```
!pip install transformers
import torch
import torch.nn as nn
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.metrics import confusion_matrix
from datetime import datetime
from pathlib import Path
import pandas as pd
import torchtext.data as ttd
```

```
Requirement already satisfied: transformers in /usr/local/lib/python3.6/dist-packages
Requirement already satisfied: dataclasses; python_version < "3.7" in /usr/local/lib/
Requirement already satisfied: regex!=2019.12.17 in /usr/local/lib/python3.6/dist-pac
Requirement already satisfied: tqdm>=4.27 in /usr/local/lib/python3.6/dist-packages (
Requirement already satisfied: sacremoses in /usr/local/lib/python3.6/dist-packages (
Requirement already satisfied: requests in /usr/local/lib/python3.6/dist-packages (fr
Requirement already satisfied: numpy in /usr/local/lib/python3.6/dist-packages (from 
Requirement already satisfied: packaging in /usr/local/lib/python3.6/dist-packages (f
Requirement already satisfied: filelock in /usr/local/lib/python3.6/dist-packages (fr
Requirement already satisfied: tokenizers==0.9.4 in /usr/local/lib/python3.6/dist-pac
Requirement already satisfied: joblib in /usr/local/lib/python3.6/dist-packages (from
Requirement already satisfied: click in /usr/local/lib/python3.6/dist-packages (from 
Requirement already satisfied: six in /usr/local/lib/python3.6/dist-packages (from sa
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.6/dist-pa
Requirement already satisfied: idna<3,>=2.5 in /usr/local/lib/python3.6/dist-packages
Requirement already satisfied: urllib3!=1.25.0,!=1.25.1,<1.26,>=1.21.1 in /usr/local/
Requirement already satisfied: chardet<4,>=3.0.2 in /usr/local/lib/python3.6/dist-pac
Requirement already satisfied: pyparsing>=2.0.2 in /usr/local/lib/python3.6/dist-pack
```

Loading Dataset

We will use The 20 Newsgroups dataset Dataset homepage:

Scikit-learn includes some nice helper functions for retrieving the 20 Newsgroups dataset-- https://scikit-learn.org/stable/modules/generated/sklearn.datasets.fetch_20newsgroups.html. We'll use them below to retrieve the dataset.

Also look at results fron non- neural net models here : https://scikit-learn.org/stable/auto_examples/text/plot_document_classification_20newsgroups.html#sphx-glr-auto-examples-text-plot-document-classification-20newsgroups-py

```
gpu_info = !nvidia-smi
gpu_info = '\n'.join(gpu_info)
if gpu_info.find('failed') >= 0:
  print('Select the Runtime > "Change runtime type" menu to enable a GPU accelerator, ')
  print('and then re-execute this cell.')
else:
  print(gpu_info)
```

```
Wed Dec  2 01:15:56 2020
+-----------------------------------------------------------------------------+
| NVIDIA-SMI 455.38       Driver Version: 418.67       CUDA Version: 10.1     |
|-------------------------------+----------------------+----------------------+
| GPU  Name        Persistence-M| Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp  Perf  Pwr:Usage/Cap|         Memory-Usage | GPU-Util  Compute M. |
|                               |                      |               MIG M. |
|===============================+======================+======================|
|   0  Tesla V100-SXM2...  Off  | 00000000:00:04.0 Off |                    0 |
| N/A   36C    P0    24W / 300W |      0MiB / 16130MiB |      0%      Default |
|                               |                      |                 ERR! |
+-------------------------------+----------------------+----------------------+

+-----------------------------------------------------------------------------+
| Processes:                                                                  |
|  GPU   GI   CI        PID   Type   Process name                  GPU Memory |
|        ID   ID                                                   Usage      |
|=============================================================================|
|  No running processes found                                                 |
+-----------------------------------------------------------------------------+
```

```
device = torch.device("cuda:0" if torch.cuda.is_available() else "cpu")
print(device)
```

```
cuda:0
```

```
from sklearn.datasets import fetch_20newsgroups

train = fetch_20newsgroups(subset='train',
                           remove=('headers', 'footers', 'quotes'))

test = fetch_20newsgroups(subset='test',
                          remove=('headers', 'footers', 'quotes'))
```

```
print(train.data[0])
```

```
I was wondering if anyone out there could enlighten me on this car I saw
the other day. It was a 2-door sports car, looked to be from the late 60s/
early 70s. It was called a Bricklin. The doors were really small. In addition,
the front bumper was separate from the rest of the body. This is
all I know. If anyone can tellme a model name, engine specs, years
of production, where this car is made, history, or whatever info you
have on this funky looking car, please e-mail.
```

```
print(train.target[0])
```

```
7
```

```
train.target_names
```

```
['alt.atheism',
 'comp.graphics',
 'comp.os.ms-windows.misc',
 'comp.sys.ibm.pc.hardware',
 'comp.sys.mac.hardware',
```

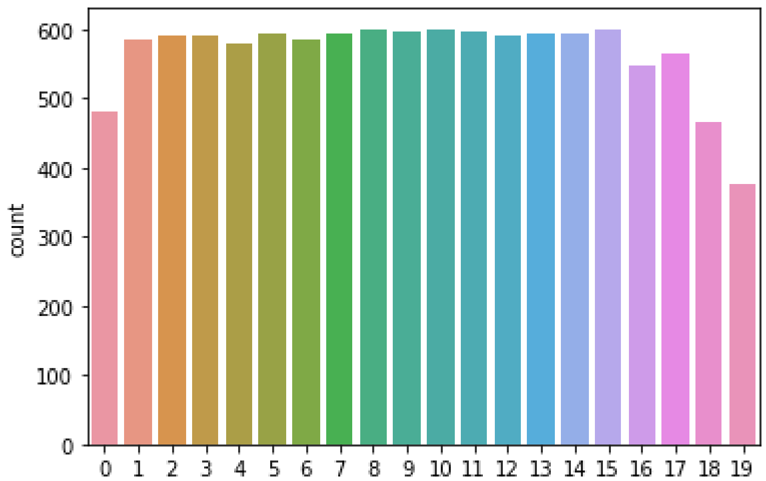
```
 'comp.windows.x',
 'misc.forsale',
 'rec.autos',
 'rec.motorcycles',
 'rec.sport.baseball',
 'rec.sport.hockey',
 'sci.crypt',
 'sci.electronics',
 'sci.med',
 'sci.space',
 'soc.religion.christian',
 'talk.politics.guns',
 'talk.politics.mideast',
 'talk.politics.misc',
 'talk.religion.misc']
```

```
len(train.target_names)
```

```
20
```

```
import seaborn as sns

# Plot the number of tokens of each length.
sns.countplot(train.target);
```

```
/usr/local/lib/python3.6/dist-packages/seaborn/_decorators.py:43: FutureWarning: Pass
  FutureWarning
```



BERT with 140 features

```
from transformers import BertTokenizer

# Load the BERT tokenizer.
print('Loading BERT tokenizer...')
tokenizer = BertTokenizer.from_pretrained('bert-base-uncased', do_lower_case=True)
```

```
Loading BERT tokenizer...
```

```
# Get last three tokens and truncate head
# Tokenize all of the sentences and map the tokens to thier word IDs.
input_ids = []
attention_masks = []
docoder_sent=[]
before_trunc=[]
maxlen=140

# For every sentence...
for sent in train.data:
    # `encode_plus` will:
    #   (1) Tokenize the sentence.
    #   (2) Prepend the `[CLS]` token to the start.
    #   (3) Append the `[SEP]` token to the end.
    #   (4) Map tokens to their IDs.
    #   (5) Pad or truncate the sentence to `max_length`
    #   (6) Create attention masks for [PAD] tokens.
    encoded_dict = tokenizer.encode_plus(
                        sent,                      # Sentence to encode.
                        add_special_tokens = True, # Add '[CLS]' and '[SEP]'
                        truncation=False,
                        padding=False,
                        #max_length = maxlen,           # Pad & truncate all sentences.
                        return_attention_mask = True,   # Construct attn. masks.
                        #return_tensors = 'pt',     # Return pytorch tensors.
                   )

    before_trunc.append(encoded_dict['input_ids'])

    ids = encoded_dict['input_ids']
    if len(ids)>=maxlen:
      ids = [ids[0]] + ids[-(maxlen-1):-1] + [102]
    else:
      ids = ids + ([0] * (maxlen-len(ids)))
    encoded_dict['input_ids']=torch.tensor([ids])

    ids = encoded_dict['attention_mask']
    if len(ids)>=maxlen:
      ids = [ids[0]] + ids[-(maxlen-1):-1] + [1]
    else:
      ids = ids + ([0] * (maxlen-len(ids)))
    encoded_dict['attention_mask']=torch.tensor([ids])

    # Add the encoded sentence to the list.
    input_ids.append(encoded_dict['input_ids'])
    #print(input_ids)

    # And its attention mask (simply differentiates padding from non-padding).
    attention_masks.append(encoded_dict['attention_mask'])

    # Get the decoded sentence
    docoder_sent.append(tokenizer.decode(encoded_dict['input_ids'].squeeze()))

# Convert the lists into tensors.
input_ids = torch.cat(input_ids, dim=0)
```

```
#print(input_ids)
attention_masks = torch.cat(attention_masks, dim=0)
labels = torch.tensor(train.target)
```

```
Token indices sequence length is longer than the specified maximum sequence length fo
```

```
# Get last three tokens and truncate head
# Tokenize all of the sentences and map the tokens to thier word IDs.
test_input_ids = []
test_attention_masks = []
test_decoder_sent=[]
test_before_trunc=[]
maxlen=140

# For every sentence...
for sent in test.data:
    # `encode_plus` will:
    #   (1) Tokenize the sentence.
    #   (2) Prepend the `[CLS]` token to the start.
    #   (3) Append the `[SEP]` token to the end.
    #   (4) Map tokens to their IDs.
    #   (5) Pad or truncate the sentence to `max_length`
    #   (6) Create attention masks for [PAD] tokens.
    encoded_dict = tokenizer.encode_plus(
                        sent,                      # Sentence to encode.
                        add_special_tokens = True, # Add '[CLS]' and '[SEP]'
                        truncation=False,
                        padding=False,
                        #max_length = maxlen,           # Pad & truncate all sentences.
                        return_attention_mask = True,   # Construct attn. masks.
                        #return_tensors = 'pt',     # Return pytorch tensors.
