[0,2]
```

Out[ ]:

```
{'array': array([ 0.00000000e+00,  2.18278728e-11,  1.45519152e-11, ...,
        -4.17522733e-06, -4.00739464e-06,  1.34157199e-06]),
 'path': './accents/datasets/common_voice_16_1/en/clips/common_voice_en_20275899.mp3',
 'sampling_rate': 16000}
```

In [ ]:

```
weights = compute_class_weight(class_weight = "balanced", classes = np.unique(data['accen
ts']), y = train_data['accents'])
print(weights)
```

```
[1.45407197 1.94367089 0.86167228 1.63004246 0.79724818 3.39712389
 8.43681319 0.29792394]
```

In [ ]:

```
train_ds = Dataset.from_pandas(train_data)
test_ds = Dataset.from_pandas(test_data)
```

In [ ]:

```
train_ds = train_ds.class_encode_column("accents")
test_ds = test_ds.class_encode_column("accents")
```

20% 80% split\ accents column类型转换了

Audio Classification without Spectrogram

In [ ]:

```
train_ds = train_ds.remove_columns("sentence")
test_ds = test_ds.remove_columns("sentence")
```

In [ ]:

```
# labels = accents_ds["train"].features["accents"].names
# label2id, id2label = dict(), dict()
# for i, label in enumerate(labels):
#     label2id[label] = str(i)
#     id2label[str(i)] = label
```

In [ ]:

```
label2id = {'Australian English': '0',
 'Canadian English': '1',
 'England English': '2',
 'Filipino': '3',
 'India and South Asia (India, Pakistan, Sri Lanka)': '4',
 'Irish English': '5',
 'Scottish English': '6',
 'United States English': '7'}
id2label = {'0': 'Australian English',
 '1': 'Canadian English',
 '2': 'England English',
 '3': 'Filipino',
 '4': 'India and South Asia (India, Pakistan, Sri Lanka)',
 '5': 'Irish English',
 '6': 'Scottish English',
 '7': 'United States English'}
```

In [10]:

```
feature_extractor = AutoFeatureExtractor.from_pretrained("facebook/wav2vec2-base")
```

```
/usr/local/lib/python3.10/dist-packages/huggingface_hub/utils/_token.py:89: UserWarning:
The secret `HF_TOKEN` does not exist in your Colab secrets.
To authenticate with the Hugging Face Hub, create a token in your settings tab (https://hu
ggingface.co/settings/tokens), set it as secret in your Google Colab and restart your sess
ion.
You will be able to reuse this secret in all of your notebooks.
Please note that authentication is recommended but still optional to access public models
or datasets.
  warnings.warn(
```

```
/usr/local/lib/python3.10/dist-packages/transformers/configuration_utils.py:363: UserWarni
ng: Passing `gradient_checkpointing` to a config initialization is deprecated and will be
removed in v5 Transformers. Using `model.gradient_checkpointing_enable()` instead, or if y
ou are using the `Trainer` API, pass `gradient_checkpointing=True` in your `TrainingArgume
nts`.
  warnings.warn(
```

In [11]:

```
feature_extractor
```

Out[11]:

```
Wav2Vec2FeatureExtractor {
  "do_normalize": true,
  "feature_extractor_type": "Wav2Vec2FeatureExtractor",
  "feature_size": 1,
  "padding_side": "right",
  "padding_value": 0.0,
  "return_attention_mask": false,
  "sampling_rate": 16000
}
```

In [ ]:

```
def transform_audio(example):
    array = np.array(example['audio']['array'], dtype=np.float32)
    sampling_rate = example['audio']['sampling_rate']  # Already set correctly, just referencing it
    return {'audio': {'array': array, 'sampling_rate': sampling_rate}}
```

In [ ]:

```
train_ds = train_ds.map(transform_audio)
test_ds = test_ds.map(transform_audio)
```

In [ ]:

```
train_ds = train_ds.cast_column("audio", Audio(sampling_rate=16_000))
test_ds = test_ds.cast_column("audio", Audio(sampling_rate=16_000))
```

In [ ]:

```
def preprocess_function(examples):
    audio_arrays = [x["array"] for x in examples["audio"]]
    inputs = feature_extractor(
        audio_arrays, sampling_rate=feature_extractor.sampling_rate, max_length=160000, truncation=True
    )

    return inputs

# Apply preprocessing
train_ds = train_ds.map(preprocess_function, remove_columns=["audio"], batched=True)
test_ds = test_ds.map(preprocess_function, remove_columns=["audio"], batched=True)

# Rename 'accents' column to 'label'
train_ds = train_ds.rename_column("accents", "label")
test_ds = test_ds.rename_column("accents", "label")
```

In [ ]:

```
train_ds.save_to_disk("train_23")
test_ds.save_to_disk("test_23")
```

In [ ]:

```
train_ds = load_from_disk("train_23")
test_ds = load_from_disk("test_23")
```

In [ ]:

```
# accuracy = evaluate.load("accuracy")
# f1 = evaluate.load("f1")
# def compute_metrics(eval_pred):
#     predictions = np.argmax(eval_pred.predictions, axis=1)
#     return {
#         'accuracy': accuracy.compute(predictions=predictions, references=eval_pred.label_ids),
#         'f1': f1.compute(predictions=predictions, references=eval_pred.label_ids, average='weighted')
#     }
```

In [ ]:

```
accuracy = evaluate.load("accuracy")
f1 = evaluate.load("f1")
precision = evaluate.load("precision")
recall = evaluate.load("recall")
mcc = evaluate.load("matthews_correlation")
```

```
def compute_metrics(eval_pred):
    predictions = np.argmax(eval_pred.predictions, axis=1)
    references = eval_pred.label_ids
    return {
        'accuracy': accuracy.compute(predictions=predictions, references=references)['accuracy'],
        'f1_weighted': f1.compute(predictions=predictions, references=references, average='weighted')['f1'],
        'precision_weighted': precision.compute(predictions=predictions, references=references, average='weighted')['precision'],
        'recall_weighted': recall.compute(predictions=predictions, references=references, average='weighted')['recall'],
        'mcc': mcc.compute(predictions=predictions, references=references)['matthews_correlation']
    }
```

In [ ]:

```
num_labels = 8
model = AutoModelForAudioClassification.from_pretrained(
    "facebook/wav2vec2-base", num_labels=num_labels, label2id=label2id, id2label=id2label
)
```

```
/usr/local/lib/python3.10/dist-packages/transformers/configuration_utils.py:363: UserWarning: Passing `gradient_checkpointing` to a config initialization is deprecated and will be removed in v5 Transformers. Using `model.gradient_checkpointing_enable()` instead, or if you are using the `Trainer` API, pass `gradient_checkpointing=True` in your `TrainingArguments`.
  warnings.warn(
Some weights of Wav2Vec2ForSequenceClassification were not initialized from the model checkpoint at facebook/wav2vec2-base and are newly initialized: ['classifier.bias', 'classifier.weight', 'projector.bias', 'projector.weight', 'wav2vec2.encoder.pos_conv_embed.conv.parametrizations.weight.original0', 'wav2vec2.encoder.pos_conv_embed.conv.parametrizations.weight.original1']
You should probably TRAIN this model on a down-stream task to be able to use it for predictions and inference.
```

In [ ]:

```
ordered_weights = [1.4475867269984917,
 1.9388888888888889,
 0.8772851919561243,
 1.581136738056013,
 0.8078703703703703,
 3.621698113207547,
 8.065126050420169,
 0.2955805358792732]
```

In [ ]:

```
classes = list(id2label.values())
class_weights = dict(zip(classes, weights))
print(class_weights)
ordered_weights = [class_weights[x] for x in id2label.values()]
```

In [ ]:

```
wandb.init(project="accents_classification_28", name = "run_2")
```

Finishing last run (ID:8cklz8mv) before initializing another...

Run history:

eval/accuracy	
eval/f1_weighted	
eval/loss	

eval/mcc	
eval/precision_weighted	
eval/recall_weighted	
eval/runtime	
eval/samples_per_second	
eval/steps_per_second	
train/epoch	
train/global_step	
train/grad_norm	
train/learning_rate	
train/loss	

Run summary:

eval/accuracy	0.71354
eval/f1_weighted	0.7255
eval/loss	1.65135
eval/mcc	0.67784
eval/precision_weighted	0.82566
eval/recall_weighted	0.71354
eval/runtime	71.2861
eval/samples_per_second	21.547
eval/steps_per_second	0.673
train/epoch	1.45833
train/global_step	70
train/grad_norm	2.82574
train/learning_rate	2e-05
train/loss	1.3193

View run run_1 at: https://wandb.ai/yiweizhou/accents_classification_28/runs/8cklz8mv
View project at: https://wandb.ai/yiweizhou/accents_classification_28
Synced 5 W&B file(s), 0 media file(s), 0 artifact file(s) and 0 other file(s)

Find logs at: `/content/wandb/run-20240428_144952-8cklz8mv/logs`

Successfully finished last run (ID:8cklz8mv). Initializing new run:

Tracking run with wandb version 0.16.6

Run data is saved locally in `/content/wandb/run-20240428_151625-4w4gl03o`

Syncing run run_2 to Weights & Biases (docs)

View project at https://wandb.ai/yiweizhou/accents_classification_28

View run at https://wandb.ai/yiweizhou/accents_classification_28/runs/4w4gl03o

Out[ ]:

Display W&B run

In [ ]:

```
training_args = TrainingArguments(
    output_dir="wav2vec-23",
    evaluation_strategy=IntervalStrategy.STEPS,
    eval_steps = 50,
    save_strategy=IntervalStrategy.STEPS,
    save_steps = 100,
    save_total_limit = 4,
    learning_rate=2e-5,
    per_device_train_batch_size=32,
    gradient_accumulation_steps=4,
    per_device_eval_batch_size=32,
    num_train_epochs=10,
    warmup_ratio=0.1,
    logging_steps=10,
    load_best_model_at_end=True,
    metric_for_best_model="accuracy",
    push_to_hub=False,
    report_to="wandb"
)
```

In [ ]:

```
class WeightedTrainer(Trainer):
    def compute_loss(self, model, inputs, return_outputs=False):
        labels = inputs.pop("labels")
        # forward pass
        outputs = model(**inputs)
        logits = outputs.get("logits")
        # compute custom loss (suppose one has labels with different weights)
        loss_fct = torch.nn.CrossEntropyLoss(weight=torch.tensor(ordered_weights, device=
model.device).float())
        loss = loss_fct(logits.view(-1, self.model.config.num_labels), labels.view(-1))
        return (loss, outputs) if return_outputs else loss
```

In [ ]:

```
trainer = WeightedTrainer(
    model=model,
    args=training_args,
    train_dataset=train_ds,
    eval_dataset=test_ds,
    tokenizer=feature_extractor,
    compute_metrics=compute_metrics,
    callbacks = [EarlyStoppingCallback(early_stopping_patience=2)]
)
```

In [ ]:

```
trainer.evaluate()
```

[48/48 01:10]

```
/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:1344: Undefined
MetricWarning: Precision is ill-defined and being set to 0.0 in labels with no predicted s
amples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
```

Out[ ]:

```
{'eval_loss': 2.081277847290039,
 'eval_accuracy': 0.095703125,
 'eval_f1_weighted': 0.11839429320686339,
 'eval_precision_weighted': 0.27227572133292505,
 'eval_recall_weighted': 0.095703125,
 'eval_mcc': -0.0022599274251548247,
 'eval_runtime': 73.9545,
 'eval_samples_per_second': 20.77,
 'eval_steps_per_second': 0.649}
```

In [ ]:

```
trained = trainer.train()
```

[462/480 1:16:22 < 02:59, 0.10 it/s, Epoch 9.60/10]

Step	Training Loss	Validation Loss	Accuracy	F1 Weighted	Precision Weighted	Recall Weighted	Mcc
50	1.837200	1.764204	0.757812	0.746339	0.794171	0.757812	0.676719
100	1.001900	0.891448	0.973307	0.973553	0.975202	0.973307	0.965212
150	0.555400	0.492019	0.995443	0.995428	0.995512	0.995443	0.993934
200	0.342900	0.296086	0.994792	0.994799	0.994855	0.994792	0.993071
250	0.236300	0.204503	0.998047	0.998049	0.998065	0.998047	0.997397
300	0.181300	0.164038	0.997396	0.997394	0.997412	0.997396	0.996528
350	0.147500	0.132456	0.998698	0.998701	0.998714	0.998698	0.998265
400	0.132700	0.117824	0.998698	0.998701	0.998714	0.998698	0.998265
450	0.123200	0.112002	0.998047	0.998050	0.998062	0.998047	0.997397

[48/48 09:30]

[480/480 1:19:03, Epoch 10/10]

Step	Training Loss	Validation Loss	Accuracy	F1 Weighted	Precision Weighted	Recall Weighted	Mcc
50	1.837200	1.764204	0.757812	0.746339	0.794171	0.757812	0.676719
100	1.001900	0.891448	0.973307	0.973553	0.975202	0.973307	0.965212
150	0.555400	0.492019	0.995443	0.995428	0.995512	0.995443	0.993934
200	0.342900	0.296086	0.994792	0.994799	0.994855	0.994792	0.993071
250	0.236300	0.204503	0.998047	0.998049	0.998065	0.998047	0.997397
300	0.181300	0.164038	0.997396	0.997394	0.997412	0.997396	0.996528
350	0.147500	0.132456	0.998698	0.998701	0.998714	0.998698	0.998265
400	0.132700	0.117824	0.998698	0.998701	0.998714	0.998698	0.998265
450	0.123200	0.112002	0.998047	0.998050	0.998062	0.998047	0.997397

In [ ]:

```
trainer.evaluate()
```

[48/48 01:09]

Out[ ]:

```
{'eval_loss': 0.11782387644052505,
 'eval_accuracy': 0.9986979166666666,
 'eval_f1_weighted': 0.9987012334284002,
 'eval_precision_weighted': 0.9987141927083334,
 'eval_recall_weighted': 0.9986979166666666,
 'eval_mcc': 0.9982646808828041,
 'eval_runtime': 72.4762,
 'eval_samples_per_second': 21.193,
 'eval_steps_per_second': 0.662,
 'epoch': 10.0}
```

In [ ]:

```
trained
```

Out[ ]:

```
TrainOutput(global_step=240, training_loss=0.7800431281328202, metrics={'train_runtime': 3
625.1638, 'train_samples_per_second': 8.471, 'train_steps_per_second': 0.066, 'total_flos'
: 2.400507469299843e+18, 'train_loss': 0.7800431281328202, 'epoch': 5.0})
```

In [ ]:

In [ ]:

```
trainer.save_model("audio_27apr")
```

In [ ]:

```
trainer.evaluate()
```

In [4]:

```
#confusion matrix
from sklearn.metrics import confusion_matrix
import seaborn as sns
import matplotlib.pyplot as plt
```

In [ ]:

```
predictions = trainer.predict(test_ds)
y_pred = np.argmax(predictions.predictions, axis=1)
y_true = test_ds['label']
```

In [ ]:

```
y_true_names = [id2label[str(id)] for id in y_true]
y_pred_names = [id2label[str(id)] for id in y_pred]
```

In [ ]:

```
cm2 = confusion_matrix(y_true_names, y_pred_names, labels = list(id2label.values()))
```

In [ ]:

```
cm2
```

Out[ ]:

```
array([[135,   0,   0,   0,   0,   0,   0,   0],
       [  0, 100,   0,   0,   0,   0,   0,   0],
       [  0,   0, 202,   0,   0,   0,   0,   1],
       [  0,   0,   0, 136,   0,   0,   0,   0],
       [  0,   0,   0,   0, 225,   0,   0,   0],
       [  0,   0,   0,   0,   0,  39,   0,   0],
       [  0,   0,   0,   0,   0,   0,  28,   0],
       [  0,   0,   0,   0,   0,   1,   0, 669]])
```

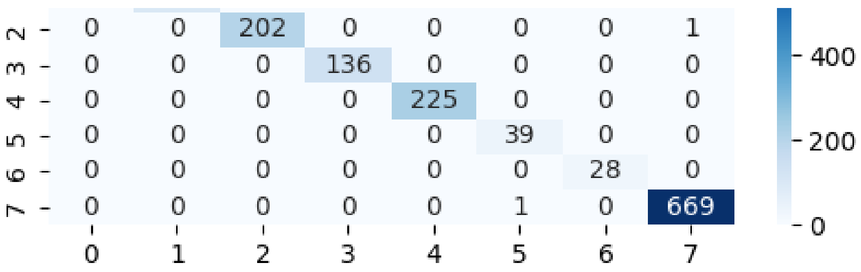
In [6]:

```
cm = np.array([[135,   0,   0,   0,   0,   0,   0,   0],
       [  0, 100,   0,   0,   0,   0,   0,   0],
       [  0,   0, 202,   0,   0,   0,   0,   1],
       [  0,   0,   0, 136,   0,   0,   0,   0],
       [  0,   0,   0,   0, 225,   0,   0,   0],
       [  0,   0,   0,   0,   0,  39,   0,   0],
       [  0,   0,   0,   0,   0,   0,  28,   0],
       [  0,   0,   0,   0,   0,   1,   0, 669]])
```

In [34]:

```
plt.figure(figsize=(6, 2))
plt.xlabel('Predicted labels')
plt.ylabel('True labels')
plt.title('True (X) and False Labels (Y)', fontsize = 10)
ax = sns.heatmap(cm, annot=True, fmt='g', cmap='Blues')

# Saving the figure with a high DPI
plt.savefig('cm_audio.png', dpi=1000)
```

True (X) and False Labels (Y)
0
1
135 0 0 0 0 0 0 0
0 100 0 0 0 0 0 0
600



In [ ]:

```
np.flatnonzero(y_true != y_pred)
```

Out[ ]:

```
array([ 469, 1529])
```

In [ ]:

```
id2label.values()
```

Out[ ]:

```
dict_values(['Australian English', 'Canadian English', 'England English', 'Filipino', 'Ind
ia and South Asia (India, Pakistan, Sri Lanka)', 'Irish English', 'Scottish English', 'Uni
ted States English'])
```

In [ ]:

```
id2label.values()
```

Out[ ]:

```
dict_values(['Australian English', 'Canadian English', 'England English', 'Filipino', 'Ind
ia and South Asia (India, Pakistan, Sri Lanka)', 'Irish English', 'Scottish English', 'Uni
ted States English'])
```

In [ ]:

```
y_true[469]
```

Out[ ]:

```
2
```

In [ ]:

```
y_pred[469]
```

Out[ ]:

```
7
```

In [ ]:

```
y_true[1529]
```

Out[ ]:

```
7
```

In [ ]:

```
y_pred[1529]
```

Out[ ]:

```
5
```

In [ ]:

```
# pred = irish
test_data.iloc[[1529]]
```

Out[ ]:

	accents	sentence	audio
7482	United States English	They are on the ground.	{'array': [2.2737367544323206e-12, 9.094947017...

In [ ]:

```
# pred = US
test_data.iloc[[469]]
```

Out[ ]:

	accents	sentence	audio
965	England English	As you wish.	{'array': [0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, ...

In [ ]:

```
# from numba import cuda
# device = cuda.get_current_device()
# device.reset()
```

In [ ]:

```
# model_local = AutoModelForAudioClassification.from_pretrained('audio_27apr')
```

Spectrogram Classification

In [ ]:

```
# !pip install librosa
# !pip install --upgrade transformers
# !pip install accelerate -U
```

In [ ]:

```
import os
import torch
import torchvision
import torch.nn as nn
import matplotlib.pyplot as plt
from torchvision import datasets, transforms
from torch.utils.data import DataLoader, SubsetRandomSampler
import torch.optim as optim
import time
import numpy as np
import pandas as pd
from tqdm.autonotebook import tqdm
from PIL import Image
import IPython.display as ipd
import numpy as np
import librosa


cuda = torch.cuda.is_available()
```

In [ ]:

```
import pyarrow.parquet as pq
```

```
df0 = pq.read_table(source= '0000.parquet').to_pandas()
df1 = pq.read_table(source= '0001.parquet').to_pandas()
df2 = pq.read_table(source= '0002.parquet').to_pandas()
df3 = pq.read_table(source= '0003.parquet').to_pandas()
df4 = pq.read_table(source= '0004.parquet').to_pandas()
df5 = pq.read_table(source= '0005.parquet').to_pandas()
df6 = pq.read_table(source= '0006.parquet').to_pandas()
df7 = pq.read_table(source= '0007.parquet').to_pandas()
```

Method 2: Add noise, change pitch and change speed

In [ ]:

```
data = pd.concat([df0,df1,df2,df3,df4,df5,df6,df7])
data.reset_index(drop=True, inplace=True)
data = data.drop(['path'], axis=1)
data = data.drop(['up_votes'], axis=1)
data = data.drop(['down_votes'], axis=1)
data = data.drop(['age'], axis=1)
data = data.drop(['gender'], axis=1)

#train test split
from sklearn.model_selection import train_test_split
data, test_data = train_test_split(data, test_size=0.2, random_state=42)

data['accents'].value_counts()
```

Out[ ]:

```
United States English                                2577
India and South Asia (India, Pakistan, Sri Lanka)     963
England English                                       891
Australian English                                    528
Filipino                                              471
Canadian English                                      395
Irish English                                         226
Scottish English                                       91
Name: accents, dtype: int64
```

In [ ]:

```
test_data['accents'].value_counts()
```

Out[ ]:

```
United States English                                670
India and South Asia (India, Pakistan, Sri Lanka)    225
England English                                      203
Filipino                                             136
Australian English                                   135
Canadian English                                     100
Irish English                                         39
Scottish English                                      28
Name: accents, dtype: int64
```

In [ ]:

```
new_audio = []
for r in data['audio']:
    new_audio.append(r['array'])
data['audio'] = new_audio
```

In [ ]:

```
us = data[data['accents'] == 'United States English']
us = us[:800]

indian = data[data['accents'] == 'India and South Asia (India, Pakistan, Sri Lanka)']
indian = indian[:800]

england = data[data['accents'] == 'England English']
england = england[:800]

filipino = data[data['accents'] == 'Filipino']
filipino.reset_index(drop=True, inplace=True)

australian = data[data['accents'] == 'Australian English']
australian.reset_index(drop=True, inplace=True)

scottish = data[data['accents'] == 'Scottish English']
scottish.reset_index(drop=True, inplace=True)

irish = data[data['accents'] == 'Irish English']
irish.reset_index(drop=True, inplace=True)

canadian = data[data['accents'] == 'Canadian English']
canadian.reset_index(drop=True, inplace=True)
```

In [ ]:

```
scottish_arrays = scottish['audio']
irish_arrays = irish['audio']
canadian_arrays = canadian['audio']
australian_arrays = australian['audio']
filipino_arrays = filipino['audio']
```

In [ ]:

```
sampling_rate = 16000  # This is the sampling rate from your data

# Function to add noise
def add_noise(audio, noise_level=0.005):
    noise = np.random.randn(len(audio))
    augmented_audio = audio + noise_level * noise
    return augmented_audio

# Function to change pitch
def change_pitch(audio, sampling_rate, n_steps=5):
    return librosa.effects.pitch_shift(audio, sr=sampling_rate, n_steps=n_steps)

# Function to change speed
def change_speed(audio, speed_factor=1.5):
    return librosa.effects.time_stretch(audio, rate=speed_factor)
```

In [ ]:

```
scottish_augmented = []
irish_augmented = []
canadian_augmented = []
australian_augmented = []
filipino_augmented = []

for i in range(len(scottish_arrays)):
    audio = scottish_arrays[i]
    noisy_audio = add_noise(audio)
    pitched_audio = change_pitch(audio, sampling_rate)
    speeded_audio = change_speed(audio)
    scottish_augmented.append(noisy_audio)
    scottish_augmented.append(pitched_audio)
    scottish_augmented.append(speeded_audio)

for i in range(190):
    audio = irish_arrays[i]
    noisy_audio = add_noise(audio)
    pitched_audio = change_pitch(audio, sampling_rate)
    speeded_audio = change_speed(audio)
    irish_augmented.append(noisy_audio)
    irish_augmented.append(pitched_audio)
    irish_augmented.append(speeded_audio)

for i in range(130):
    audio = canadian_arrays[i]
    noisy_audio = add_noise(audio)
    pitched_audio = change_pitch(audio, sampling_rate)
    speeded_audio = change_speed(audio)
    canadian_augmented.append(noisy_audio)
    canadian_augmented.append(pitched_audio)
    canadian_augmented.append(speeded_audio)

for i in range(75):
    audio = australian_arrays[i]
    noisy_audio = add_noise(audio)
    pitched_audio = change_pitch(audio, sampling_rate)
    speeded_audio = change_speed(audio)
    australian_augmented.append(noisy_audio)
    australian_augmented.append(pitched_audio)
    australian_augmented.append(speeded_audio)

for i in range(80):
    audio = filipino_arrays[i]
    noisy_audio = add_noise(audio)
    pitched_audio = change_pitch(audio, sampling_rate)
    speeded_audio = change_speed(audio)
    filipino_augmented.append(noisy_audio)
    filipino_augmented.append(pitched_audio)
    filipino_augmented.append(speeded_audio)
```

In [ ]:

```
scottish_augmented_sentence = []
irish_augmented_sentence = []
canadian_augmented_sentence = []
australian_augmented_sentence = []
filipino_augmented_sentence = []

for i in range(len(scottish)):
    scottish_augmented_sentence.append(scottish['sentence'][i])
    scottish_augmented_sentence.append(scottish['sentence'][i])
    scottish_augmented_sentence.append(scottish['sentence'][i])

for i in range(190):
    irish_augmented_sentence.append(irish['sentence'][i])
    irish_augmented_sentence.append(irish['sentence'][i])
    irish_augmented_sentence.append(irish['sentence'][i])

for i in range(130):
    canadian_augmented_sentence.append(canadian['sentence'][i])
    canadian_augmented_sentence.append(canadian['sentence'][i])
    canadian_augmented_sentence.append(canadian['sentence'][i])

for i in range(75):
    australian_augmented_sentence.append(australian['sentence'][i])
    australian_augmented_sentence.append(australian['sentence'][i])
    australian_augmented_sentence.append(australian['sentence'][i])

for i in range(80):
    filipino_augmented_sentence.append(filipino['sentence'][i])
    filipino_augmented_sentence.append(filipino['sentence'][i])
    filipino_augmented_sentence.append(filipino['sentence'][i])
```

In [ ]:

```
scottish_augmented_df = pd.DataFrame({'accents': 'Scottish English', 'sentence': scottish_
augmented_sentence, 'audio': scottish_augmented})
irish_augmented_df = pd.DataFrame({'accents': 'Irish English', 'sentence': irish_augmented
_sentence, 'audio': irish_augmented})
canadian_augmented_df = pd.DataFrame({'accents': 'Canadian English', 'sentence': canadian_
augmented_sentence, 'audio': canadian_augmented})
australian_augmented_df = pd.DataFrame({'accents': 'Australian English', 'sentence': austr
alian_augmented_sentence, 'audio': australian_augmented})
filipino_augmented_df = pd.DataFrame({'accents': 'Filipino', 'sentence': filipino_augment
ed_sentence, 'audio': filipino_augmented})

scottish = pd.concat([scottish, scottish_augmented_df])
```

```
scottish.reset_index(drop=True, inplace=True)
irish = pd.concat([irish, irish_augmented_df])
irish.reset_index(drop=True, inplace=True)
canadian = pd.concat([canadian, canadian_augmented_df])
canadian.reset_index(drop=True, inplace=True)
australian = pd.concat([australian, australian_augmented_df])
australian.reset_index(drop=True, inplace=True)
filipino = pd.concat([filipino, filipino_augmented_df])
filipino.reset_index(drop=True, inplace=True)
```

In [ ]:

```
data_augmented = pd.concat([us,indian,england,scottish,irish,canadian,australian,filipino
])
```

In [ ]:

```
#second round augmentation for scottish
scottish_augmented = []
for i in range(120, 240):
    audio = scottish['audio'][i]
    noisy_audio = add_noise(audio)
    pitched_audio = change_pitch(audio, sampling_rate)
    speeded_audio = change_speed(audio)
    scottish_augmented.append(noisy_audio)
    scottish_augmented.append(pitched_audio)
    scottish_augmented.append(speeded_audio)

scottish_augmented_sentence = []
for i in range(120, 240):
    scottish_augmented_sentence.append(scottish['sentence'][i])
    scottish_augmented_sentence.append(scottish['sentence'][i])
    scottish_augmented_sentence.append(scottish['sentence'][i])

scottish_augmented_df = pd.DataFrame({'accents': 'Scottish English', 'sentence': scottish_
augmented_sentence, 'audio': scottish_augmented})
data_augmented = pd.concat([data_augmented, scottish_augmented_df])
```

In [ ]:

```
data_augmented['accents'].value_counts()
```

Out[ ]:

```
United States English                          800
India and South Asia (India, Pakistan, Sri Lanka)     800
England English                                800
Irish English                                  796
Canadian English                               785
Australian English                             753
Scottish English                               724
Filipino                                       711
Name: accents, dtype: int64
```

In [ ]:

```
test_audio = []
for audio in test_data['audio']:
    test_audio.append(audio['array'])
test_data['audio'] = test_audio
```

In [ ]:

```
test_data['accents'].value_counts()
test_data.reset_index(drop=True, inplace=True)
```

In [ ]:

```
data_augmented.reset_index(drop=True, inplace=True)
```

Audio to Image spectra

Audio to image spectro

- **ViT (Vision Transformer)**

In [ ]:

```
import torch
import torchvision.models as models
import torch.nn as nn
import matplotlib.pyplot as plt
from torchvision import datasets, transforms
from torch.utils.data import DataLoader, SubsetRandomSampler
import torch.optim as optim   # SGD
import time
import numpy as np
from tqdm.autonotebook import tqdm   #adds a progress bar to track training
import pandas as pd
```

In [ ]:

```
#turn audio array to spectrogram
def audio_to_melspectrogram(audio, sr = sampling_rate):
    melspec = librosa.feature.melspectrogram(y=audio, sr = sr, n_mels=128)
    melspec_db = librosa.power_to_db(melspec, ref=np.max)
    return melspec_db
```

In [ ]:

```
#turn all audio arrays to melspectrograms
melspectrograms = []
for audio in data_augmented['audio']:
    melspec = audio_to_melspectrogram(audio)
    melspectrograms.append(melspec)
```

In [ ]:

```
melspectrograms_test = []
for audio in test_data['audio']:
    melspec = audio_to_melspectrogram(audio)
    melspectrograms_test.append(melspec)
```

In [ ]:

```
#pip install opencv-python
```

```
Collecting opencv-python
  Downloading opencv_python-4.9.0.80-cp37-abi3-macosx_10_16_x86_64.whl.metadata (20 kB)
Requirement already satisfied: numpy>=1.17.0 in /Users/dongzhehu/opt/anaconda3/lib/python3
.8/site-packages (from opencv-python) (1.24.4)
Downloading opencv_python-4.9.0.80-cp37-abi3-macosx_10_16_x86_64.whl (55.7 MB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 55.7/55.7 MB 15.8 MB/s eta 0:00:0000:0100:01
Installing collected packages: opencv-python
Successfully installed opencv-python-4.9.0.80
Note: you may need to restart the kernel to use updated packages.
```

In [ ]:

```
import cv2
import numpy as np
def resize_images(images, size=(224, 224)):
    resized_images = []
    for img in images:
        resized_image = cv2.resize(img, size, interpolation=cv2.INTER_CUBIC)   # Using INT
ER_CUBIC for better resizing quality
        resized_images.append(resized_image)
    return np.array(resized_images)

# # Call the resize function
resized_images = resize_images(melspectrograms)
resized_images_test = resize_images(melspectrograms_test)
```

In [ ]:

```
#normalize the images
normalized_images = abs(resized_images / 255)
normalized_images_test = abs(resized_images_test / 255)
```

In [ ]:

```
#3 channel images
final_images = []
for img in normalized_images:
    final_image = np.stack((img,)*3, axis=-1)
    final_images.append(final_image)
final_images = np.array(final_images)

final_images_test = []
for img in normalized_images_test:
    final_image = np.stack((img,)*3, axis=-1)
    final_images_test.append(final_image)
final_images_test = np.array(final_images_test)
```

In [ ]:

```
#output images to a folder
import os
import cv2
import numpy as np
from PIL import Image
import matplotlib.pyplot as plt

def save_images(images, path):
    for i in range(len(images)):
        image = images[i]
        image = Image.fromarray((image * 255).astype(np.uint8))
        image.save(f'{path}/image_{i}.png')

save_images(final_images, 'train_images')
save_images(final_images_test, 'test_images')
```

```
---------------------------------------------------------------------------
NameError                                 Traceback (most recent call last)
/Users/dongzhehu/Documents/ST311 Final/parquet.ipynb Cell 30 in 1
     <a href='vscode-notebook-cell:/Users/dongzhehu/Documents/ST311%20Final/parquet.ipynb#
Y540sZmlsZQ%3D%3D?line=10'>11</a>         image = Image.fromarray((image * 255).astype(np.
uint8))
     <a href='vscode-notebook-cell:/Users/dongzhehu/Documents/ST311%20Final/parquet.ipynb#
Y540sZmlsZQ%3D%3D?line=11'>12</a>         image.save(f'{path}/image_{i}.png')
---> <a href='vscode-notebook-cell:/Users/dongzhehu/Documents/ST311%20Final/parquet.ipynb#
Y540sZmlsZQ%3D%3D?line=13'>14</a> save_images(final_images, 'train_images')
     <a href='vscode-notebook-cell:/Users/dongzhehu/Documents/ST311%20Final/parquet.ipynb#
Y540sZmlsZQ%3D%3D?line=14'>15</a> save_images(final_images_test, 'test_images')

NameError: name 'final_images' is not defined
```

In [ ]:

```
data_augmented['accents'] = data_augmented['accents'].astype('category')
test_data['accents'] = test_data['accents'].astype('category')
```

In [ ]:

```
lables = data_augmented['accents']
lables_test = test_data['accents']
#output the labels to a csv file
lables.to_csv('text_labels.csv', index=False)
lables_test.to_csv('text_labels_test.csv', index=False)
```

In [ ]:

```
# #melspectrogram back to audio
# def melspectrogram_to_audio(spec_img):
```

```
#     mel_inverted = librosa.feature.inverse.mel_to_audio(spec_img, sr=sampling_rate, n_it
er=32)
#     return mel_inverted

# audio_test = melspectrogram_to_audio(melspec_df['melspectrogram'][0])
# ipd.Audio(audio_test, rate=sampling_rate)
```

Load Local Data

In [ ]:

```
# #unzip file
# import zipfile
# with zipfile.ZipFile('train_images.zip', 'r') as zip_ref:
#     zip_ref.extractall('train_images')
# with zipfile.ZipFile('test_images.zip', 'r') as zip_ref:
#     zip_ref.extractall('test_images')
```

In [ ]:

```
from datasets import Dataset, Image
#load all images
train_images_path = []
for i in range(0, 6169):
    train_images_path.append(f'train_images/image_{i}.png')

test_images_path = []
for i in range(0, 1536):
    test_images_path.append(f'test_images/image_{i}.png')
```

In [ ]:

```
train_dataset = Dataset.from_dict({"image": train_images_path}).cast_column("image", Imag
e())
test_dataset = Dataset.from_dict({"image": test_images_path}).cast_column("image", Image(
))
```

In [ ]:

```
#remove column name
import pandas as pd
train_labels = pd.read_csv('text_labels.csv')
test_labels = pd.read_csv('text_labels_test.csv')
```

In [ ]:

```
#replace each label with number
train_labels['accents'] = train_labels['accents'].replace({'United States English': 0, 'I
ndia and South Asia (India, Pakistan, Sri Lanka)': 1, 'England English': 2, 'Scottish Engl
ish': 3, 'Irish English': 4, 'Canadian English': 5, 'Australian English': 6, 'Filipino':
7})
test_labels['accents'] = test_labels['accents'].replace({'United States English': 0, 'Ind
ia and South Asia (India, Pakistan, Sri Lanka)': 1, 'England English': 2, 'Scottish Englis
h': 3, 'Irish English': 4, 'Canadian English': 5, 'Australian English': 6, 'Filipino': 7}
)
```

In [ ]:

```
#add the labels to the dataset
train_dataset = train_dataset.add_column("labels", train_labels['accents'])
test_dataset = test_dataset.add_column("labels", test_labels['accents'])
```

In [ ]:

```

```

In [ ]:

```
from transformers import ViTImageProcessor
```

```
model_name_or_path = 'google/vit-base-patch16-224-in21k'
processor = ViTImageProcessor.from_pretrained(model_name_or_path)
```

In [ ]:

```
#processing
def process_example(example):
    inputs = processor(example['image'], return_tensors='pt')
    inputs['labels'] = example['labels']
    return inputs

process_example(train_dataset[0])
process_example(test_dataset[0])
```

Out[ ]:

```
{'pixel_values': tensor([[[[-0.6000, -0.6549, -0.6863,  ..., -0.6078, -0.5843, -0.5451],
          [-0.5922, -0.6392, -0.6706,  ..., -0.5922, -0.5765, -0.5451],
          [-0.5686, -0.6157, -0.6392,  ..., -0.5765, -0.5686, -0.5451],
          ...,
          [-0.3725, -0.3804, -0.3725,  ..., -0.3725, -0.3725, -0.3725],
          [-0.3725, -0.3804, -0.3725,  ..., -0.3725, -0.3725, -0.3725],
          [-0.3725, -0.3725, -0.3804,  ..., -0.3725, -0.3725, -0.3725]],

         [[-0.6000, -0.6549, -0.6863,  ..., -0.6078, -0.5843, -0.5451],
          [-0.5922, -0.6392, -0.6706,  ..., -0.5922, -0.5765, -0.5451],
          [-0.5686, -0.6157, -0.6392,  ..., -0.5765, -0.5686, -0.5451],
          ...,
          [-0.3725, -0.3804, -0.3725,  ..., -0.3725, -0.3725, -0.3725],
          [-0.3725, -0.3804, -0.3725,  ..., -0.3725, -0.3725, -0.3725],
          [-0.3725, -0.3725, -0.3804,  ..., -0.3725, -0.3725, -0.3725]],

         [[-0.6000, -0.6549, -0.6863,  ..., -0.6078, -0.5843, -0.5451],
          [-0.5922, -0.6392, -0.6706,  ..., -0.5922, -0.5765, -0.5451],
          [-0.5686, -0.6157, -0.6392,  ..., -0.5765, -0.5686, -0.5451],
          ...,
          [-0.3725, -0.3804, -0.3725,  ..., -0.3725, -0.3725, -0.3725],
          [-0.3725, -0.3804, -0.3725,  ..., -0.3725, -0.3725, -0.3725],
          [-0.3725, -0.3725, -0.3804,  ..., -0.3725, -0.3725, -0.3725]]]]), 'labels': 5}
```

In [ ]:

```
def transform(example_batch):
    # Take a list of PIL images and turn them to pixel values
    inputs = processor([x for x in example_batch['image']], return_tensors='pt')

    # Don't forget to include the labels!
    inputs['labels'] = example_batch['labels']
    return inputs
```

In [ ]:

```
prepared_ds = train_dataset.with_transform(transform)
prepared_ds_test = test_dataset.with_transform(transform)
```

In [ ]:

```
#data collator
import torch

def collate_fn(batch):
    return {
        'pixel_values': torch.stack([x['pixel_values'] for x in batch]),
        'labels': torch.tensor([x['labels'] for x in batch])
    }

#evaluation metrics
import numpy as np
from datasets import load_metric
```

```
metric = load_metric("accuracy")
def compute_metrics(p):
    return metric.compute(predictions=np.argmax(p.predictions, axis=1), references=p.labe
l_ids)
```

Model

In [ ]:

```
import wandb
wandb.login()
wandb.init(project='accent-classification')
```

```
wandb: Logging into wandb.ai. (Learn how to deploy a W&B server locally: https://wandb.me/
wandb-server)
wandb: You can find your API key in your browser here: https://wandb.ai/authorize
wandb: Paste an API key from your profile and hit enter, or press ctrl+c to quit:wandb: Ap
pending key for api.wandb.ai to your netrc file: /root/.netrc
wandb: Currently logged in as: alexhudongzhe (aleksss). Use `wandb login --relogin` to for
ce relogin
```

wandb version 0.16.6 is available! To upgrade, please run: $ pip install wandb --upgrade

Tracking run with wandb version 0.13.4

Run data is saved locally in `/notebooks/wandb/run-20240429_150221-2puargng`

Syncing run azure-yogurt-3 to Weights & Biases (docs)

Out[ ]:

Display W&B run

In [ ]:

```
from transformers import ViTForImageClassification

labels = list(set(train_dataset['labels']))

model = ViTForImageClassification.from_pretrained(
    model_name_or_path,
    num_labels=len(labels),
    id2label={str(i): c for i, c in enumerate(labels)},
    label2id={c: str(i) for i, c in enumerate(labels)}
)
```

```
Some weights of ViTForImageClassification were not initialized from the model checkpoint a
t google/vit-base-patch16-224-in21k and are newly initialized: ['classifier.bias', 'classi
fier.weight']
You should probably TRAIN this model on a down-stream task to be able to use it for predic
tions and inference.
```

In [ ]:

```
#arguments
from transformers import TrainingArguments

training_args = TrainingArguments(
  output_dir="./vit-base-beans",
  per_device_train_batch_size=32,
  evaluation_strategy="epoch",
  save_strategy="epoch",
  num_train_epochs=3,
  fp16=True,
  learning_rate=2e-4,
  save_total_limit=2,
  remove_unused_columns=False,
  push_to_hub=False,
  load_best_model_at_end=True,
  report_to='wandb',
)
```

In [ ]:

```
from transformers import Trainer

trainer = Trainer(
    model=model,
    args=training_args,
    data_collator=collate_fn,
    compute_metrics=compute_metrics,
    train_dataset=prepared_ds,
    eval_dataset=prepared_ds_test,
    tokenizer=processor,
)
```

In [ ]:

```
train_results = trainer.train()
trainer.save_model()
trainer.log_metrics("train", train_results.metrics)
trainer.save_metrics("train", train_results.metrics)
trainer.save_state()
```

[579/579 05:38, Epoch 3/3]

Epoch	Training Loss	Validation Loss	Accuracy
1	No log	0.324341	0.914714
2	No log	0.062901	0.986979
3	0.283300	0.038180	0.992188

```
***** train metrics *****
  epoch                    =          3.0
  total_flos               = 1335722743GF
  train_loss               =       0.2472
  train_runtime            =   0:05:47.14
  train_samples_per_second =       53.312
  train_steps_per_second   =        1.668
```

In [ ]:

```
#evaluation
metrics = trainer.evaluate(prepared_ds_test)
trainer.log_metrics("eval", metrics)
trainer.save_metrics("eval", metrics)
```

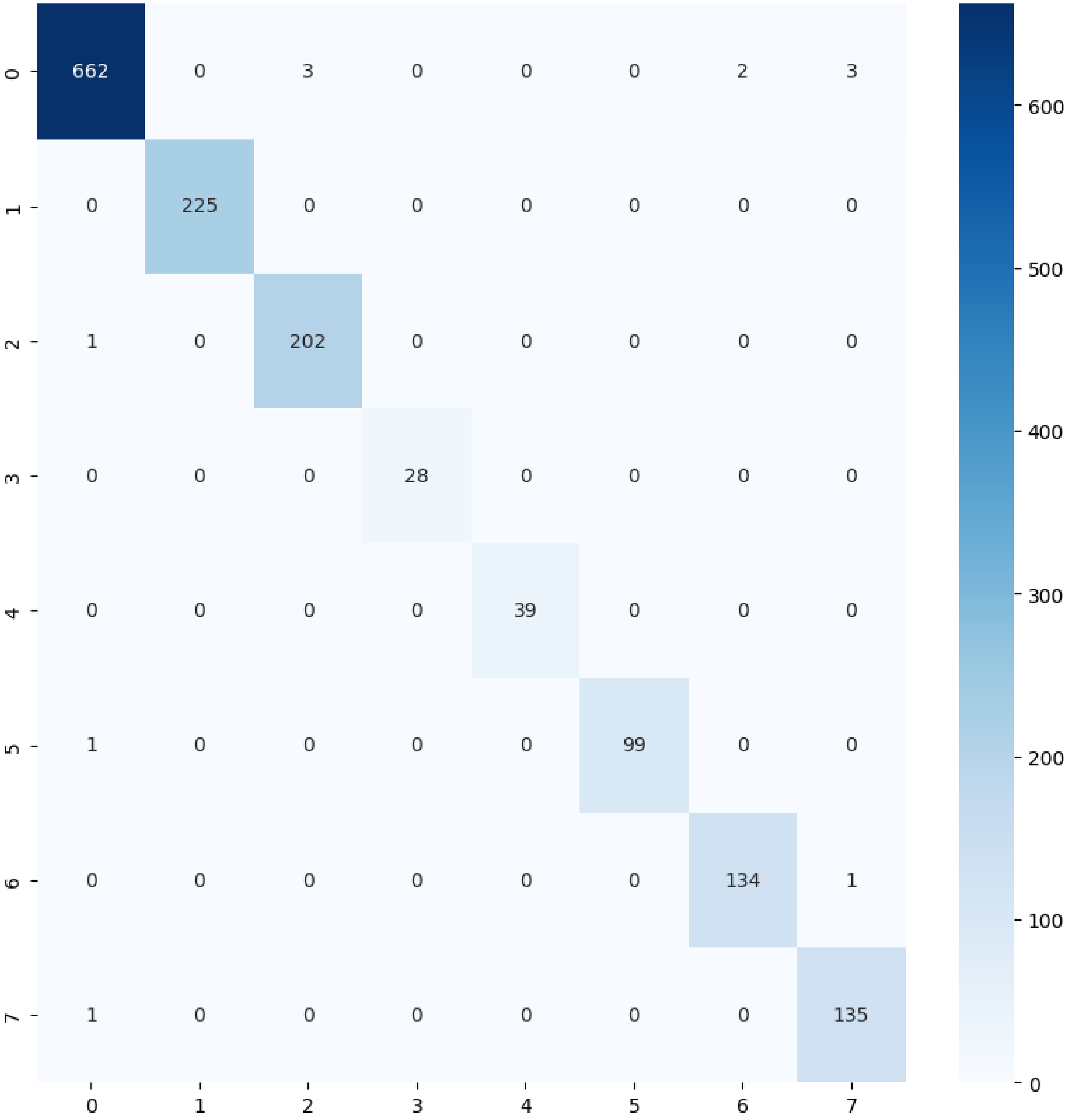
```
***** eval metrics *****
  epoch                   =        3.0
  eval_accuracy           =     0.9922
  eval_loss               =     0.0382
  eval_runtime            = 0:00:09.79
  eval_samples_per_second =    156.796
  eval_steps_per_second   =     19.599
```

In [ ]:

```
#confusion matrix
from sklearn.metrics import confusion_matrix
import seaborn as sns
import matplotlib.pyplot as plt

predictions = trainer.predict(prepared_ds_test)
y_pred = np.argmax(predictions.predictions, axis=1)
y_true = test_labels
cm = confusion_matrix(y_true, y_pred)
```

Out[ ]:

```
<AxesSubplot: >
```



In [ ]:

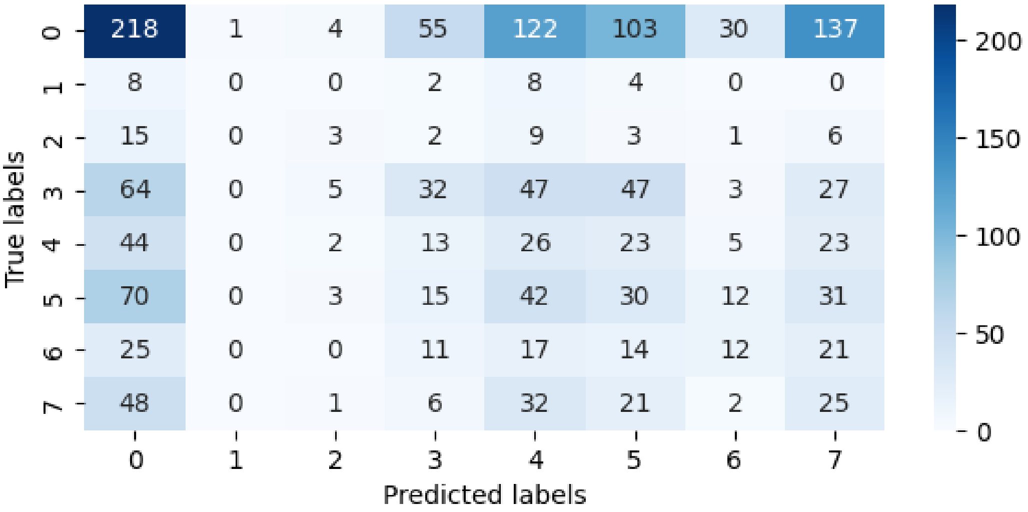
```
cm = ([[662,   2,   2,   0,   0,   0,   2,   2],
       [  2, 223,   0,   0,   0,   0,   0,   0],
       [  2,   0, 200,   0,   0,   1,   0,   0],
       [  0,   0,   0,  28,   0,   0,   0,   0],
       [  0,   0,   0,   0,  39,   0,   0,   0],
       [  0,   0,   0,   0,   0, 100,   0,   0],
       [  0,   0,   0,   0,   0,   0, 135,   0],
       [  2,   0,   0,   0,   0,   0,   0, 134]])

cm2 = ([[459,2,47,2,152]])

cm3 =  [
    [25, 2, 21, 32, 6, 1, 0, 48],
    [21, 12, 14, 17, 11, 0, 0, 25],
    [31, 12, 30, 42, 15, 3, 0, 70],
    [23, 5, 23, 26, 13, 2, 0, 44],
    [27, 3, 47, 47, 32, 5, 0, 64],
    [6, 1, 3, 9, 2, 3, 0, 15],
    [0, 0, 4, 8, 2, 0, 0, 8],
    [137, 30, 103, 122, 55, 4, 1, 218]
]

cm3_reversed = [
    [218, 1, 4, 55, 122, 103, 30, 137],
    [8, 0, 0, 2, 8, 4, 0, 0],
    [15, 0, 3, 2, 9, 3, 1, 6],
    [64, 0, 5, 32, 47, 47, 3, 27],
    [44, 0, 2, 13, 26, 23, 5, 23],
    [70, 0, 3, 15, 42, 30, 12, 31],
    [25, 0, 0, 11, 17, 14, 12, 21],
    [48, 0, 1, 6, 32, 21, 2, 25]
]


cm4 = ([[669,   0,   0,   0,   1,   0,   0,   0],
       [  0, 225,   0,   0,   0,   0,   0,   0],
       [  1,   0, 202,   0,   0,   0,   0,   0],
       [  0,   0,   0,  28,   0,   0,   0,   0],
       [  0,   0,   0,   0,  39,   0,   0,   0],
       [  0,   0,   0,   0,   0, 100,   0,   0],
       [  0,   0,   0,   0,   0,   0, 135,   0],
       [  0,   0,   0,   0,   0,   0,   0, 136]])
```

In [ ]:

```
plt.figure(figsize=(7, 3))
sns.heatmap(cm3_reversed, annot=True, fmt='g', cmap='Blues')
#x-axis labels

plt.xlabel('Predicted labels')
plt.ylabel('True labels')
```

Out[ ]:

```
Text(58.222222222222214, 0.5, 'True labels')
```



Extra Test

In [ ]:

```
# load us audio
extra = pq.read_table(source= 'extra.parquet').to_pandas()
```

In [ ]:

```
extra_audio = []
for r in extra['audio']:
    extra_audio.append(r['array'])
```

```
extra_melspectrograms = []
for audio in extra_audio:
    melspec = audio_to_melspectrogram(audio)
    extra_melspectrograms.append(melspec)

extra_resized_images = resize_images(extra_melspectrograms)
extra_normalized_images = abs(extra_resized_images / 255)
extra_final_images = []
for img in extra_normalized_images:
    final_image = np.stack((img,)*3, axis=-1)
    extra_final_images.append(final_image)
extra_final_images = np.array(extra_final_images)
```

In [ ]:

```
#output images to a folder
def save_images(images, path):
    for i in range(len(images)):
        image = images[i]
        image = Image.fromarray((image * 255).astype(np.uint8))
        image.save(f'{path}/image_{i}.png')

save_images(extra_final_images, 'extra_images')
```

In [ ]:

```
#save label
extra_labels = extra['accents']
#output the labels to a csv file
extra_labels.to_csv('extra_labels.csv', index=False)
#replace with numner
extra_labels = extra_labels.replace({'United States English': 0, 'India and South Asia (India, Pakistan, Sri Lanka)': 1, 'England English': 2, 'Scottish English': 3, 'Irish English': 4, 'Canadian English': 5, 'Australian English': 6, 'Filipino': 7})
```

In [ ]:

```
#load images randomly
from datasets import Dataset, Image
extra_images_path = []
for i in range(0, 698):
    extra_images_path.append(f'extra_images/image_{i}.png')

extra_dataset = Dataset.from_dict({"image": extra_images_path}).cast_column("image", Image())
```

In [ ]:

```
#first 1000 labels
extra_labels = extra_labels[:1000]
```

In [ ]:

```
extra_dataset = extra_dataset.add_column("labels", extra_labels)
```

In [ ]:

```
#predict
prepared_extra_ds = extra_dataset.with_transform(transform)
predictions = trainer.predict(prepared_extra_ds)
```

In [ ]:

```
predictions = np.argmax(predictions.predictions, axis=1)
```

In [ ]:

```
predictions
```

In [ ]:

```
#accuracy
from sklearn.metrics import accuracy_score
accuracy_score(extra_labels, predictions)
```

Out[ ]:

```
0.7091690544412608
```

In [ ]:

```
#count unique in predictions
unique, counts = np.unique(predictions, return_counts=True)
dict(zip(unique, counts))
```

Out[ ]:

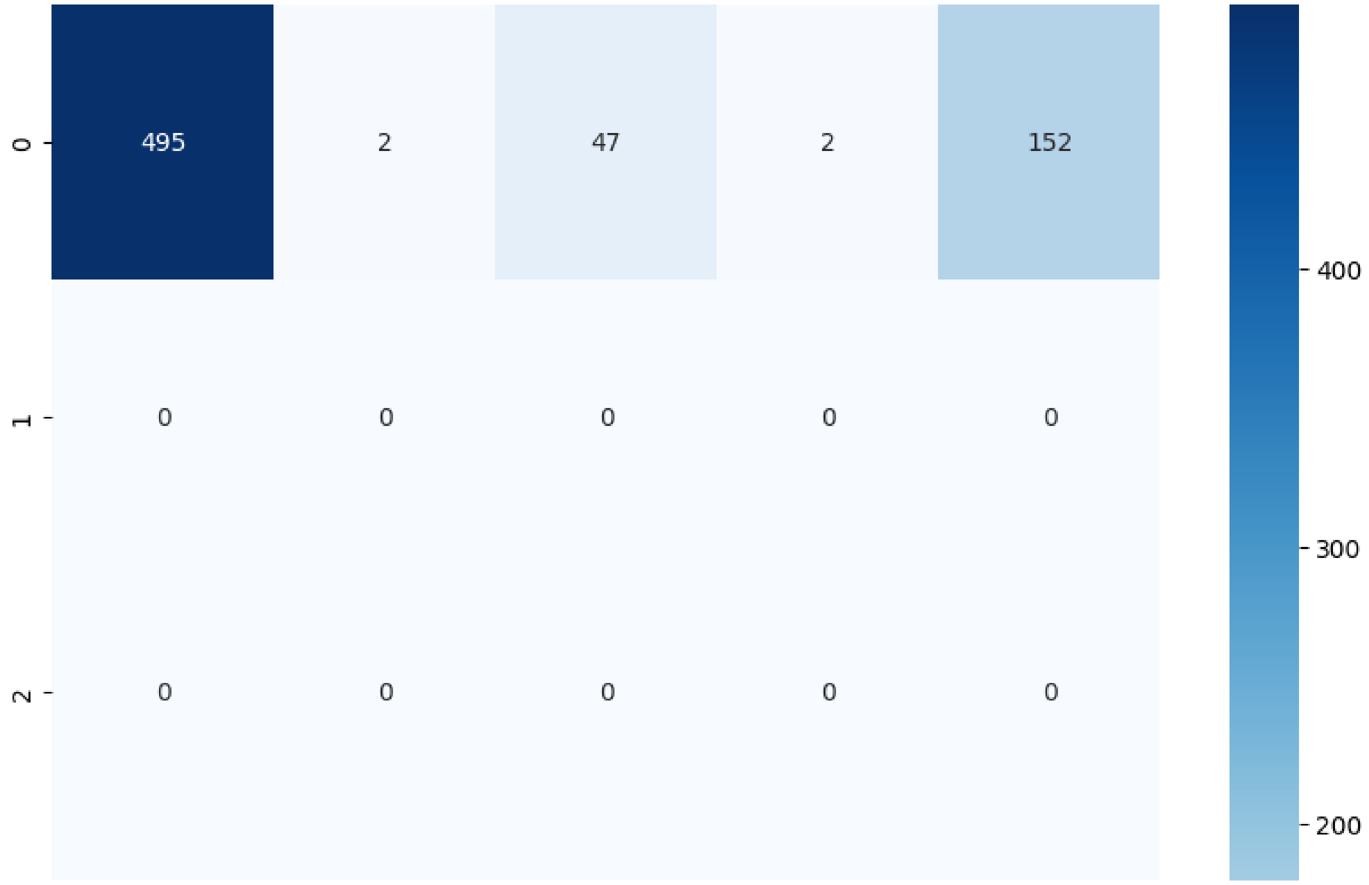
```
{0: 495, 2: 2, 3: 47, 5: 2, 7: 152}
```

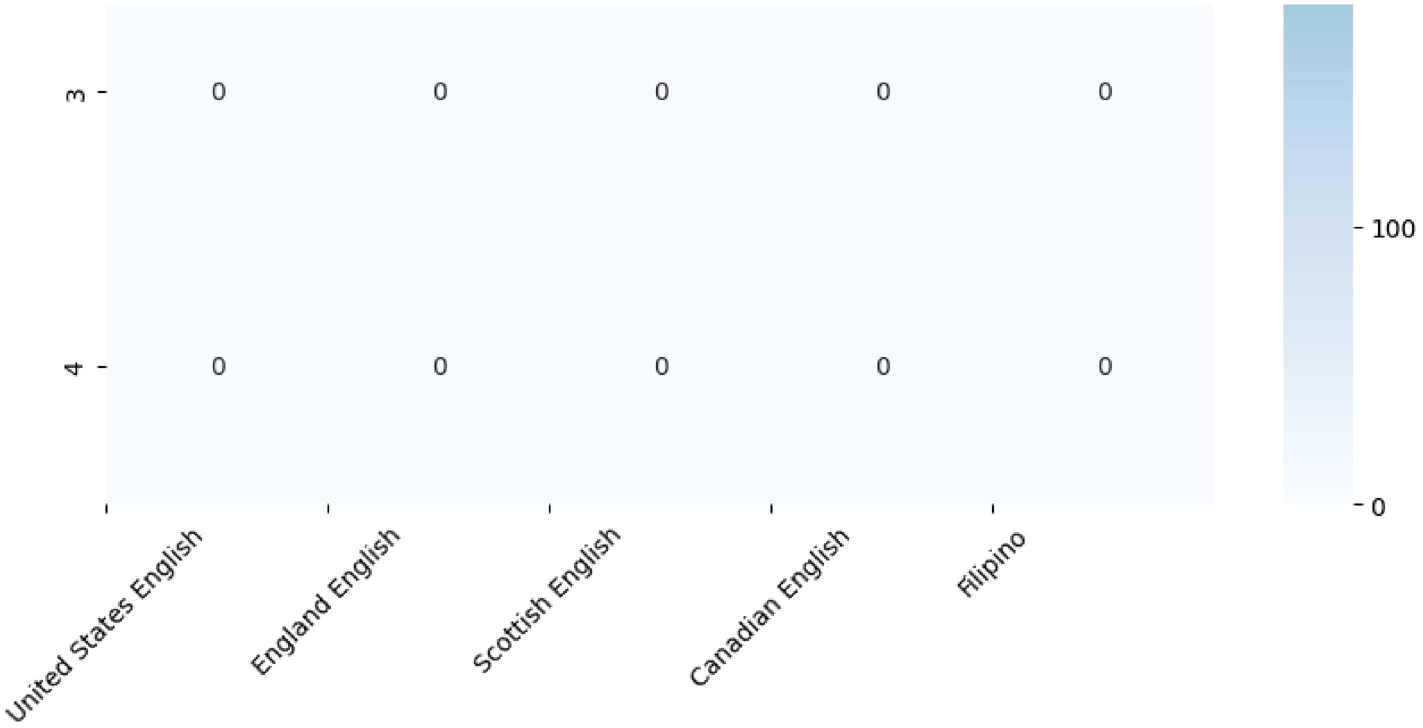
In [ ]:

```
#confusion matrix
from sklearn.metrics import confusion_matrix
import seaborn as sns
import matplotlib.pyplot as plt

cm = confusion_matrix(extra_labels, predictions)
plt.figure(figsize=(10, 10))
sns.heatmap(cm, annot=True, fmt='g', cmap='Blues')
#change x labels
plt.xticks(np.arange(5), ['United States English', 'England English', 'Scottish English',
'Canadian English', 'Filipino'], rotation=45)
```

Out[ ]:

```
([<matplotlib.axis.XTick at 0x7f92fe0cce50>,
  <matplotlib.axis.XTick at 0x7f92fe0cce20>,
  <matplotlib.axis.XTick at 0x7f92fe0ad880>,
  <matplotlib.axis.XTick at 0x7f92fe0ba280>,
  <matplotlib.axis.XTick at 0x7f92fe0bad30>],
 [Text(0, 0, 'United States English'),
  Text(1, 0, 'England English'),
  Text(2, 0, 'Scottish English'),
  Text(3, 0, 'Canadian English'),
  Text(4, 0, 'Filipino')])
```





Extra 2

In [ ]:

```
extra2 = pq.read_table(source= 'extra2.parquet').to_pandas()
```

In [ ]:

```
extra_audio = []
for r in extra2['audio']:
    extra_audio.append(r['array'])

extra_melspectrograms = []
for audio in extra_audio:
    melspec = audio_to_melspectrogram(audio)
    extra_melspectrograms.append(melspec)

extra_resized_images = resize_images(extra_melspectrograms)
extra_normalized_images = abs(extra_resized_images / 255)
extra_final_images = []
for img in extra_normalized_images:
    final_image = np.stack((img,)*3, axis=-1)
    extra_final_images.append(final_image)
extra_final_images = np.array(extra_final_images)
```

In [ ]:

```
#output images to a folder
from PIL import Image
def save_images(images, path):
    for i in range(len(images)):
        image = images[i]
        image = Image.fromarray((image * 255).astype(np.uint8))
        image.save(f'{path}/image_{i}.png')

save_images(extra_final_images, 'extra2_images')
```

In [ ]:

```
extra2_labels = extra2['accents']
#output the labels to a csv file
extra2_labels.to_csv('extra2_labels.csv', index=False)
#replace with numner
extra2_labels = extra2_labels.replace({'United States English': 0, 'India and South Asia
(India, Pakistan, Sri Lanka)': 1, 'England English': 2, 'Scottish English': 3, 'Irish Engl
ish': 4, 'Canadian English': 5, 'Australian English': 6, 'Filipino': 7})
```

In [ ]:

```
#load images randomly
from datasets import Dataset, Image
extra2_images_path = []
for i in range(0, 697):
    extra2_images_path.append(f'extra2_images/image_{i}.png')

extra2_dataset = Dataset.from_dict({"image": extra2_images_path}).cast_column("image", Im
age())
extra2_dataset = extra2_dataset.add_column("labels", extra2_labels)
```

In [ ]:

```
#predict
prepared_extra2_ds = extra2_dataset.with_transform(transform)
predictions = trainer.predict(prepared_extra2_ds)
```

In [ ]:

```
#accuracy
predictions = np.argmax(predictions.predictions, axis=1)
accuracy_score(extra2_labels, predictions)
```

Out[ ]:

```
0.975609756097561
```

Text Classification (Speech Transcript)

In [ ]:

```
import os
import torch
import torchvision
import torch.nn as nn
import matplotlib.pyplot as plt
from torchvision import datasets, transforms
from torch.utils.data import DataLoader, SubsetRandomSampler, Subset
import torch.optim as optim
import time
import numpy as np
import pandas as pd
from tqdm.autonotebook import tqdm
from PIL import Image
import librosa
from datasets import Dataset, Audio
from sklearn.model_selection import train_test_split
from sklearn.utils.class_weight import compute_class_weight





cuda = torch.cuda.is_available()
```

Import the data

Data Source:
https://huggingface.co/datasets/WillHeld/accented_common_voice/tree/refs%2Fconvert%2Fparquet/default/partia
train

Text Transformer 1, PERT: https://huggingface.co/google-bert/bert-base-uncased

Due to the size and format of the original data file parquet, we decided to download the data and import it from our own laptop. The file link can be found above.

In [ ]:

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

```
Drive already mounted at /content/drive; to attempt to forcibly remount, call drive.mount(
"/content/drive", force_remount=True).
```

In [ ]:

```
import pyarrow.parquet as pq

df0 = pq.read_table(source= '/content/drive/MyDrive/year3/ST311/0000.parquet').to_pandas()
df1 = pq.read_table(source= '/content/drive/MyDrive/year3/ST311/0001.parquet').to_pandas()
df2 = pq.read_table(source= '/content/drive/MyDrive/year3/ST311/0002.parquet').to_pandas()
df3 = pq.read_table(source= '/content/drive/MyDrive/year3/ST311/0003.parquet').to_pandas()
df4 = pq.read_table(source= '/content/drive/MyDrive/year3/ST311/0004.parquet').to_pandas()
df5 = pq.read_table(source= '/content/drive/MyDrive/year3/ST311/0005.parquet').to_pandas()
df6 = pq.read_table(source= '/content/drive/MyDrive/year3/ST311/0006.parquet').to_pandas()
df7 = pq.read_table(source= '/content/drive/MyDrive/year3/ST311/0007.parquet').to_pandas()
```

In [ ]:

```
data = pd.concat([df0,df1,df2,df3,df4,df5,df6,df7])
data.reset_index(drop=True, inplace=True)
```

In [ ]:

```
data
```

Out[ ]:

	path	accents	sentence	up_votes	down_votes	age	gender	audio
0	common_voice_en_23608720.mp3	India and South Asia (India, Pakistan, Sri Lanka)	The liner notes were written by Mark Paytress ...	2.0	1.0	twenties	female	{'array': [-1.7462298274040222e-10, -4.2200554...
1	common_voice_en_23608721.mp3	India and South Asia (India, Pakistan, Sri Lanka)	Microsoft has not made public statements about...	2.0	0.0	twenties	female	{'array': [5.093170329928398e-11, 7.3669070843...
2	common_voice_en_23608722.mp3	India and South Asia (India, Pakistan, Sri Lanka)	It indicates a letter that must be typed and m...	2.0	0.0	twenties	female	{'array': [0.0, -2.9103830456733704e-11, 4.365...
3	common_voice_en_23608754.mp3	India and South Asia (India, Pakistan, Sri Lanka)	Nasseri was born in the Anglo-Persian Oil Comp...	2.0	0.0	twenties	female	{'array': [5.4569682106375694e-11, -7.27595761...
		India						

	path	accents	sentence	up_votes	down_votes	age	gender	audio
4	common_voice_en_23608756.mp3	and South Asia (India, Pakistan, Sri Lanka)	He was also an ordained minister and led vario...	2.0	1.0	twenties	female	{'array': [-8.731149137020111e-11, 1.273292582...
...	...	...	...	...	...	...	...	...
7673	common_voice_en_25122812.mp3	United States English	A Game Gear game by the same name was publishe...	2.0	0.0			{'array': [-2.4556356947869062e-11, -7.2759576...
7674	common_voice_en_25122824.mp3	United States English	He is the only President of Latvia to die in o...	2.0	0.0			{'array': [-1.0913936421275139e-11, -2.1827872...
7675	common_voice_en_25122825.mp3	United States English	Luther Rice College and Seminary is a private ...	2.0	0.0			{'array': [9.094947017729282e-13, -9.094947017...
7676	common_voice_en_25122826.mp3	United States English	Songs from these albums have also been feature...	2.0	1.0			{'array': [-2.7284841053187847e-12, -3.6379788...
7677	common_voice_en_25122827.mp3	United States English	Another head had intake and exhaust ports reve...	2.0	0.0			{'array': [2.2737367544323206e-11, 1.182343112...

7678 rows × 8 columns

In [ ]:

```
set(data['accents'])
```

Out[ ]:

```
{'Australian English',
 'Canadian English',
 'England English',
 'Filipino',
 'India and South Asia (India, Pakistan, Sri Lanka)',
 'Irish English',
 'Scottish English',
 'United States English'}
```

In [ ]:

```
data['audio'][0]
```

Out[ ]:

```
{'array': array([-1.74622983e-10, -4.22005542e-10, -2.03726813e-10, ...,
         4.54552310e-06,  1.05218151e-05,  1.69793075e-05]),
 'path': './accents/datasets/common_voice_16_1/en/clips/common_voice_en_23608720.mp3',
 'sampling_rate': 16000}
```

Data Pre-processing

Dealing with the class imbalance issues as the proportion of certain accents is far fewer than others. We first drop the columns that are unrelated to this research.

In [ ]:

```
data = data.drop(['path'], axis=1)
data = data.drop(['up_votes'], axis=1)
data = data.drop(['down_votes'], axis=1)
data = data.drop(['age'], axis=1)
data = data.drop(['gender'], axis=1)
data['accents'].value_counts()
```

Out[ ]:

```
accents
United States English                                   3247
India and South Asia (India, Pakistan, Sri Lanka)       1188
England English                                         1094
Australian English                                       663
Filipino                                                 607
Canadian English                                         495
Irish English                                            265
Scottish English                                         119
Name: count, dtype: int64
```

Then split the data to train and test set in the proportion of 8:2.

In [ ]:

```
#train test split
train, test = train_test_split(data, test_size=0.2, random_state=42)

train['accents'].value_counts()
```

Out[ ]:

```
accents
United States English                                   2577
India and South Asia (India, Pakistan, Sri Lanka)        963
England English                                          891
Australian English                                       528
Filipino                                                 471
Canadian English                                         395
Irish English                                            226
Scottish English                                          91
Name: count, dtype: int64
```

Then we upsamle and downsample the minority and majority class.

In [ ]:

```
import pandas as pd
from sklearn.utils import resample

# Down sampling three classes
US = train[train['accents'] == 'United States English']
US = US.sample(n=550)

India_south_asia = train[train['accents'] == 'India and South Asia (India, Pakistan, Sri L
anka)']
India_south_asia = India_south_asia.sample(n=550)

england = train[train['accents'] == 'England English']
england = england.sample(n=550)

# Upsample minority class
scottish = train[train['accents'] == 'Scottish English']
Irish = train[train['accents'] == 'Irish English']
scottish = resample(scottish,replace=True,n_samples= 270, random_state=42)
Irish = resample(Irish,replace=True,n_samples= 450, random_state=42)
```

```
# Combine all classes
the_rest = []
new = []
the_rest = pd.concat([train[train['accents'] == 'Australian English'],train[train['accents'] == "Filipino"], train[train['accents'] == 'Canadian English']])
new = pd.concat([US, India_south_asia,england,scottish,Irish,the_rest])

# Display new class counts
new.reset_index(drop=True, inplace=True)
new['accents'].value_counts()
```

Out[ ]:

```
accents
United States English                                 550
India and South Asia (India, Pakistan, Sri Lanka)     550
England English                                       550
Australian English                                    528
Filipino                                              471
Irish English                                         450
Canadian English                                      395
Scottish English                                      270
Name: count, dtype: int64
```

In [ ]:

```
train_ds = Dataset.from_pandas(new)
test_ds = Dataset.from_pandas(test)

train_ds = train_ds.class_encode_column("accents")
test_ds = test_ds.class_encode_column("accents")
```

Audio is not the interest of text classification, therefore remove the column.

In [ ]:

```
train_ds = train_ds.remove_columns("audio")
test_ds = test_ds.remove_columns("audio")
```

In [ ]:

```
labels = train_ds.features["accents"].names
label2id, id2label = dict(), dict()
for i, label in enumerate(labels):
    label2id[label] = str(i)
    id2label[str(i)] = label
```

In [ ]:

```
train_ds
```

Out[ ]:

```
Dataset({
    features: ['accents', 'sentence'],
    num_rows: 3764
})
```

Bert

Tokenize the data

In [ ]:

```
# tokenize the data
from transformers import AutoTokenizer, DataCollatorWithPadding

checkpoint = "bert-base-uncased"
```

```
tokenizer = AutoTokenizer.from_pretrained(checkpoint)

def tokenize_function(example):
    return tokenizer(example["sentence"], padding = "max_length")

tokenized_datasets_train = train_ds.map(tokenize_function, batched=True)
tokenized_datasets_test = test_ds.map(tokenize_function, batched=True)

tokenized_datasets_train = tokenized_datasets_train.rename_column("accents","label")
tokenized_datasets_test = tokenized_datasets_test.rename_column("accents","label")

data_collator = DataCollatorWithPadding(tokenizer=tokenizer)
```

```
/usr/local/lib/python3.10/dist-packages/huggingface_hub/utils/_token.py:89: UserWarning:
The secret `HF_TOKEN` does not exist in your Colab secrets.
To authenticate with the Hugging Face Hub, create a token in your settings tab (https://hu
ggingface.co/settings/tokens), set it as secret in your Google Colab and restart your sess
ion.
You will be able to reuse this secret in all of your notebooks.
Please note that authentication is recommended but still optional to access public models
or datasets.
  warnings.warn(
```

In [ ]:

```
tokenized_datasets_train
```

Out[ ]:

```
Dataset({
    features: ['label', 'sentence', 'input_ids', 'token_type_ids', 'attention_mask'],
    num_rows: 3764
})
```

In [ ]:

```
pip install transformers[torch]
```

In [ ]:

```
pip install evaluate
```

8 epoch

Define and train the BERT model with 8 epochs.

In [ ]:

```
#Define a training arguments class
from transformers import TrainingArguments
training_args = TrainingArguments("test-trainer", evaluation_strategy="epoch", num_train_e
pochs=8)


#Define the model
num_labels = len(id2label)
num_labels
from transformers import AutoModelForSequenceClassification
model = AutoModelForSequenceClassification.from_pretrained(checkpoint,num_labels=num_label
s)


#Define the compute metrics
import evaluate

def compute_metrics(eval_preds):
    metric = evaluate.load("accuracy")
    logits, labels = eval_preds
    predictions = np.argmax(logits, axis=-1)
    return metric.compute(predictions=predictions, references=labels)


#Define a trainer
from transformers import Trainer

trainer = Trainer(
    model,
    training_args,
    train_dataset=tokenized_datasets_train,
    eval_dataset=tokenized_datasets_test,
    data_collator=data_collator,
    tokenizer=tokenizer,
    compute_metrics = compute_metrics,
)
```

```
Some weights of BertForSequenceClassification were not initialized from the model checkpoi
nt at bert-base-uncased and are newly initialized: ['classifier.bias', 'classifier.weight'
]
You should probably TRAIN this model on a down-stream task to be able to use it for predic
tions and inference.
```

In [ ]:

```
trainer.train()
```

[3768/3768 14:34, Epoch 8/8]

Epoch	Training Loss	Validation Loss	Accuracy
1	No log	1.984597	0.160807
2	2.062500	1.947822	0.218099
3	1.762400	2.161429	0.187500
4	1.226100	2.723784	0.177083
5	0.585400	4.005829	0.184896
6	0.166800	4.573924	0.234375
7	0.049300	5.164403	0.202474
8	0.006100	5.232408	0.208984

Out[ ]:

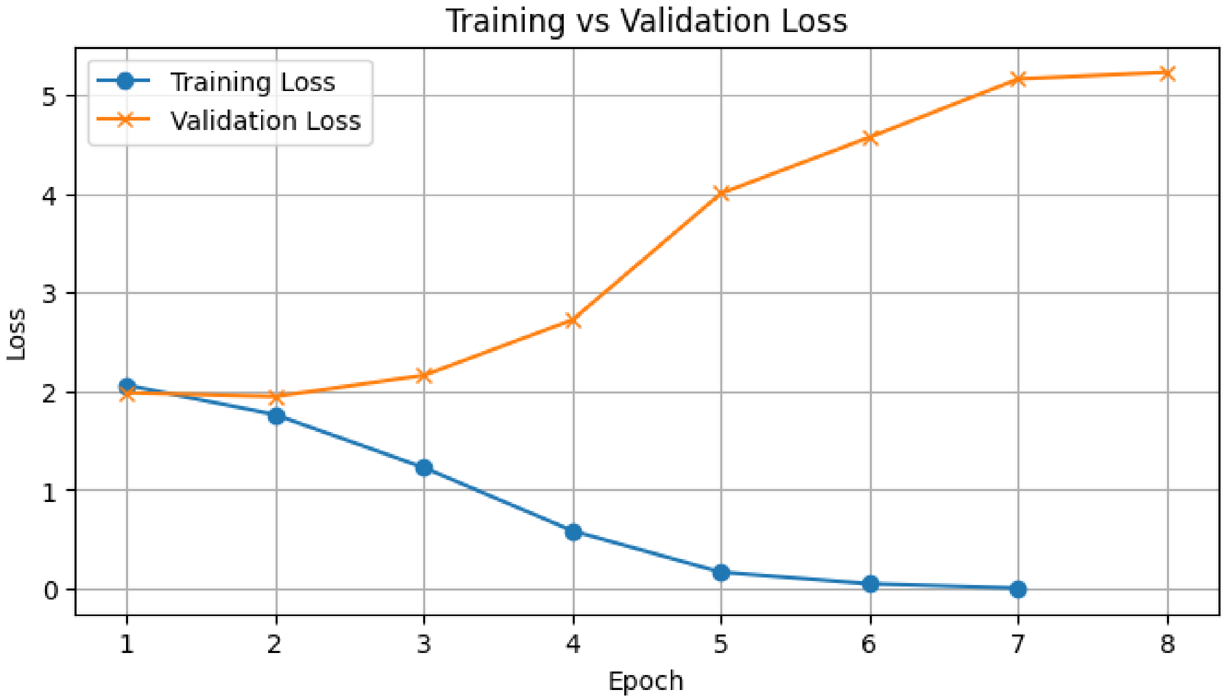
```
TrainOutput(global_step=3768, training_loss=0.7775677567043375, metrics={'train_runtime':
875.9845, 'train_samples_per_second': 34.375, 'train_steps_per_second': 4.301, 'total_flos
': 7923226912751616.0, 'train_loss': 0.7775677567043375, 'epoch': 8.0})
```

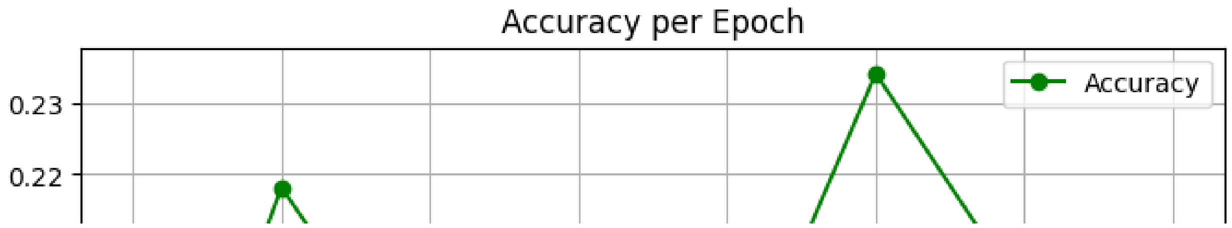
The plot on the changes of trainingh loss, validation loss and accuracy

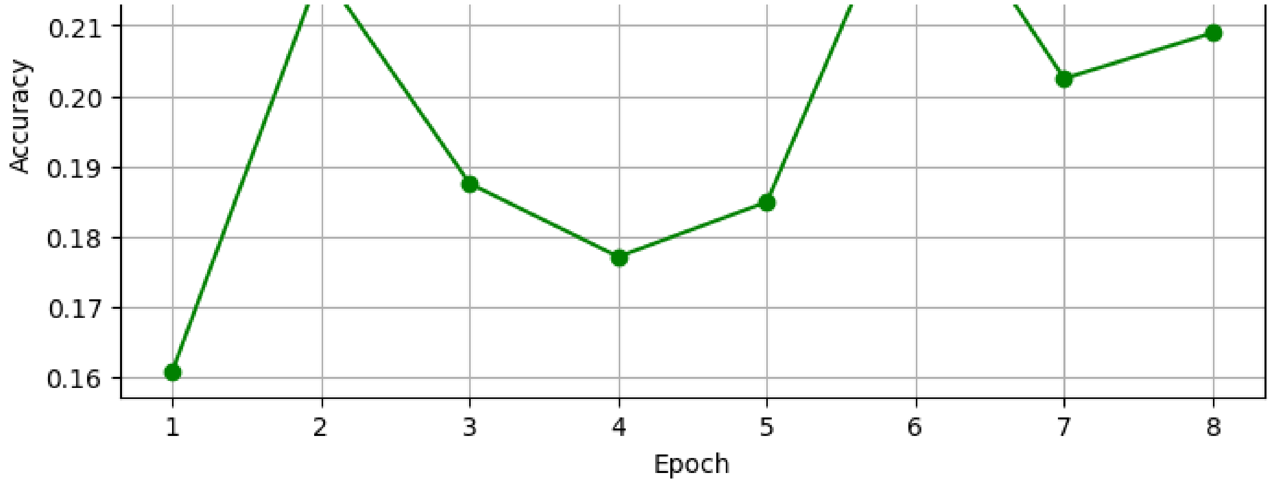
In [ ]:

```
import matplotlib.pyplot as plt

log_history = trainer.state.log_history

epochs = []
training_loss = [None] * len(epochs)  # Initialize with None
validation_loss = [None] * len(epochs)  # Initialize with None
accuracy = []

# Extracting data from log_history
for log in log_history:
    if 'epoch' in log:
        epoch_index = int(log['epoch']) - 1  # Convert to 0-indexed
        while len(epochs) <= epoch_index:  # Append to epochs list if this epoch is not y
et included
```

```
            epochs.append(len(epochs) + 1)
            training_loss.append(None)  # Append None for this new epoch
            validation_loss.append(None)  # Append None for this new epoch
        # Now we safely assume that the lengths of the lists are equal to epoch_index + 1
        if 'loss' in log:
            training_loss[epoch_index] = log['loss']
        if 'eval_loss' in log:
            validation_loss[epoch_index] = log['eval_loss']
        if 'eval_accuracy' in log:
            accuracy.append(log['eval_accuracy'])

# Filter out the epochs where we have validation loss to match with training loss
valid_epochs = [epoch for epoch, val_loss in zip(epochs, validation_loss) if val_loss is
not None]
valid_validation_loss = [val_loss for val_loss in validation_loss if val_loss is not None]

# Comparison plot of training and validation loss
plt.figure(figsize=(8, 4))
plt.plot(epochs, training_loss, label='Training Loss', marker='o')
plt.plot(valid_epochs, valid_validation_loss, label='Validation Loss', marker='x')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.title('Training vs Validation Loss')
plt.legend()
plt.grid(True)
plt.show()

# Ensure the list lengths match for accuracy plot
while len(accuracy) < len(epochs):
    accuracy.append(None)

# Separate plot for accuracy
plt.figure(figsize=(8, 4))
plt.plot(epochs, accuracy, label='Accuracy', color='green', marker='o')
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.title('Accuracy per Epoch')
plt.legend()
plt.grid(True)
plt.show()
```



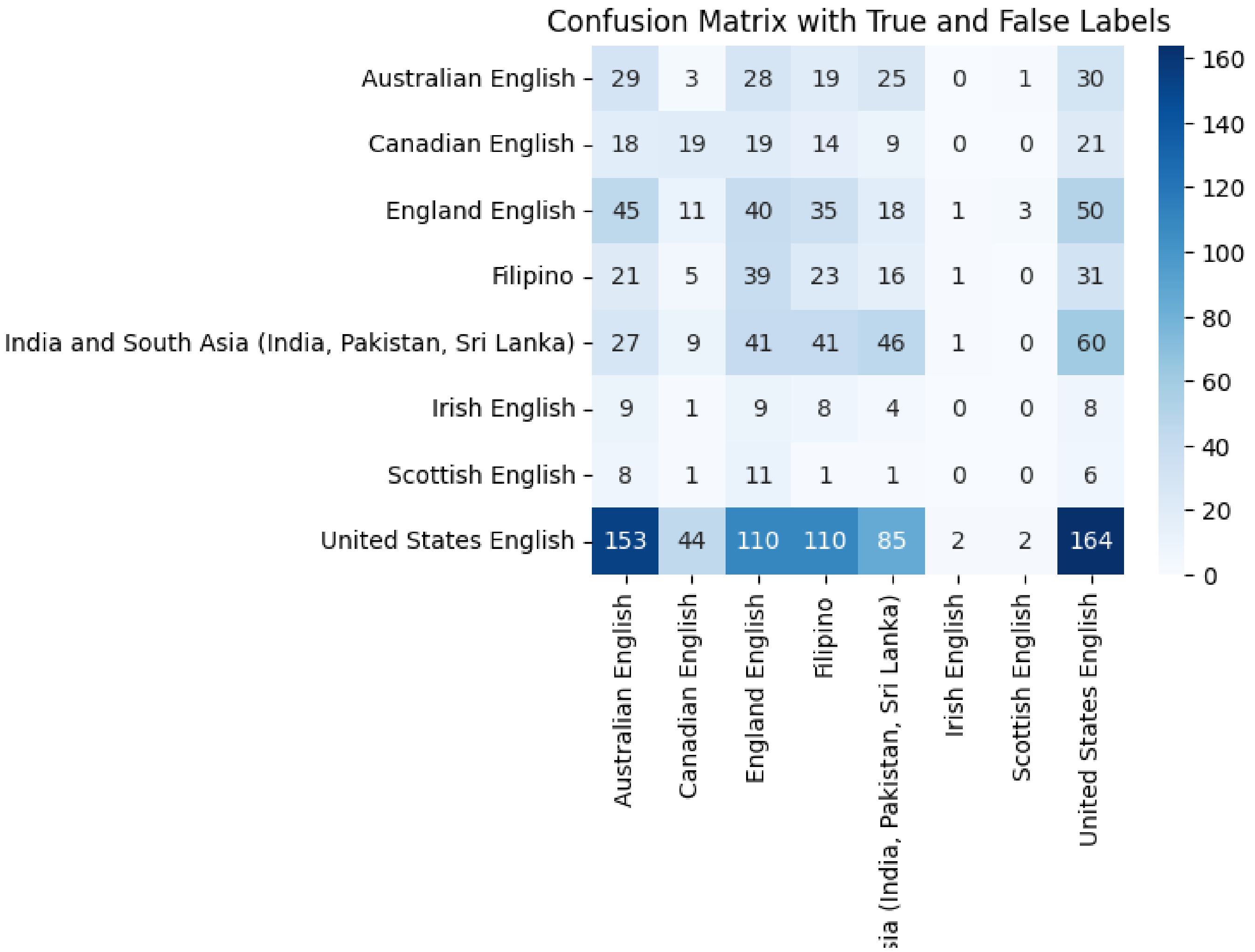




Confusion Matrix on the BERT Transformer

In [ ]:

```
#confusion matrix
from sklearn.metrics import confusion_matrix
import seaborn as sns
import matplotlib.pyplot as plt

predictions = trainer.predict(tokenized_datasets_test)
y_pred = np.argmax(predictions.predictions, axis=1)
y_true = tokenized_datasets_test['label']
cm = confusion_matrix(y_true, y_pred)

plt.figure(figsize=(5, 4))
plt.xlabel('Predicted labels')
plt.ylabel('True labels')
plt.title('Confusion Matrix with True and False Labels')
ax = sns.heatmap(cm, annot=True, fmt='g', cmap='Blues', xticklabels=id2label.values(), yt
icklabels=id2label.values())
```



5 epoch

Define and train the model with 5 epochs.

In [ ]:

```
#Define a training arguments class
from transformers import TrainingArguments
training_args = TrainingArguments("test-trainer", evaluation_strategy="epoch", num_train_epochs=5)


#Define the model
num_labels = len(id2label)
num_labels
from transformers import AutoModelForSequenceClassification
model = AutoModelForSequenceClassification.from_pretrained(checkpoint,num_labels=num_labels)


#Define the compute metrics
import evaluate

def compute_metrics(eval_preds):
    metric = evaluate.load("accuracy")
    logits, labels = eval_preds
    predictions = np.argmax(logits, axis=-1)
    return metric.compute(predictions=predictions, references=labels)


#Define a trainer
from transformers import Trainer

trainer = Trainer(
    model,
    training_args,
    train_dataset=tokenized_datasets_train,
    eval_dataset=tokenized_datasets_test,
    data_collator=data_collator,
    tokenizer=tokenizer,
    compute_metrics = compute_metrics,
)
```

```
Some weights of BertForSequenceClassification were not initialized from the model checkpoint at bert-base-uncased and are newly initialized: ['classifier.bias', 'classifier.weight']
You should probably TRAIN this model on a down-stream task to be able to use it for predictions and inference.
```

In [ ]:

```
trainer.train()
```

[2355/2355 09:07, Epoch 5/5]

Epoch	Training Loss	Validation Loss	Accuracy
1	No log	2.004365	0.134766
2	2.071700	1.953544	0.162109

Epoch	Training Loss	Validation Loss	Accuracy
3	1.789400	2.034272	0.203776
4	1.268700	2.584093	0.171224
5	0.686900	2.747876	0.225260

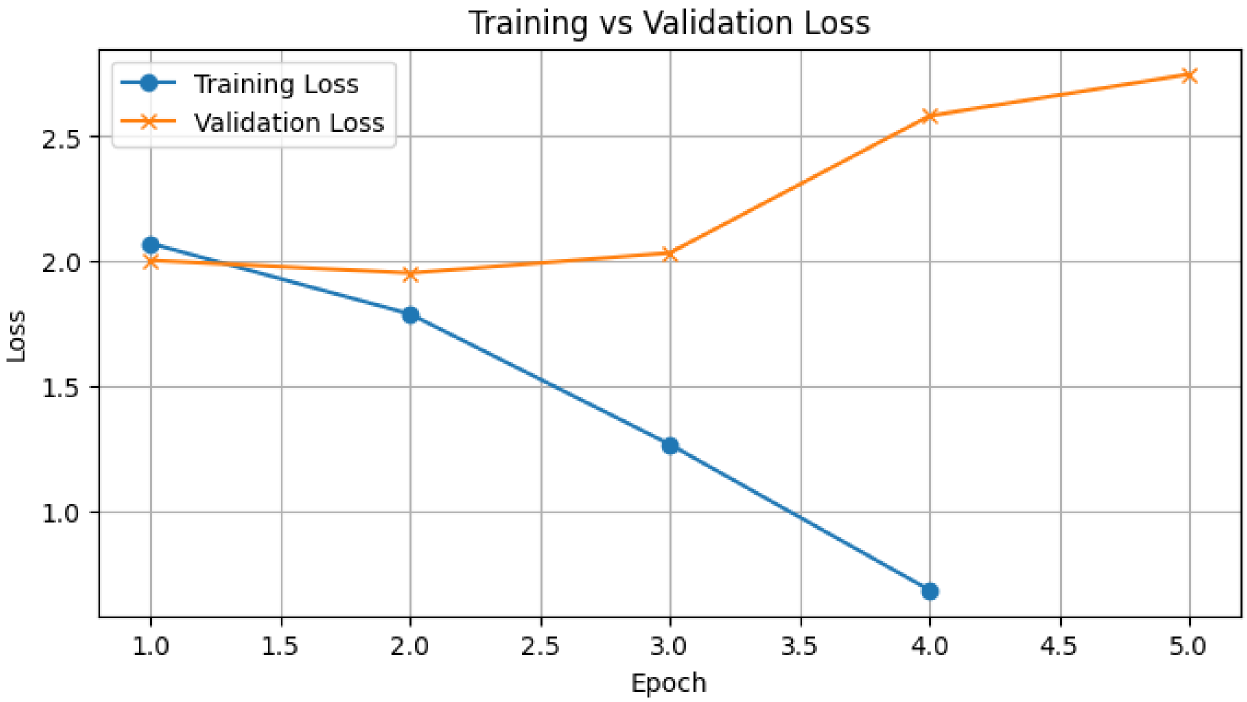
Out[ ]:

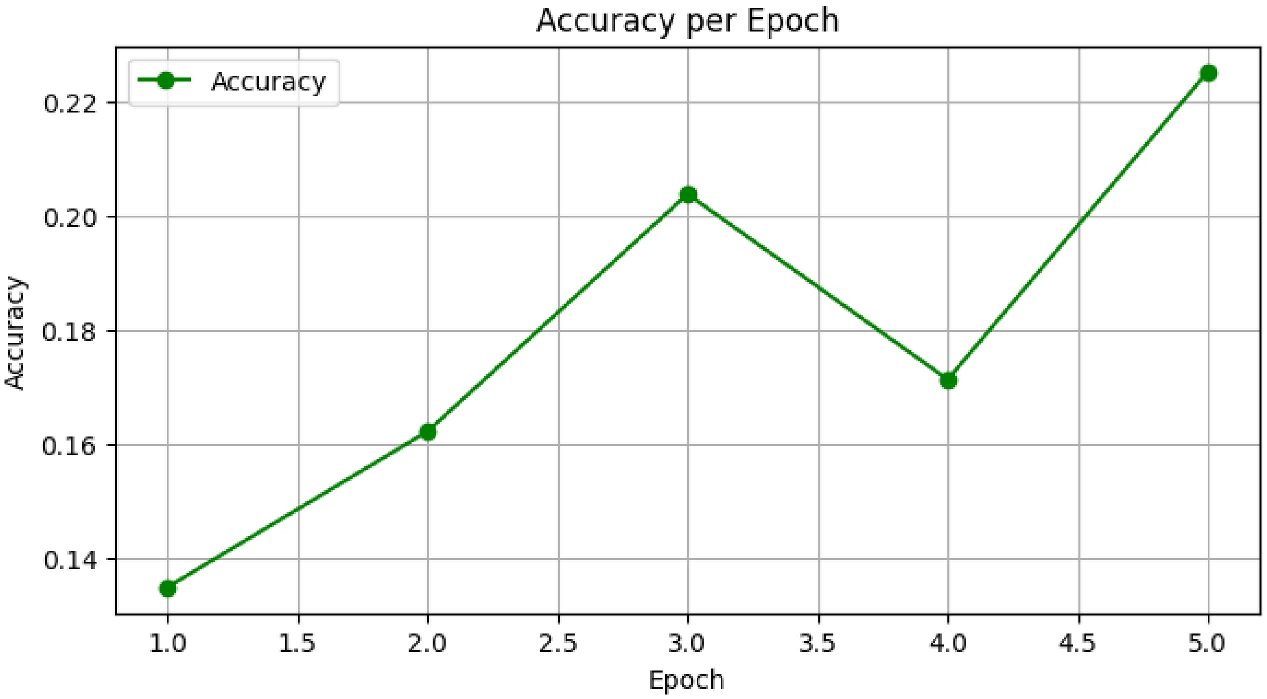
```
TrainOutput(global_step=2355, training_loss=1.2882614556897725, metrics={'train_runtime':
548.8262, 'train_samples_per_second': 34.291, 'train_steps_per_second': 4.291, 'total_flos
': 4952016820469760.0, 'train_loss': 1.2882614556897725, 'epoch': 5.0})
```

Do the plotting as above.

In [ ]:

```
import matplotlib.pyplot as plt

# Assuming trainer.state.log_history contains the logged metrics
log_history = trainer.state.log_history

epochs = []
training_loss = [None] * len(epochs)   # Initialize with None
validation_loss = [None] * len(epochs)   # Initialize with None
accuracy = []

# Extracting data from log_history
for log in log_history:
    if 'epoch' in log:
        epoch_index = int(log['epoch']) - 1   # Convert to 0-indexed
        while len(epochs) <= epoch_index:   # Append to epochs list if this epoch is not y
et included
            epochs.append(len(epochs) + 1)
            training_loss.append(None)   # Append None for this new epoch
            validation_loss.append(None)   # Append None for this new epoch
        # Now we safely assume that the lengths of the lists are equal to epoch_index + 1
        if 'loss' in log:
            training_loss[epoch_index] = log['loss']
        if 'eval_loss' in log:
            validation_loss[epoch_index] = log['eval_loss']
        if 'eval_accuracy' in log:
            accuracy.append(log['eval_accuracy'])

# Filter out the epochs where we have validation loss to match with training loss
valid_epochs = [epoch for epoch, val_loss in zip(epochs, validation_loss) if val_loss is
not None]
valid_validation_loss = [val_loss for val_loss in validation_loss if val_loss is not None]

# Comparison plot of training and validation loss
plt.figure(figsize=(8, 4))
plt.plot(epochs, training_loss, label='Training Loss', marker='o')
plt.plot(valid_epochs, valid_validation_loss, label='Validation Loss', marker='x')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.title('Training vs Validation Loss')
plt.legend()
plt.grid(True)
plt.show()

# Ensure the list lengths match for accuracy plot
while len(accuracy) < len(epochs):
    accuracy.append(None)

# Separate plot for accuracy
plt.figure(figsize=(8, 4))
plt.plot(epochs, accuracy, label='Accuracy', color='green', marker='o')
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.title('Accuracy per Epoch')
plt.legend()
plt.grid(True)
plt.show()
```

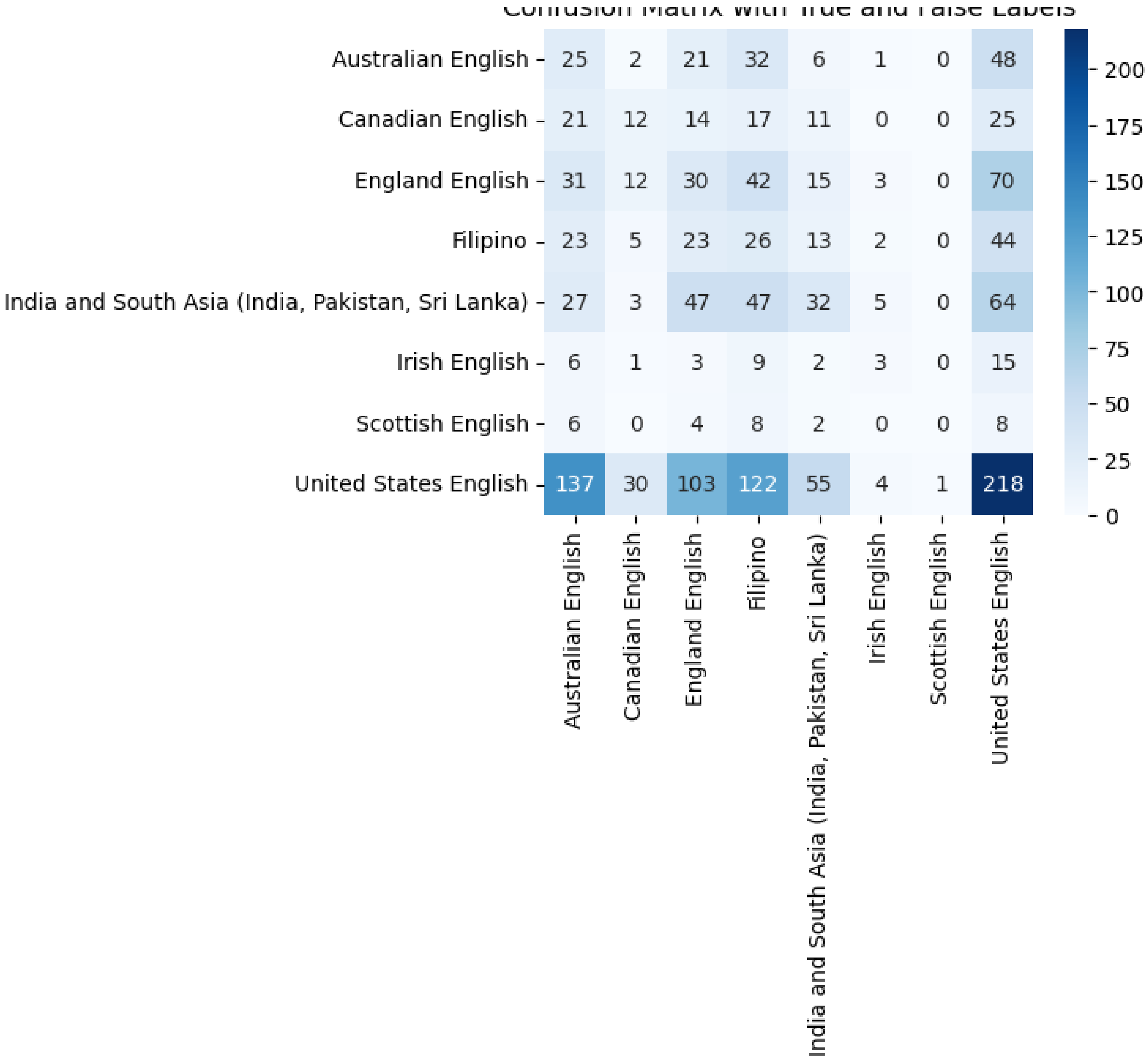




And this is the confusion matrix.

In [ ]:

```
#confusion matrix
from sklearn.metrics import confusion_matrix
import seaborn as sns
import matplotlib.pyplot as plt

predictions = trainer.predict(tokenized_datasets_test)
y_pred = np.argmax(predictions.predictions, axis=1)
y_true = tokenized_datasets_test['label']
cm = confusion_matrix(y_true, y_pred)

plt.figure(figsize=(5, 4))
plt.xlabel('Predicted labels')
plt.ylabel('True labels')
plt.title('Confusion Matrix with True and False Labels')
ax = sns.heatmap(cm, annot=True, fmt='g', cmap='Blues', xticklabels=id2label.values(), yt
icklabels=id2label.values())
```


Confusion Matrix with True and False Labels
Australian English 25 2 21 32 6 1 0 48
Canadian English 21 12 14 17 11 0 0 25
England English 31 12 30 42 15 3 0 70
Filipino 23 5 23 26 13 2 0 44
India and South Asia (India, Pakistan, Sri Lanka) 27 3 47 47 32 5 0 64
Irish English 6 1 3 9 2 3 0 15
Scottish English 6 0 4 8 2 0 0 8
United States English 137 30 103 122 55 4 1 218
Australian English
Canadian English
England English
Filipino
India and South Asia (India, Pakistan, Sri Lanka)
Irish English
Scottish English
United States English
200
175
150
125
100
75
50
25
0