                   )

    test_before_trunc.append(encoded_dict['input_ids'])

    ids = encoded_dict['input_ids']
    if len(ids)>=maxlen:
      ids = [ids[0]] + ids[-(maxlen-1):-1] + [102]
    else:
      ids = ids + ([0] * (maxlen-len(ids)))
    encoded_dict['input_ids']=torch.tensor([ids])

    ids = encoded_dict['attention_mask']
    if len(ids)>=maxlen:
      ids = [ids[0]] + ids[-(maxlen-1):-1] + [1]
    else:
      ids = ids + ([0] * (maxlen-len(ids)))
    encoded_dict['attention_mask']=torch.tensor([ids])

    # Add the encoded sentence to the list.
    test_input_ids.append(encoded_dict['input_ids'])
    #print(input_ids)

    # And its attention mask (simply differentiates padding from non-padding)
```

```
        # And its attention mask (simply differentiates padding from non-padding).
        test_attention_masks.append(encoded_dict['attention_mask'])

        # Get the decoded sentence
        test_decoder_sent.append(tokenizer.decode(encoded_dict['input_ids'].squeeze()))

    # Convert the lists into tensors.
    test_input_ids = torch.cat(test_input_ids, dim=0)
    #print(input_ids)
    test_attention_masks = torch.cat(test_attention_masks, dim=0)
    test_labels = torch.tensor(test.target)


    from torch.utils.data import TensorDataset, random_split

    # Combine the training inputs into a TensorDataset.
    dataset = TensorDataset(input_ids, attention_masks, labels)
    test_dataset = TensorDataset(test_input_ids, test_attention_masks, test_labels)

    # Create a 90-10 train-validation split.

    # Calculate the number of samples to include in each set.
    train_size = int(0.9 * len(dataset))
    val_size = len(dataset) - train_size

    # Divide the dataset by randomly selecting samples.
    train_dataset, val_dataset = random_split(dataset, [train_size, val_size])

    print('{:>5,} training samples'.format(train_size))
    print('{:>5,} validation samples'.format(val_size))
    print('{:>5,} test samples'.format(len(test_dataset)))
```

```
    10,182 training samples
    1,132 validation samples
    7,532 test samples
```

```
    from torch.utils.data import DataLoader, RandomSampler, SequentialSampler

    # The DataLoader needs to know our batch size for training, so we specify it
    # here. For fine-tuning BERT on a specific task, the authors recommend a batch
    # size of 16 or 32.
    batch_size = 8

    # Create the DataLoaders for our training and validation sets.
    # We'll take training samples in random order.
    train_dataloader = DataLoader(
                train_dataset,  # The training samples.
                sampler = RandomSampler(train_dataset), # Select batches randomly
                batch_size = batch_size # Trains with this batch size.
            )

    # For validation the order doesn't matter, so we'll just read them sequentially.
    validation_dataloader = DataLoader(
                val_dataset, # The validation samples.
                sampler = SequentialSampler(val_dataset), # Pull out batches sequentially.
                batch_size = batch_size # Evaluate with this batch size.
```

```
            batch_size = batch_size # Evaluate with this batch size.
        )

test_dataloader = DataLoader(
            test_dataset,  # The training samples.
            sampler = RandomSampler(test_dataset), # Select batches randomly
            batch_size = batch_size # Trains with this batch size.
        )
```

```
from transformers import  BertModel

bert_model = BertModel.from_pretrained('bert-base-uncased')
```

Downloading: 100% 433/433 [00:00<00:00, 1.26kB/s]

Downloading: 100% 440M/440M [00:06<00:00, 72.7MB/s]

```
bert_model
```

```
          (output): BertOutput(
            (dense): Linear(in_features=3072, out_features=768, bias=True)
            (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
            (dropout): Dropout(p=0.1, inplace=False)
          )
        )
        (10): BertLayer(
          (attention): BertAttention(
            (self): BertSelfAttention(
              (query): Linear(in_features=768, out_features=768, bias=True)
              (key): Linear(in_features=768, out_features=768, bias=True)
              (value): Linear(in_features=768, out_features=768, bias=True)
              (dropout): Dropout(p=0.1, inplace=False)
            )
            (output): BertSelfOutput(
              (dense): Linear(in_features=768, out_features=768, bias=True)
              (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
              (dropout): Dropout(p=0.1, inplace=False)
            )
          )
          (intermediate): BertIntermediate(
            (dense): Linear(in_features=768, out_features=3072, bias=True)
          )
          (output): BertOutput(
            (dense): Linear(in_features=3072, out_features=768, bias=True)
            (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
            (dropout): Dropout(p=0.1, inplace=False)
          )
        )
        (11): BertLayer(
          (attention): BertAttention(
            (self): BertSelfAttention(
              (query): Linear(in_features=768, out_features=768, bias=True)
              (key): Linear(in_features=768, out_features=768, bias=True)
              (value): Linear(in_features=768, out_features=768, bias=True)
              (dropout): Dropout(p=0.1, inplace=False)
            )
            (output): BertSelfOutput(
```

```
          (dense): Linear(in_features=768, out_features=768, bias=True)
          (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
          (dropout): Dropout(p=0.1, inplace=False)
        )
      )
      (intermediate): BertIntermediate(
        (dense): Linear(in_features=768, out_features=3072, bias=True)
      )
      (output): BertOutput(
        (dense): Linear(in_features=3072, out_features=768, bias=True)
        (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
        (dropout): Dropout(p=0.1, inplace=False)
      )
    )
  )
)
(pooler): BertPooler(
  (dense): Linear(in_features=768, out_features=768, bias=True)
  (activation): Tanh()
)
)
```

```
# Define the model
class linear(nn.Module):

  def __init__(self, bert_model, n_outputs, dropout_rate):

    super(linear, self).__init__()

    self.D = bert_model.config.to_dict()['hidden_size']
    self.bert_model = bert_model
    self.K = n_outputs
    self.dropout_rate=dropout_rate

    # embedding layer
    #self.embed = nn.Embedding(self.V, self.D)


    # dense layer
    self.fc = nn.Linear(self.D , self.K)

    # dropout layer
    self.dropout= nn.Dropout(self.dropout_rate)

  def forward(self, X):

    with torch.no_grad():
      embedding = self.bert_model(X)[0][:,0,:]

    #embedding= self.dropout(embedding)

    output = self.fc(embedding)
    output= self.dropout(output)

    return output
```

```
n_outputs = 20
dropout_rate = 0.5


#model = RNN(n_vocab, embed_dim, n_hidden, n_rnnlayers, n_outputs, bidirectional, dropout_
model = linear(bert_model, n_outputs, dropout_rate)
model.to(device)
```

```
            )
          )
          (10): BertLayer(
            (attention): BertAttention(
              (self): BertSelfAttention(
                (query): Linear(in_features=768, out_features=768, bias=True)
                (key): Linear(in_features=768, out_features=768, bias=True)
                (value): Linear(in_features=768, out_features=768, bias=True)
                (dropout): Dropout(p=0.1, inplace=False)
              )
              (output): BertSelfOutput(
                (dense): Linear(in_features=768, out_features=768, bias=True)
                (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
                (dropout): Dropout(p=0.1, inplace=False)
              )
            )
            (intermediate): BertIntermediate(
              (dense): Linear(in_features=768, out_features=3072, bias=True)
            )
            (output): BertOutput(
              (dense): Linear(in_features=3072, out_features=768, bias=True)
              (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
              (dropout): Dropout(p=0.1, inplace=False)
            )
          )
          (11): BertLayer(
            (attention): BertAttention(
              (self): BertSelfAttention(
                (query): Linear(in_features=768, out_features=768, bias=True)
                (key): Linear(in_features=768, out_features=768, bias=True)
                (value): Linear(in_features=768, out_features=768, bias=True)
                (dropout): Dropout(p=0.1, inplace=False)
              )
              (output): BertSelfOutput(
                (dense): Linear(in_features=768, out_features=768, bias=True)
                (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
                (dropout): Dropout(p=0.1, inplace=False)
              )
            )
            (intermediate): BertIntermediate(
              (dense): Linear(in_features=768, out_features=3072, bias=True)
            )
            (output): BertOutput(
              (dense): Linear(in_features=3072, out_features=768, bias=True)
              (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
              (dropout): Dropout(p=0.1, inplace=False)
            )
          )
        )
      )
      (pooler): BertPooler(
        (dense): Linear(in_features=768, out_features=768, bias=True)
        (activation): Tanh()
```

```
      )
    )
    (fc): Linear(in_features=768, out_features=20, bias=True)

    (dropout): Dropout(p=0.5, inplace=False)
  )
```

```
print(model)
```

```
            (dropout): Dropout(p=0.1, inplace=False)
          )
        )
        (10): BertLayer(
          (attention): BertAttention(
            (self): BertSelfAttention(
              (query): Linear(in_features=768, out_features=768, bias=True)
              (key): Linear(in_features=768, out_features=768, bias=True)
              (value): Linear(in_features=768, out_features=768, bias=True)
              (dropout): Dropout(p=0.1, inplace=False)
            )
            (output): BertSelfOutput(
              (dense): Linear(in_features=768, out_features=768, bias=True)
              (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
              (dropout): Dropout(p=0.1, inplace=False)
            )
          )
          (intermediate): BertIntermediate(
            (dense): Linear(in_features=768, out_features=3072, bias=True)
          )
          (output): BertOutput(
            (dense): Linear(in_features=3072, out_features=768, bias=True)
            (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
            (dropout): Dropout(p=0.1, inplace=False)
          )
        )
        (11): BertLayer(
          (attention): BertAttention(
            (self): BertSelfAttention(
              (query): Linear(in_features=768, out_features=768, bias=True)
              (key): Linear(in_features=768, out_features=768, bias=True)
              (value): Linear(in_features=768, out_features=768, bias=True)
              (dropout): Dropout(p=0.1, inplace=False)
            )
            (output): BertSelfOutput(
              (dense): Linear(in_features=768, out_features=768, bias=True)
              (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
              (dropout): Dropout(p=0.1, inplace=False)
            )
          )
          (intermediate): BertIntermediate(
            (dense): Linear(in_features=768, out_features=3072, bias=True)
          )
          (output): BertOutput(
            (dense): Linear(in_features=3072, out_features=768, bias=True)
            (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
            (dropout): Dropout(p=0.1, inplace=False)
          )
        )
      )
    )
    (pooler): BertPooler(
```

```
    (pooler): BertPooler(
      (dense): Linear(in_features=768, out_features=768, bias=True)
      (activation): Tanh()
    )
  )
  (fc): Linear(in_features=768, out_features=20, bias=True)
  (dropout): Dropout(p=0.5, inplace=False)
)
```

```
for name, param in model.named_parameters():
  print(name, param.shape)
```

```
bert_model.encoder.layer.8.attention.output.LayerNorm.bias torch.Size([768])
bert_model.encoder.layer.8.intermediate.dense.weight torch.Size([3072, 768])
bert_model.encoder.layer.8.intermediate.dense.bias torch.Size([3072])
bert_model.encoder.layer.8.output.dense.weight torch.Size([768, 3072])
bert_model.encoder.layer.8.output.dense.bias torch.Size([768])
bert_model.encoder.layer.8.output.LayerNorm.weight torch.Size([768])
bert_model.encoder.layer.8.output.LayerNorm.bias torch.Size([768])
bert_model.encoder.layer.9.attention.self.query.weight torch.Size([768, 768])
bert_model.encoder.layer.9.attention.self.query.bias torch.Size([768])
bert_model.encoder.layer.9.attention.self.key.weight torch.Size([768, 768])
bert_model.encoder.layer.9.attention.self.key.bias torch.Size([768])
bert_model.encoder.layer.9.attention.self.value.weight torch.Size([768, 768])
bert_model.encoder.layer.9.attention.self.value.bias torch.Size([768])
bert_model.encoder.layer.9.attention.output.dense.weight torch.Size([768, 768])
bert_model.encoder.layer.9.attention.output.dense.bias torch.Size([768])
bert_model.encoder.layer.9.attention.output.LayerNorm.weight torch.Size([768])
bert_model.encoder.layer.9.attention.output.LayerNorm.bias torch.Size([768])
bert_model.encoder.layer.9.intermediate.dense.weight torch.Size([3072, 768])
bert_model.encoder.layer.9.intermediate.dense.bias torch.Size([3072])
bert_model.encoder.layer.9.output.dense.weight torch.Size([768, 3072])
bert_model.encoder.layer.9.output.dense.bias torch.Size([768])
bert_model.encoder.layer.9.output.LayerNorm.weight torch.Size([768])
bert_model.encoder.layer.9.output.LayerNorm.bias torch.Size([768])
bert_model.encoder.layer.10.attention.self.query.weight torch.Size([768, 768])
bert_model.encoder.layer.10.attention.self.query.bias torch.Size([768])
bert_model.encoder.layer.10.attention.self.key.weight torch.Size([768, 768])
bert_model.encoder.layer.10.attention.self.key.bias torch.Size([768])
bert_model.encoder.layer.10.attention.self.value.weight torch.Size([768, 768])
bert_model.encoder.layer.10.attention.self.value.bias torch.Size([768])
bert_model.encoder.layer.10.attention.output.dense.weight torch.Size([768, 768])
bert_model.encoder.layer.10.attention.output.dense.bias torch.Size([768])
bert_model.encoder.layer.10.attention.output.LayerNorm.weight torch.Size([768])
bert_model.encoder.layer.10.attention.output.LayerNorm.bias torch.Size([768])
bert_model.encoder.layer.10.intermediate.dense.weight torch.Size([3072, 768])
bert_model.encoder.layer.10.intermediate.dense.bias torch.Size([3072])
bert_model.encoder.layer.10.output.dense.weight torch.Size([768, 3072])
bert_model.encoder.layer.10.output.dense.bias torch.Size([768])
bert_model.encoder.layer.10.output.LayerNorm.weight torch.Size([768])
bert_model.encoder.layer.10.output.LayerNorm.bias torch.Size([768])
bert_model.encoder.layer.11.attention.self.query.weight torch.Size([768, 768])
bert_model.encoder.layer.11.attention.self.query.bias torch.Size([768])
bert_model.encoder.layer.11.attention.self.key.weight torch.Size([768, 768])
bert_model.encoder.layer.11.attention.self.key.bias torch.Size([768])
bert_model.encoder.layer.11.attention.self.value.weight torch.Size([768, 768])
bert_model.encoder.layer.11.attention.self.value.bias torch.Size([768])
bert_model.encoder.layer.11.attention.output.dense.weight torch.Size([768, 768])
bert_model.encoder.layer.11.attention.output.dense.bias torch.Size([768])
bert_model.encoder.layer.11.attention.output.LayerNorm.weight torch.Size([768])
bert_model.encoder.layer.11.attention.output.LayerNorm.bias torch.Size([768])
```

```
bert_model.encoder.layer.11.attention.output.LayerNorm.bias torch.Size([768])
bert_model.encoder.layer.11.intermediate.dense.weight torch.Size([3072, 768])
bert_model.encoder.layer.11.intermediate.dense.bias torch.Size([3072])
bert_model.encoder.layer.11.output.dense.weight torch.Size([768, 3072])
bert_model.encoder.layer.11.output.dense.bias torch.Size([768])
bert_model.encoder.layer.11.output.LayerNorm.weight torch.Size([768])
bert_model.encoder.layer.11.output.LayerNorm.bias torch.Size([768])
bert_model.pooler.dense.weight torch.Size([768, 768])
bert_model.pooler.dense.bias torch.Size([768])
fc.weight torch.Size([20, 768])
fc.bias torch.Size([20])
```

```
import random

seed = 123

random.seed(seed)
np.random.seed(seed)
torch.manual_seed(seed)
torch.cuda.manual_seed_all(seed)

learning_rate = 0.001
epochs=10

# STEP 5: INSTANTIATE LOSS CLASS
criterion = nn.CrossEntropyLoss()

# STEP 6: INSTANTIATE OPTIMIZER CLASS

optimizer = torch.optim.Adam(model.parameters(), lr=learning_rate)

# Freeze embedding Layer

#freeze embeddings
#model.embed.weight.requires_grad  = False

# STEP 7: TRAIN THE MODEL

train_losses= np.zeros(epochs)
valid_losses= np.zeros(epochs)


for epoch in range(epochs):

  t0= datetime.now()
  train_loss=[]

  model.train()
  for batch in train_dataloader:

    # forward pass
    output= model(batch[0].to(device))
    loss=criterion(output,batch[2].to(device))

    # set gradients to zero
    optimizer.zero_grad()
```

```
      # backward pass
      loss.backward()
      optimizer.step()
      train_loss.append(loss.item())

    train_loss=np.mean(train_loss)

    valid_loss=[]
    model.eval()
    with torch.no_grad():
      for batch in validation_dataloader:

        # forward pass
        output= model(batch[0].to(device))
        loss=criterion(output,batch[2].to(device))

        valid_loss.append(loss.item())

      valid_loss=np.mean(valid_loss)

    # save Losses
    train_losses[epoch]= train_loss
    valid_losses[epoch]= valid_loss
    dt= datetime.now()-t0
    print(f'Epoch {epoch+1}/{epochs}, Train Loss: {train_loss:.4f}    Valid Loss: {valid_los
```

```
Epoch 1/10, Train Loss: 2.8169    Valid Loss: 2.3916, Duration: 0:00:33.408414
Epoch 2/10, Train Loss: 2.6087    Valid Loss: 2.2411, Duration: 0:00:33.444696
Epoch 3/10, Train Loss: 2.5485    Valid Loss: 2.1191, Duration: 0:00:33.461446
Epoch 4/10, Train Loss: 2.5170    Valid Loss: 2.0605, Duration: 0:00:33.362643
Epoch 5/10, Train Loss: 2.5109    Valid Loss: 2.0442, Duration: 0:00:33.420326
Epoch 6/10, Train Loss: 2.4841    Valid Loss: 1.9653, Duration: 0:00:33.425726
Epoch 7/10, Train Loss: 2.4805    Valid Loss: 1.9527, Duration: 0:00:33.450313
Epoch 8/10, Train Loss: 2.4489    Valid Loss: 1.9174, Duration: 0:00:33.355541
Epoch 9/10, Train Loss: 2.4518    Valid Loss: 1.9252, Duration: 0:00:33.429696
Epoch 10/10, Train Loss: 2.4513    Valid Loss: 1.9301, Duration: 0:00:33.472276
```

```
# Accuracy- write a function to get accuracy
# use this function to get accuracy and print accuracy
def get_accuracy(data_iter, model):
  model.eval()
  with torch.no_grad():
    correct =0
    total =0

    for batch in data_iter:

      output=model(batch[0].to(device))
      _,indices = torch.max(output,dim=1)
      correct+= (batch[2].to(device)==indices).sum().item()
      total += batch[2].shape[0]

    acc= correct/total

    return acc
```

```
    return acc
```

```
train_acc = get_accuracy(train_dataloader, model)
valid_acc = get_accuracy(validation_dataloader, model)
test_acc = get_accuracy(test_dataloader ,model)
print(f'Train acc: {train_acc:.4f},\t Valid acc: {valid_acc:.4f},\t Test acc: {test_acc:.4
```

```
     Train acc: 0.4783,       Valid acc: 0.4452,      Test acc: 0.4092
```

```
# Write a function to get predictions

def get_predictions(test_iter, model):
  model.eval()
  with torch.no_grad():
    predictions= np.array([])
    y_test= np.array([])

    for batch in test_iter:

      output=model(batch[0].to(device))
      _,indices = torch.max(output,dim=1)
      predictions=np.concatenate((predictions,indices.cpu().numpy()))
      y_test = np.concatenate((y_test,batch[2].numpy()))

  return y_test, predictions
```

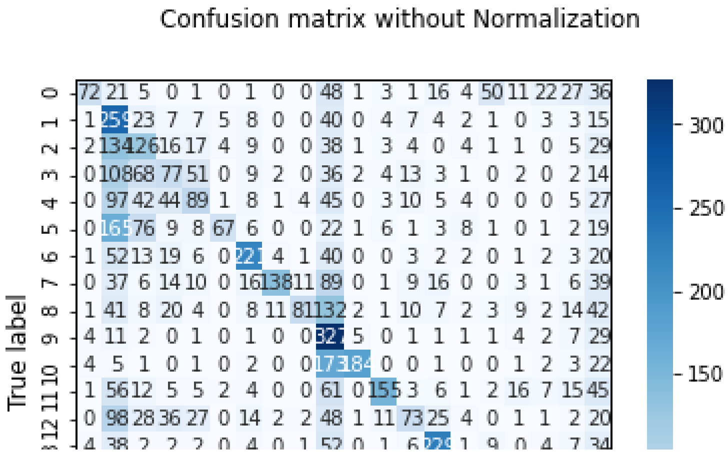
```
y_test, predictions=get_predictions(test_dataloader, model)
```

```
# Confusion Matrix
cm=confusion_matrix(y_test,predictions)
cm
```

```
     array([[ 72,  21,   5,   0,   1,   0,   1,   0,   0,  48,   1,   3,   1,
             16,   4,  50,  11,  22,  27,  36],
            [  1, 259,  23,   7,   7,   5,   8,   0,   0,  40,   0,   4,   7,
              4,   2,   1,   0,   3,   3,  15],
            [  2, 134, 126,  16,  17,   4,   9,   0,   0,  38,   1,   3,   4,
              0,   4,   1,   1,   0,   5,  29],
            [  0, 108,  68,  77,  51,   0,   9,   2,   0,  36,   2,   4,  13,
              3,   1,   0,   2,   0,   2,  14],
            [  0,  97,  42,  44,  89,   1,   8,   1,   4,  45,   0,   3,  10,
              5,   4,   0,   0,   0,   5,  27],
            [  0, 165,  76,   9,   8,  67,   6,   0,   0,  22,   1,   6,   1,
              3,   8,   1,   0,   1,   2,  19],
            [  1,  52,  13,  19,   6,   0, 221,   4,   1,  40,   0,   0,   3,
              2,   2,   0,   1,   2,   3,  20],
            [  0,  37,   6,  14,  10,   0,  16, 138,  11,  89,   0,   1,   9,
             16,   0,   0,   3,   1,   6,  39],
            [  1,  41,   8,  20,   4,   0,   8,  11,  81, 132,   2,   1,  10,
              7,   2,   3,   9,   2,  14,  42],
            [  4,  11,   2,   0,   1,   0,   1,   0,   0, 327,   5,   0,   1,
              1,   1,   1,   4,   2,   7,  29],
            [  4,   5,   1,   0,   1,   0,   2,   0,   0, 173, 184,   0,   0,
              1,   0,   0,   1,   2,   3,  22],
            [  1,  56,  12,   5,   5,   2,   4,   0,   0,  61,   0, 155,   3,
```

```
          6,   1,   2,  16,   7,  15,  45],
       [  0,  98,  28,  36,  27,   0,  14,   2,   2,  48,   1,  11,  73,
         25,   4,   0,   1,   1,   2,  20],
       [  4,  38,   2,   2,   2,   0,   4,   0,   1,  52,   0,   1,   6,
        229,   1,   9,   0,   4,   7,  34],
       [  4,  44,   9,   6,   0,   1,   9,   0,   0,  68,   0,   3,   6,
         13, 180,   2,   3,   2,   9,  35],
       [ 12,  16,   6,   0,   0,   0,   1,   0,   0,  25,   0,   1,   1,
         10,   0, 273,   3,   4,   6,  40],
       [  4,  21,   4,   5,   0,   0,   3,   0,   1,  67,   0,  14,   1,
         14,   0,   5, 138,   9,  39,  39],
       [  9,   9,   3,   1,   1,   0,   2,   0,   0,  46,   1,   1,   0,
          0,   1,   7,   5, 247,  17,  26],
       [ 14,  15,   0,   6,   0,   1,   1,   1,   0,  63,   0,   8,   0,
         14,   4,   3,  42,  14, 103,  21],
       [ 20,  17,   2,   3,   0,   0,   1,   0,   0,  45,   0,   2,   1,
         10,   1,  71,  14,   8,  13,  43]])
```

```
# Write a function to print confusion matrix
# plot confusion matrix
# need to import confusion_matrix from sklearn for this function to work
# need to import seaborn as sns
# import seaborn as sns
# import matplotlib.pyplot as plt
# from sklearn.metrics import confusion_matrix

def plot_confusion_matrix(y_true,y_pred,normalize=None):
  cm=confusion_matrix(y_true,y_pred,normalize=normalize)
  fig, ax = plt.subplots(figsize=(6,5))
  if normalize == None:
    fmt='d'
    fig.suptitle('Confusion matrix without Normalization', fontsize=12)

  else :
    fmt='0.2f'
    fig.suptitle('Normalized confusion matrix', fontsize=12)

  ax=sns.heatmap(cm,cmap=plt.cm.Blues,annot=True,fmt=fmt)
  ax.axhline(y=0, color='k',linewidth=1)
  ax.axhline(y=cm.shape[1], color='k',linewidth=2)
  ax.axvline(x=0, color='k',linewidth=1)
  ax.axvline(x=cm.shape[0], color='k',linewidth=2)

  ax.set_xlabel('Predicted label', fontsize=12)
  ax.set_ylabel('True label', fontsize=12)


plot_confusion_matrix(y_test,predictions)
```



BERT with 128

```
from transformers import BertTokenizer

# Load the BERT tokenizer.
print('Loading BERT tokenizer...')
tokenizer = BertTokenizer.from_pretrained('bert-base-uncased', do_lower_case=True)
```

```
Loading BERT tokenizer...
```

```
# Get last three tokens and truncate head
# Tokenize all of the sentences and map the tokens to thier word IDs.
input_ids = []
attention_masks = []
docoder_sent=[]
before_trunc=[]
maxlen=128

# For every sentence...
for sent in train.data:
    # `encode_plus` will:
    #   (1) Tokenize the sentence.
    #   (2) Prepend the `[CLS]` token to the start.
    #   (3) Append the `[SEP]` token to the end.
    #   (4) Map tokens to their IDs.
    #   (5) Pad or truncate the sentence to `max_length`
    #   (6) Create attention masks for [PAD] tokens.
    encoded_dict = tokenizer.encode_plus(
                        sent,                      # Sentence to encode.
                        add_special_tokens = True, # Add '[CLS]' and '[SEP]'
                        truncation=False,
                        padding=False,
                        #max_length = maxlen,           # Pad & truncate all sentences.
                        return_attention_mask = True,   # Construct attn. masks.
                        #return_tensors = 'pt',     # Return pytorch tensors.
                   )

    before_trunc.append(encoded_dict['input_ids'])
```

```
        ids = encoded_dict['input_ids']
        if len(ids)>=maxlen:
          ids = [ids[0]] + ids[-(maxlen-1):-1] + [102]
        else:
          ids = ids + ([0] * (maxlen-len(ids)))
        encoded_dict['input_ids']=torch.tensor([ids])

        ids = encoded_dict['attention_mask']
        if len(ids)>=maxlen:
          ids = [ids[0]] + ids[-(maxlen-1):-1] + [1]
        else:
          ids = ids + ([0] * (maxlen-len(ids)))
        encoded_dict['attention_mask']=torch.tensor([ids])

        # Add the encoded sentence to the list.
        input_ids.append(encoded_dict['input_ids'])
        #print(input_ids)

        # And its attention mask (simply differentiates padding from non-padding).
        attention_masks.append(encoded_dict['attention_mask'])

        # Get the decoded sentence
        docoder_sent.append(tokenizer.decode(encoded_dict['input_ids'].squeeze()))

    # Convert the lists into tensors.
    input_ids = torch.cat(input_ids, dim=0)
    #print(input_ids)
    attention_masks = torch.cat(attention_masks, dim=0)
    labels = torch.tensor(train.target)
```

```
Token indices sequence length is longer than the specified maximum sequence length fo
```

```
    # Get last three tokens and truncate head
    # Tokenize all of the sentences and map the tokens to thier word IDs.
    test_input_ids = []
    test_attention_masks = []
    test_decoder_sent=[]
    test_before_trunc=[]
    maxlen=128
    test_labels = torch.tensor(test.target)
    # For every sentence...
    for sent in test.data:
        # `encode_plus` will:
        #   (1) Tokenize the sentence.
        #   (2) Prepend the `[CLS]` token to the start.
        #   (3) Append the `[SEP]` token to the end.
        #   (4) Map tokens to their IDs.
        #   (5) Pad or truncate the sentence to `max_length`
        #   (6) Create attention masks for [PAD] tokens.
        encoded_dict = tokenizer.encode_plus(
                            sent,                      # Sentence to encode.
                            add_special_tokens = True, # Add '[CLS]' and '[SEP]'
                            truncation=False,
                            padding=False,
```

```
                        padding=False,
                        #max_length = maxlen,           # Pad & truncate all sentences.
                        return_attention_mask = True,   # Construct attn. masks.
                        #return_tensors = 'pt',     # Return pytorch tensors.
                   )

    test_before_trunc.append(encoded_dict['input_ids'])

    ids = encoded_dict['input_ids']
    if len(ids)>=maxlen:
      ids = [ids[0]] + ids[-(maxlen-1):-1] + [102]
    else:
      ids = ids + ([0] * (maxlen-len(ids)))
    encoded_dict['input_ids']=torch.tensor([ids])

    ids = encoded_dict['attention_mask']
    if len(ids)>=maxlen:
      ids = [ids[0]] + ids[-(maxlen-1):-1] + [1]
    else:
      ids = ids + ([0] * (maxlen-len(ids)))
    encoded_dict['attention_mask']=torch.tensor([ids])

    # Add the encoded sentence to the list.
    test_input_ids.append(encoded_dict['input_ids'])
    #print(input_ids)

    # And its attention mask (simply differentiates padding from non-padding).
    test_attention_masks.append(encoded_dict['attention_mask'])

    # Get the decoded sentence
    test_decoder_sent.append(tokenizer.decode(encoded_dict['input_ids'].squeeze()))

# Convert the lists into tensors.
test_input_ids = torch.cat(test_input_ids, dim=0)
#print(input_ids)
test_attention_masks = torch.cat(test_attention_masks, dim=0)


from torch.utils.data import TensorDataset, random_split

# Combine the training inputs into a TensorDataset.
dataset = TensorDataset(input_ids, attention_masks, labels)
test_dataset = TensorDataset(test_input_ids, test_attention_masks, test_labels)

# Create a 90-10 train-validation split.

# Calculate the number of samples to include in each set.
train_size = int(0.9 * len(dataset))
val_size = len(dataset) - train_size

# Divide the dataset by randomly selecting samples.
train_dataset, val_dataset = random_split(dataset, [train_size, val_size])

print('{:>5,} training samples'.format(train_size))
print('{:>5,} validation samples'.format(val_size))
print('{:>5,} test samples'.format(len(test_dataset)))
```

```
    10,182 training samples
    1,132 validation samples
    7,532 test samples
```

```
from torch.utils.data import DataLoader, RandomSampler, SequentialSampler

# The DataLoader needs to know our batch size for training, so we specify it
# here. For fine-tuning BERT on a specific task, the authors recommend a batch
# size of 16 or 32.
batch_size = 8

# Create the DataLoaders for our training and validation sets.
# We'll take training samples in random order.
train_dataloader = DataLoader(
            train_dataset,  # The training samples.
            sampler = RandomSampler(train_dataset), # Select batches randomly
            batch_size = batch_size # Trains with this batch size.
        )

# For validation the order doesn't matter, so we'll just read them sequentially.
validation_dataloader = DataLoader(
            val_dataset, # The validation samples.
            sampler = SequentialSampler(val_dataset), # Pull out batches sequentially.
            batch_size = batch_size # Evaluate with this batch size.
        )

test_dataloader = DataLoader(
            test_dataset,  # The training samples.
            sampler = RandomSampler(test_dataset), # Select batches randomly
            batch_size = batch_size # Trains with this batch size.
        )
```

```
from transformers import  BertModel

bert_model = BertModel.from_pretrained('bert-base-uncased')
```

```
bert_model
```

```
          (output): BertOutput(
            (dense): Linear(in_features=3072, out_features=768, bias=True)
            (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
            (dropout): Dropout(p=0.1, inplace=False)
          )
        )
        (10): BertLayer(
          (attention): BertAttention(
            (self): BertSelfAttention(
              (query): Linear(in_features=768, out_features=768, bias=True)
              (key): Linear(in_features=768, out_features=768, bias=True)
              (value): Linear(in_features=768, out_features=768, bias=True)
              (dropout): Dropout(p=0.1, inplace=False)
            )
            (output): BertSelfOutput(
              (dense): Linear(in_features=768, out_features=768, bias=True)
              (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
```

```
          (dropout): Dropout(p=0.1, inplace=False)
        )
      )
      (intermediate): BertIntermediate(
        (dense): Linear(in_features=768, out_features=3072, bias=True)
      )
      (output): BertOutput(
        (dense): Linear(in_features=3072, out_features=768, bias=True)
        (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
        (dropout): Dropout(p=0.1, inplace=False)
      )
    )
    (11): BertLayer(
      (attention): BertAttention(
        (self): BertSelfAttention(
          (query): Linear(in_features=768, out_features=768, bias=True)
          (key): Linear(in_features=768, out_features=768, bias=True)
          (value): Linear(in_features=768, out_features=768, bias=True)
          (dropout): Dropout(p=0.1, inplace=False)
        )
        (output): BertSelfOutput(
          (dense): Linear(in_features=768, out_features=768, bias=True)
          (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
          (dropout): Dropout(p=0.1, inplace=False)
        )
      )
      (intermediate): BertIntermediate(
        (dense): Linear(in_features=768, out_features=3072, bias=True)
      )
      (output): BertOutput(
        (dense): Linear(in_features=3072, out_features=768, bias=True)
        (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
        (dropout): Dropout(p=0.1, inplace=False)
      )
    )
  )
)
(pooler): BertPooler(
  (dense): Linear(in_features=768, out_features=768, bias=True)
  (activation): Tanh()
)
)
```

```
# Define the model
class linear(nn.Module):

  def __init__(self, bert_model, n_outputs, dropout_rate):

    super(linear, self).__init__()

    self.D = bert_model.config.to_dict()['hidden_size']
    self.bert_model = bert_model
    self.K = n_outputs
    self.dropout_rate=dropout_rate

    # embedding layer
    #self.embed = nn.Embedding(self.V, self.D)
```

```
      # dense layer
      self.fc = nn.Linear(self.D , self.K)

      # dropout layer
      self.dropout= nn.Dropout(self.dropout_rate)

    def forward(self, X):

      with torch.no_grad():
        embedding = self.bert_model(X)[0][:,0,:]

      #embedding= self.dropout(embedding)

      output = self.fc(embedding)
      output= self.dropout(output)

      return output


n_outputs = 20
dropout_rate = 0.5


#model = RNN(n_vocab, embed_dim, n_hidden, n_rnnlayers, n_outputs, bidirectional, dropout_
model = linear(bert_model, n_outputs, dropout_rate)
model.to(device)
```

```
                (dropout): Dropout(p=0.1, inplace=False)
              )
            )
            (10): BertLayer(
              (attention): BertAttention(
                (self): BertSelfAttention(
                  (query): Linear(in_features=768, out_features=768, bias=True)
                  (key): Linear(in_features=768, out_features=768, bias=True)
                  (value): Linear(in_features=768, out_features=768, bias=True)
                  (dropout): Dropout(p=0.1, inplace=False)
                )
                (output): BertSelfOutput(
                  (dense): Linear(in_features=768, out_features=768, bias=True)
                  (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
                  (dropout): Dropout(p=0.1, inplace=False)
                )
              )
              (intermediate): BertIntermediate(
                (dense): Linear(in_features=768, out_features=3072, bias=True)
              )
              (output): BertOutput(
                (dense): Linear(in_features=3072, out_features=768, bias=True)
                (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
                (dropout): Dropout(p=0.1, inplace=False)
              )
            )
            (11): BertLayer(
              (attention): BertAttention(
                (self): BertSelfAttention(
                  (query): Linear(in_features=768, out_features=768, bias=True)
                  (key): Linear(in_features=768, out_features=768, bias=True)
                  (value): Linear(in_features=768, out_features=768, bias=True)
```

```
              (dropout): Dropout(p=0.1, inplace=False)
            )
            (output): BertSelfOutput(
              (dense): Linear(in_features=768, out_features=768, bias=True)
              (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
              (dropout): Dropout(p=0.1, inplace=False)
            )
          )
          (intermediate): BertIntermediate(
            (dense): Linear(in_features=768, out_features=3072, bias=True)
          )
          (output): BertOutput(
            (dense): Linear(in_features=3072, out_features=768, bias=True)
            (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
            (dropout): Dropout(p=0.1, inplace=False)
          )
        )
      )
    )
    (pooler): BertPooler(
      (dense): Linear(in_features=768, out_features=768, bias=True)
      (activation): Tanh()
    )
  )
  (fc): Linear(in_features=768, out_features=20, bias=True)
  (dropout): Dropout(p=0.5, inplace=False)
)
```

```
print(model)
```

```
            (dropout): Dropout(p=0.1, inplace=False)
          )
        )
        (10): BertLayer(
          (attention): BertAttention(
            (self): BertSelfAttention(
              (query): Linear(in_features=768, out_features=768, bias=True)
              (key): Linear(in_features=768, out_features=768, bias=True)
              (value): Linear(in_features=768, out_features=768, bias=True)
              (dropout): Dropout(p=0.1, inplace=False)
            )
            (output): BertSelfOutput(
              (dense): Linear(in_features=768, out_features=768, bias=True)
              (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
              (dropout): Dropout(p=0.1, inplace=False)
            )
          )
          (intermediate): BertIntermediate(
            (dense): Linear(in_features=768, out_features=3072, bias=True)
          )
          (output): BertOutput(
            (dense): Linear(in_features=3072, out_features=768, bias=True)
            (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
            (dropout): Dropout(p=0.1, inplace=False)
          )
        )
        (11): BertLayer(
          (attention): BertAttention(
            (self): BertSelfAttention(
              (query): Linear(in_features=768, out_features=768, bias=True)
              (key): Linear(in_features=768, out_features=768, bias=True)
```

```
                (key): Linear(in_features=768, out_features=768, bias=True)
                (value): Linear(in_features=768, out_features=768, bias=True)
                (dropout): Dropout(p=0.1, inplace=False)
              )
              (output): BertSelfOutput(
                (dense): Linear(in_features=768, out_features=768, bias=True)
                (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
                (dropout): Dropout(p=0.1, inplace=False)
              )
            )
            (intermediate): BertIntermediate(
              (dense): Linear(in_features=768, out_features=3072, bias=True)
            )
            (output): BertOutput(
              (dense): Linear(in_features=3072, out_features=768, bias=True)
              (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
              (dropout): Dropout(p=0.1, inplace=False)
            )
          )
        )
      )
      (pooler): BertPooler(
        (dense): Linear(in_features=768, out_features=768, bias=True)
        (activation): Tanh()
      )
    )
    (fc): Linear(in_features=768, out_features=20, bias=True)
    (dropout): Dropout(p=0.5, inplace=False)
  )
```

```
for name, param in model.named_parameters():
  print(name, param.shape)
```

```
bert_model.encoder.layer.8.attention.output.LayerNorm.bias torch.Size([768])
bert_model.encoder.layer.8.intermediate.dense.weight torch.Size([3072, 768])
bert_model.encoder.layer.8.intermediate.dense.bias torch.Size([3072])
bert_model.encoder.layer.8.output.dense.weight torch.Size([768, 3072])
bert_model.encoder.layer.8.output.dense.bias torch.Size([768])
bert_model.encoder.layer.8.output.LayerNorm.weight torch.Size([768])
bert_model.encoder.layer.8.output.LayerNorm.bias torch.Size([768])
bert_model.encoder.layer.9.attention.self.query.weight torch.Size([768, 768])
bert_model.encoder.layer.9.attention.self.query.bias torch.Size([768])
bert_model.encoder.layer.9.attention.self.key.weight torch.Size([768, 768])
bert_model.encoder.layer.9.attention.self.key.bias torch.Size([768])
bert_model.encoder.layer.9.attention.self.value.weight torch.Size([768, 768])
bert_model.encoder.layer.9.attention.self.value.bias torch.Size([768])
bert_model.encoder.layer.9.attention.output.dense.weight torch.Size([768, 768])
bert_model.encoder.layer.9.attention.output.dense.bias torch.Size([768])
bert_model.encoder.layer.9.attention.output.LayerNorm.weight torch.Size([768])
bert_model.encoder.layer.9.attention.output.LayerNorm.bias torch.Size([768])
bert_model.encoder.layer.9.intermediate.dense.weight torch.Size([3072, 768])
bert_model.encoder.layer.9.intermediate.dense.bias torch.Size([3072])
bert_model.encoder.layer.9.output.dense.weight torch.Size([768, 3072])
bert_model.encoder.layer.9.output.dense.bias torch.Size([768])
bert_model.encoder.layer.9.output.LayerNorm.weight torch.Size([768])
bert_model.encoder.layer.9.output.LayerNorm.bias torch.Size([768])
bert_model.encoder.layer.10.attention.self.query.weight torch.Size([768, 768])
bert_model.encoder.layer.10.attention.self.query.bias torch.Size([768])
bert_model.encoder.layer.10.attention.self.key.weight torch.Size([768, 768])
bert_model.encoder.layer.10.attention.self.key.bias torch.Size([768])
bert_model.encoder.layer.10.attention.self.value.weight torch.Size([768, 768])
```

```
bert_model.encoder.layer.10.attention.self.value.weight torch.Size([768, 768])
bert_model.encoder.layer.10.attention.self.value.bias torch.Size([768])
bert_model.encoder.layer.10.attention.output.dense.weight torch.Size([768, 768])
bert_model.encoder.layer.10.attention.output.dense.bias torch.Size([768])
bert_model.encoder.layer.10.attention.output.LayerNorm.weight torch.Size([768])
bert_model.encoder.layer.10.attention.output.LayerNorm.bias torch.Size([768])
bert_model.encoder.layer.10.intermediate.dense.weight torch.Size([3072, 768])
bert_model.encoder.layer.10.intermediate.dense.bias torch.Size([3072])
bert_model.encoder.layer.10.output.dense.weight torch.Size([768, 3072])
bert_model.encoder.layer.10.output.dense.bias torch.Size([768])
bert_model.encoder.layer.10.output.LayerNorm.weight torch.Size([768])
bert_model.encoder.layer.10.output.LayerNorm.bias torch.Size([768])
bert_model.encoder.layer.11.attention.self.query.weight torch.Size([768, 768])
bert_model.encoder.layer.11.attention.self.query.bias torch.Size([768])
bert_model.encoder.layer.11.attention.self.key.weight torch.Size([768, 768])
bert_model.encoder.layer.11.attention.self.key.bias torch.Size([768])
bert_model.encoder.layer.11.attention.self.value.weight torch.Size([768, 768])
bert_model.encoder.layer.11.attention.self.value.bias torch.Size([768])
bert_model.encoder.layer.11.attention.output.dense.weight torch.Size([768, 768])
bert_model.encoder.layer.11.attention.output.dense.bias torch.Size([768])
bert_model.encoder.layer.11.attention.output.LayerNorm.weight torch.Size([768])
bert_model.encoder.layer.11.attention.output.LayerNorm.bias torch.Size([768])
bert_model.encoder.layer.11.intermediate.dense.weight torch.Size([3072, 768])
bert_model.encoder.layer.11.intermediate.dense.bias torch.Size([3072])
bert_model.encoder.layer.11.output.dense.weight torch.Size([768, 3072])
bert_model.encoder.layer.11.output.dense.bias torch.Size([768])
bert_model.encoder.layer.11.output.LayerNorm.weight torch.Size([768])
bert_model.encoder.layer.11.output.LayerNorm.bias torch.Size([768])
bert_model.pooler.dense.weight torch.Size([768, 768])
bert_model.pooler.dense.bias torch.Size([768])
fc.weight torch.Size([20, 768])
fc.bias torch.Size([20])
```

```
import random

seed = 123

random.seed(seed)
np.random.seed(seed)
torch.manual_seed(seed)
torch.cuda.manual_seed_all(seed)

learning_rate = 0.001
epochs=10

# STEP 5: INSTANTIATE LOSS CLASS
criterion = nn.CrossEntropyLoss()

# STEP 6: INSTANTIATE OPTIMIZER CLASS

optimizer = torch.optim.Adam(model.parameters(), lr=learning_rate)

# Freeze embedding Layer

#freeze embeddings
#model.embed.weight.requires_grad  = False

# STEP 7: TRAIN THE MODEL
```

```
train_losses= np.zeros(epochs)
valid_losses= np.zeros(epochs)


for epoch in range(epochs):

  t0= datetime.now()
  train_loss=[]

  model.train()
  for batch in train_dataloader:

    # forward pass
    output= model(batch[0].to(device))
    loss=criterion(output,batch[2].to(device))

    # set gradients to zero
    optimizer.zero_grad()

    # backward pass
    loss.backward()
    optimizer.step()
    train_loss.append(loss.item())

  train_loss=np.mean(train_loss)

  valid_loss=[]
  model.eval()
  with torch.no_grad():
    for batch in validation_dataloader:

      # forward pass
      output= model(batch[0].to(device))
      loss=criterion(output,batch[2].to(device))

      valid_loss.append(loss.item())

    valid_loss=np.mean(valid_loss)

  # save Losses
  train_losses[epoch]= train_loss
  valid_losses[epoch]= valid_loss
  dt= datetime.now()-t0
  print(f'Epoch {epoch+1}/{epochs}, Train Loss: {train_loss:.4f}    Valid Loss: {valid_los
```

```
Epoch 1/10, Train Loss: 2.7723    Valid Loss: 2.3595, Duration: 0:00:30.957401
Epoch 2/10, Train Loss: 2.5724    Valid Loss: 2.1447, Duration: 0:00:31.078342
Epoch 3/10, Train Loss: 2.5064    Valid Loss: 2.0680, Duration: 0:00:30.977611
Epoch 4/10, Train Loss: 2.4700    Valid Loss: 1.9957, Duration: 0:00:30.962295
Epoch 5/10, Train Loss: 2.4389    Valid Loss: 1.9679, Duration: 0:00:31.048614
Epoch 6/10, Train Loss: 2.4290    Valid Loss: 1.9644, Duration: 0:00:31.023816
Epoch 7/10, Train Loss: 2.4126    Valid Loss: 1.9506, Duration: 0:00:30.992088
Epoch 8/10, Train Loss: 2.4059    Valid Loss: 1.9297, Duration: 0:00:30.942897
Epoch 9/10, Train Loss: 2.4054    Valid Loss: 1.9053, Duration: 0:00:31.043710
Epoch 10/10, Train Loss: 2.3881    Valid Loss: 1.8428, Duration: 0:00:31.040517
```

```
# Accuracy- write a function to get accuracy
# use this function to get accuracy and print accuracy
def get_accuracy(data_iter, model):
  model.eval()
  with torch.no_grad():
    correct =0
    total =0

    for batch in data_iter:

      output=model(batch[0].to(device))
      _,indices = torch.max(output,dim=1)
      correct+= (batch[2].to(device)==indices).sum().item()
      total += batch[2].shape[0]

    acc= correct/total

    return acc


train_acc = get_accuracy(train_dataloader, model)
valid_acc = get_accuracy(validation_dataloader, model)
test_acc = get_accuracy(test_dataloader ,model)
print(f'Train acc: {train_acc:.4f},\t Valid acc: {valid_acc:.4f},\t Test acc: {test_acc:.4
```

```
Train acc: 0.5290,       Valid acc: 0.4841,      Test acc: 0.4446
```

```
# Write a function to get predictions

def get_predictions(test_iter, model):
  model.eval()
  with torch.no_grad():
    predictions= np.array([])
    y_test= np.array([])

    for batch in test_iter:

      output=model(batch[0].to(device))
      _,indices = torch.max(output,dim=1)
      predictions=np.concatenate((predictions,indices.cpu().numpy()))
      y_test = np.concatenate((y_test,batch[2].numpy()))

  return y_test, predictions


y_test, predictions=get_predictions(test_dataloader, model)


# Confusion Matrix
cm=confusion_matrix(y_test,predictions)
cm
```

```
array([[ 52,   2,   5,   0,   1,   0,   2,   1,   0,  15,   4,   5,   0,
         23,  66,  53,  25,  24,  18,  23],
```

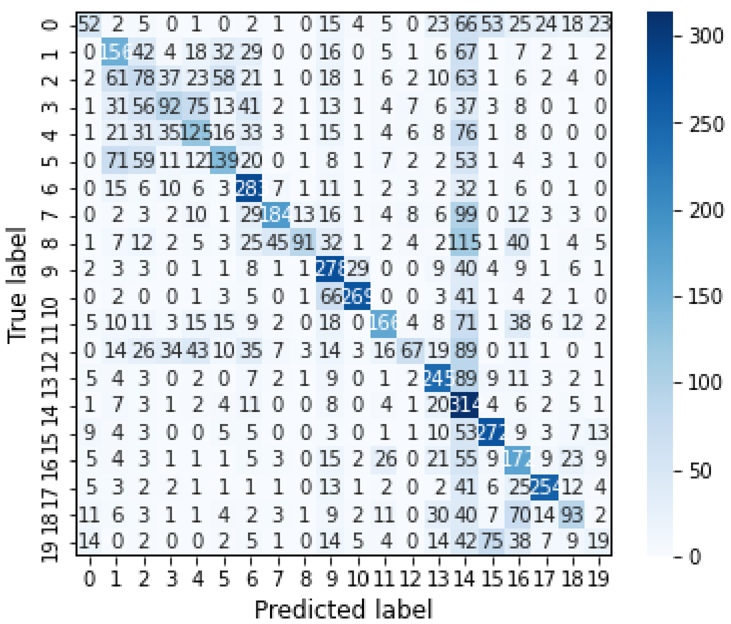
```
       [  0, 156,  42,   4,  18,  32,  29,   0,   0,  16,   0,   5,   1,
          6,  67,   1,   7,   2,   1,   2],
       [  2,  61,  78,  37,  23,  58,  21,   1,   0,  18,   1,   6,   2,
         10,  63,   1,   6,   2,   4,   0],
       [  1,  31,  56,  92,  75,  13,  41,   2,   1,  13,   1,   4,   7,
          6,  37,   3,   8,   0,   1,   0],
       [  1,  21,  31,  35, 125,  16,  33,   3,   1,  15,   1,   4,   6,
          8,  76,   1,   8,   0,   0,   0],
       [  0,  71,  59,  11,  12, 139,  20,   0,   1,   8,   1,   7,   2,
          2,  53,   1,   4,   3,   1,   0],
       [  0,  15,   6,  10,   6,   3, 283,   7,   1,  11,   1,   2,   3,
          2,  32,   1,   6,   0,   1,   0],
       [  0,   2,   3,   2,  10,   1,  29, 184,  13,  16,   1,   4,   8,
          6,  99,   0,  12,   3,   3,   0],
       [  1,   7,  12,   2,   5,   3,  25,  45,  91,  32,   1,   2,   4,
          2, 115,   1,  40,   1,   4,   5],
       [  2,   3,   3,   0,   1,   1,   8,   1,   1, 278,  29,   0,   0,
          9,  40,   4,   9,   1,   6,   1],
       [  0,   2,   0,   0,   1,   3,   5,   0,   1,  66, 269,   0,   0,
          3,  41,   1,   4,   2,   1,   0],
       [  5,  10,  11,   3,  15,  15,   9,   2,   0,  18,   0, 166,   4,
          8,  71,   1,  38,   6,  12,   2],
       [  0,  14,  26,  34,  43,  10,  35,   7,   3,  14,   3,  16,  67,
         19,  89,   0,  11,   1,   0,   1],
       [  5,   4,   3,   0,   2,   0,   7,   2,   1,   9,   0,   1,   2,
        245,  89,   9,  11,   3,   2,   1],
       [  1,   7,   3,   1,   2,   4,  11,   0,   0,   8,   0,   4,   1,
         20, 314,   4,   6,   2,   5,   1],
       [  9,   4,   3,   0,   0,   5,   5,   0,   0,   3,   0,   1,   1,
         10,  53, 272,   9,   3,   7,  13],
       [  5,   4,   3,   1,   1,   1,   5,   3,   0,  15,   2,  26,   0,
         21,  55,   9, 172,   9,  23,   9],
       [  5,   3,   2,   2,   1,   1,   1,   1,   0,  13,   1,   2,   0,
          2,  41,   6,  25, 254,  12,   4],
       [ 11,   6,   3,   1,   1,   4,   2,   3,   1,   9,   2,  11,   0,
         30,  40,   7,  70,  14,  93,   2],
       [ 14,   0,   2,   0,   0,   2,   5,   1,   0,  14,   5,   4,   0,
         14,  42,  75,  38,   7,   9,  19]])
```

```python
# Write a function to print confusion matrix
# plot confusion matrix
# need to import confusion_matrix from sklearn for this function to work
# need to import seaborn as sns
# import seaborn as sns
# import matplotlib.pyplot as plt
# from sklearn.metrics import confusion_matrix

def plot_confusion_matrix(y_true,y_pred,normalize=None):
  cm=confusion_matrix(y_true,y_pred,normalize=normalize)
  fig, ax = plt.subplots(figsize=(6,5))
  if normalize == None:
    fmt='d'
    fig.suptitle('Confusion matrix without Normalization', fontsize=12)

  else :
    fmt='0.2f'
    fig.suptitle('Normalized confusion matrix', fontsize=12)
```

```
  ax=sns.heatmap(cm,cmap=plt.cm.Blues,annot=True,fmt=fmt)
  ax.axhline(y=0, color='k',linewidth=1)
  ax.axhline(y=cm.shape[1], color='k',linewidth=2)
  ax.axvline(x=0, color='k',linewidth=1)
  ax.axvline(x=cm.shape[0], color='k',linewidth=2)

  ax.set_xlabel('Predicted label', fontsize=12)
  ax.set_ylabel('True label', fontsize=12)
```

```
plot_confusion_matrix(y_test,predictions)
```

Confusion matrix without Normalization



BERT 512 Features

```
from transformers import BertTokenizer

# Load the BERT tokenizer.
print('Loading BERT tokenizer...')
tokenizer = BertTokenizer.from_pretrained('bert-base-uncased', do_lower_case=True)
```

```
Loading BERT tokenizer...
```

```
# Get last three tokens and truncate head
# Tokenize all of the sentences and map the tokens to thier word IDs.
input_ids = []
attention_masks = []
docoder_sent=[]
before_trunc=[]
maxlen=512
labels = torch.tensor(train.target)
# For every sentence...
for sent in train.data:
    # `encode_plus` will:
```

```
    #   encode_plus  will:
    #   (1) Tokenize the sentence.
    #   (2) Prepend the `[CLS]` token to the start.
    #   (3) Append the `[SEP]` token to the end.
    #   (4) Map tokens to their IDs.
    #   (5) Pad or truncate the sentence to `max_length`
    #   (6) Create attention masks for [PAD] tokens.
    encoded_dict = tokenizer.encode_plus(
                        sent,                      # Sentence to encode.
                        add_special_tokens = True, # Add '[CLS]' and '[SEP]'
                        truncation=False,
                        padding=False,
                        #max_length = maxlen,           # Pad & truncate all sentences.
                        return_attention_mask = True,   # Construct attn. masks.
                        #return_tensors = 'pt',     # Return pytorch tensors.
                   )

    before_trunc.append(encoded_dict['input_ids'])

    ids = encoded_dict['input_ids']
    if len(ids)>=maxlen:
      ids = [ids[0]] + ids[-(maxlen-1):-1] + [102]
    else:
      ids = ids + ([0] * (maxlen-len(ids)))
    encoded_dict['input_ids']=torch.tensor([ids])

    ids = encoded_dict['attention_mask']
    if len(ids)>=maxlen:
      ids = [ids[0]] + ids[-(maxlen-1):-1] + [1]
    else:
      ids = ids + ([0] * (maxlen-len(ids)))
    encoded_dict['attention_mask']=torch.tensor([ids])

    # Add the encoded sentence to the list.
    input_ids.append(encoded_dict['input_ids'])
    #print(input_ids)

    # And its attention mask (simply differentiates padding from non-padding).
    attention_masks.append(encoded_dict['attention_mask'])

    # Get the decoded sentence
    docoder_sent.append(tokenizer.decode(encoded_dict['input_ids'].squeeze()))

# Convert the lists into tensors.
input_ids = torch.cat(input_ids, dim=0)
#print(input_ids)
attention_masks = torch.cat(attention_masks, dim=0)
```

```
Token indices sequence length is longer than the specified maximum sequence length fo
```

```
# Get last three tokens and truncate head
# Tokenize all of the sentences and map the tokens to thier word IDs.
test_input_ids = []
test_attention_masks = []
```

```
test_decoder_sent=[]
test_before_trunc=[]
maxlen=512
test_labels = torch.tensor(test.target)
# For every sentence...
for sent in test.data:
    # `encode_plus` will:
    #   (1) Tokenize the sentence.
    #   (2) Prepend the `[CLS]` token to the start.
    #   (3) Append the `[SEP]` token to the end.
    #   (4) Map tokens to their IDs.
    #   (5) Pad or truncate the sentence to `max_length`
    #   (6) Create attention masks for [PAD] tokens.
    encoded_dict = tokenizer.encode_plus(
                        sent,                      # Sentence to encode.
                        add_special_tokens = True, # Add '[CLS]' and '[SEP]'
                        truncation=False,
                        padding=False,
                        #max_length = maxlen,           # Pad & truncate all sentences.
                        return_attention_mask = True,   # Construct attn. masks.
                        #return_tensors = 'pt',     # Return pytorch tensors.
                   )

    test_before_trunc.append(encoded_dict['input_ids'])

    ids = encoded_dict['input_ids']
    if len(ids)>=maxlen:
      ids = [ids[0]] + ids[-(maxlen-1):-1] + [102]
    else:
      ids = ids + ([0] * (maxlen-len(ids)))
    encoded_dict['input_ids']=torch.tensor([ids])

    ids = encoded_dict['attention_mask']
    if len(ids)>=maxlen:
      ids = [ids[0]] + ids[-(maxlen-1):-1] + [1]
    else:
      ids = ids + ([0] * (maxlen-len(ids)))
    encoded_dict['attention_mask']=torch.tensor([ids])

    # Add the encoded sentence to the list.
    test_input_ids.append(encoded_dict['input_ids'])
    #print(input_ids)

    # And its attention mask (simply differentiates padding from non-padding).
    test_attention_masks.append(encoded_dict['attention_mask'])

    # Get the decoded sentence
    test_decoder_sent.append(tokenizer.decode(encoded_dict['input_ids'].squeeze()))

# Convert the lists into tensors.
test_input_ids = torch.cat(test_input_ids, dim=0)
#print(input_ids)
test_attention_masks = torch.cat(test_attention_masks, dim=0)
```

```
from torch.utils.data import TensorDataset, random_split

# Combine the training inputs into a TensorDataset.
dataset = TensorDataset(input_ids, attention_masks, labels)
test_dataset = TensorDataset(test_input_ids, test_attention_masks, test_labels)

# Create a 90-10 train-validation split.

# Calculate the number of samples to include in each set.
train_size = int(0.9 * len(dataset))
val_size = len(dataset) - train_size

# Divide the dataset by randomly selecting samples.
train_dataset, val_dataset = random_split(dataset, [train_size, val_size])

print('{:>5,} training samples'.format(train_size))
print('{:>5,} validation samples'.format(val_size))
print('{:>5,} test samples'.format(len(test_dataset)))
```

```
10,182 training samples
1,132 validation samples
7,532 test samples
```

```
from torch.utils.data import DataLoader, RandomSampler, SequentialSampler

# The DataLoader needs to know our batch size for training, so we specify it
# here. For fine-tuning BERT on a specific task, the authors recommend a batch
# size of 16 or 32.
batch_size = 8

# Create the DataLoaders for our training and validation sets.
# We'll take training samples in random order.
train_dataloader = DataLoader(
            train_dataset,  # The training samples.
            sampler = RandomSampler(train_dataset), # Select batches randomly
            batch_size = batch_size # Trains with this batch size.
        )

# For validation the order doesn't matter, so we'll just read them sequentially.
validation_dataloader = DataLoader(
            val_dataset, # The validation samples.
            sampler = SequentialSampler(val_dataset), # Pull out batches sequentially.
            batch_size = batch_size # Evaluate with this batch size.
        )

test_dataloader = DataLoader(
            test_dataset,  # The training samples.
            sampler = RandomSampler(test_dataset), # Select batches randomly
            batch_size = batch_size # Trains with this batch size.
        )
```

```
from transformers import  BertModel

bert_model = BertModel.from_pretrained('bert-base-uncased')
```

```
bert_model
          (output): BertOutput(
            (dense): Linear(in_features=3072, out_features=768, bias=True)
            (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
            (dropout): Dropout(p=0.1, inplace=False)
          )
        )
        (10): BertLayer(
          (attention): BertAttention(
            (self): BertSelfAttention(
              (query): Linear(in_features=768, out_features=768, bias=True)
              (key): Linear(in_features=768, out_features=768, bias=True)
              (value): Linear(in_features=768, out_features=768, bias=True)
              (dropout): Dropout(p=0.1, inplace=False)
            )
            (output): BertSelfOutput(
              (dense): Linear(in_features=768, out_features=768, bias=True)
              (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
              (dropout): Dropout(p=0.1, inplace=False)
            )
          )
          (intermediate): BertIntermediate(
            (dense): Linear(in_features=768, out_features=3072, bias=True)
          )
          (output): BertOutput(
            (dense): Linear(in_features=3072, out_features=768, bias=True)
            (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
            (dropout): Dropout(p=0.1, inplace=False)
          )
        )
        (11): BertLayer(
          (attention): BertAttention(
            (self): BertSelfAttention(
              (query): Linear(in_features=768, out_features=768, bias=True)
              (key): Linear(in_features=768, out_features=768, bias=True)
              (value): Linear(in_features=768, out_features=768, bias=True)
              (dropout): Dropout(p=0.1, inplace=False)
            )
            (output): BertSelfOutput(
              (dense): Linear(in_features=768, out_features=768, bias=True)
              (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
              (dropout): Dropout(p=0.1, inplace=False)
            )
          )
          (intermediate): BertIntermediate(
            (dense): Linear(in_features=768, out_features=3072, bias=True)
          )
          (output): BertOutput(
            (dense): Linear(in_features=3072, out_features=768, bias=True)
            (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
            (dropout): Dropout(p=0.1, inplace=False)
          )
        )
      )
    )
    (pooler): BertPooler(
      (dense): Linear(in_features=768, out_features=768, bias=True)
      (activation): Tanh()
    )
```

```
    )


# Define the model
class linear(nn.Module):

  def __init__(self, bert_model, n_outputs, dropout_rate):

    super(linear, self).__init__()

    self.D = bert_model.config.to_dict()['hidden_size']
    self.bert_model = bert_model
    self.K = n_outputs
    self.dropout_rate=dropout_rate

    # embedding layer
    #self.embed = nn.Embedding(self.V, self.D)


    # dense layer
    self.fc = nn.Linear(self.D , self.K)

    # dropout layer
    self.dropout= nn.Dropout(self.dropout_rate)

  def forward(self, X):

    with torch.no_grad():
      embedding = self.bert_model(X)[0][:,0,:]

    #embedding= self.dropout(embedding)

    output = self.fc(embedding)
    output= self.dropout(output)

    return output


n_outputs = 20
dropout_rate = 0.5


#model = RNN(n_vocab, embed_dim, n_hidden, n_rnnlayers, n_outputs, bidirectional, dropout_
model = linear(bert_model, n_outputs, dropout_rate)
model.to(device)
```

```
              (dropout): Dropout(p=0.1, inplace=False)
            )
          )
          (10): BertLayer(
            (attention): BertAttention(
              (self): BertSelfAttention(
                (query): Linear(in_features=768, out_features=768, bias=True)
                (key): Linear(in_features=768, out_features=768, bias=True)
                (value): Linear(in_features=768, out_features=768, bias=True)
                (dropout): Dropout(p=0.1, inplace=False)
              )
              (output): BertSelfOutput(
```

```
            (dense): Linear(in_features=768, out_features=768, bias=True)
            (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
            (dropout): Dropout(p=0.1, inplace=False)
          )
        )
        (intermediate): BertIntermediate(
          (dense): Linear(in_features=768, out_features=3072, bias=True)
        )
        (output): BertOutput(
          (dense): Linear(in_features=3072, out_features=768, bias=True)
          (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
          (dropout): Dropout(p=0.1, inplace=False)
        )
      )
      (11): BertLayer(
        (attention): BertAttention(
          (self): BertSelfAttention(
            (query): Linear(in_features=768, out_features=768, bias=True)
            (key): Linear(in_features=768, out_features=768, bias=True)
            (value): Linear(in_features=768, out_features=768, bias=True)
            (dropout): Dropout(p=0.1, inplace=False)
          )
          (output): BertSelfOutput(
            (dense): Linear(in_features=768, out_features=768, bias=True)
            (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
            (dropout): Dropout(p=0.1, inplace=False)
          )
        )
        (intermediate): BertIntermediate(
          (dense): Linear(in_features=768, out_features=3072, bias=True)
        )
        (output): BertOutput(
          (dense): Linear(in_features=3072, out_features=768, bias=True)
          (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
          (dropout): Dropout(p=0.1, inplace=False)
        )
      )
    )
  )
  (pooler): BertPooler(
    (dense): Linear(in_features=768, out_features=768, bias=True)
    (activation): Tanh()
  )
)
(fc): Linear(in_features=768, out_features=20, bias=True)
(dropout): Dropout(p=0.5, inplace=False)
)
```

```
print(model)
```

```
          (dropout): Dropout(p=0.1, inplace=False)
        )
      )
      (10): BertLayer(
        (attention): BertAttention(
          (self): BertSelfAttention(
            (query): Linear(in_features=768, out_features=768, bias=True)
            (key): Linear(in_features=768, out_features=768, bias=True)
            (value): Linear(in_features=768, out_features=768, bias=True)
            (dropout): Dropout(p=0.1, inplace=False)
          )
```

```
              ,
              (output): BertSelfOutput(
                (dense): Linear(in_features=768, out_features=768, bias=True)
                (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
                (dropout): Dropout(p=0.1, inplace=False)
              )
            )
            (intermediate): BertIntermediate(
              (dense): Linear(in_features=768, out_features=3072, bias=True)
            )
            (output): BertOutput(
              (dense): Linear(in_features=3072, out_features=768, bias=True)
              (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
              (dropout): Dropout(p=0.1, inplace=False)
            )
          )
          (11): BertLayer(
            (attention): BertAttention(
              (self): BertSelfAttention(
                (query): Linear(in_features=768, out_features=768, bias=True)
                (key): Linear(in_features=768, out_features=768, bias=True)
                (value): Linear(in_features=768, out_features=768, bias=True)
                (dropout): Dropout(p=0.1, inplace=False)
              )
              (output): BertSelfOutput(
                (dense): Linear(in_features=768, out_features=768, bias=True)
                (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
                (dropout): Dropout(p=0.1, inplace=False)
              )
            )
            (intermediate): BertIntermediate(
              (dense): Linear(in_features=768, out_features=3072, bias=True)
            )
            (output): BertOutput(
              (dense): Linear(in_features=3072, out_features=768, bias=True)
              (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
              (dropout): Dropout(p=0.1, inplace=False)
            )
          )
        )
      )
      (pooler): BertPooler(
        (dense): Linear(in_features=768, out_features=768, bias=True)
        (activation): Tanh()
      )
    )
    (fc): Linear(in_features=768, out_features=20, bias=True)
    (dropout): Dropout(p=0.5, inplace=False)
  )
```

```
for name, param in model.named_parameters():
  print(name, param.shape)
```

```
bert_model.encoder.layer.8.attention.output.LayerNorm.bias torch.Size([768])
bert_model.encoder.layer.8.intermediate.dense.weight torch.Size([3072, 768])
bert_model.encoder.layer.8.intermediate.dense.bias torch.Size([3072])
bert_model.encoder.layer.8.output.dense.weight torch.Size([768, 3072])
bert_model.encoder.layer.8.output.dense.bias torch.Size([768])
bert_model.encoder.layer.8.output.LayerNorm.weight torch.Size([768])
bert_model.encoder.layer.8.output.LayerNorm.bias torch.Size([768])
bert_model.encoder.layer.9.attention.self.query.weight torch.Size([768, 768])
```

```
bert_model.encoder.layer.9.attention.self.query.bias torch.Size([768])
bert_model.encoder.layer.9.attention.self.key.weight torch.Size([768, 768])
bert_model.encoder.layer.9.attention.self.key.bias torch.Size([768])
bert_model.encoder.layer.9.attention.self.value.weight torch.Size([768, 768])
bert_model.encoder.layer.9.attention.self.value.bias torch.Size([768])
bert_model.encoder.layer.9.attention.output.dense.weight torch.Size([768, 768])
bert_model.encoder.layer.9.attention.output.dense.bias torch.Size([768])
bert_model.encoder.layer.9.attention.output.LayerNorm.weight torch.Size([768])
bert_model.encoder.layer.9.attention.output.LayerNorm.bias torch.Size([768])
bert_model.encoder.layer.9.intermediate.dense.weight torch.Size([3072, 768])
bert_model.encoder.layer.9.intermediate.dense.bias torch.Size([3072])
bert_model.encoder.layer.9.output.dense.weight torch.Size([768, 3072])
bert_model.encoder.layer.9.output.dense.bias torch.Size([768])
bert_model.encoder.layer.9.output.LayerNorm.weight torch.Size([768])
bert_model.encoder.layer.9.output.LayerNorm.bias torch.Size([768])
bert_model.encoder.layer.10.attention.self.query.weight torch.Size([768, 768])
bert_model.encoder.layer.10.attention.self.query.bias torch.Size([768])
bert_model.encoder.layer.10.attention.self.key.weight torch.Size([768, 768])
bert_model.encoder.layer.10.attention.self.key.bias torch.Size([768])
bert_model.encoder.layer.10.attention.self.value.weight torch.Size([768, 768])
bert_model.encoder.layer.10.attention.self.value.bias torch.Size([768])
bert_model.encoder.layer.10.attention.output.dense.weight torch.Size([768, 768])
bert_model.encoder.layer.10.attention.output.dense.bias torch.Size([768])
bert_model.encoder.layer.10.attention.output.LayerNorm.weight torch.Size([768])
bert_model.encoder.layer.10.attention.output.LayerNorm.bias torch.Size([768])
bert_model.encoder.layer.10.intermediate.dense.weight torch.Size([3072, 768])
bert_model.encoder.layer.10.intermediate.dense.bias torch.Size([3072])
bert_model.encoder.layer.10.output.dense.weight torch.Size([768, 3072])
bert_model.encoder.layer.10.output.dense.bias torch.Size([768])
bert_model.encoder.layer.10.output.LayerNorm.weight torch.Size([768])
bert_model.encoder.layer.10.output.LayerNorm.bias torch.Size([768])
bert_model.encoder.layer.11.attention.self.query.weight torch.Size([768, 768])
bert_model.encoder.layer.11.attention.self.query.bias torch.Size([768])
bert_model.encoder.layer.11.attention.self.key.weight torch.Size([768, 768])
bert_model.encoder.layer.11.attention.self.key.bias torch.Size([768])
bert_model.encoder.layer.11.attention.self.value.weight torch.Size([768, 768])
bert_model.encoder.layer.11.attention.self.value.bias torch.Size([768])
bert_model.encoder.layer.11.attention.output.dense.weight torch.Size([768, 768])
bert_model.encoder.layer.11.attention.output.dense.bias torch.Size([768])
bert_model.encoder.layer.11.attention.output.LayerNorm.weight torch.Size([768])
bert_model.encoder.layer.11.attention.output.LayerNorm.bias torch.Size([768])
bert_model.encoder.layer.11.intermediate.dense.weight torch.Size([3072, 768])
bert_model.encoder.layer.11.intermediate.dense.bias torch.Size([3072])
bert_model.encoder.layer.11.output.dense.weight torch.Size([768, 3072])
bert_model.encoder.layer.11.output.dense.bias torch.Size([768])
bert_model.encoder.layer.11.output.LayerNorm.weight torch.Size([768])
bert_model.encoder.layer.11.output.LayerNorm.bias torch.Size([768])
bert_model.pooler.dense.weight torch.Size([768, 768])
bert_model.pooler.dense.bias torch.Size([768])
fc.weight torch.Size([20, 768])
fc.bias torch.Size([20])
```

```
import random

seed = 123

random.seed(seed)
np.random.seed(seed)
torch.manual_seed(seed)
torch.cuda.manual_seed_all(seed)
```

```
torch.cuda.manual_seed_all(seed)

learning_rate = 0.001
epochs=10

# STEP 5: INSTANTIATE LOSS CLASS
criterion = nn.CrossEntropyLoss()

# STEP 6: INSTANTIATE OPTIMIZER CLASS

optimizer = torch.optim.Adam(model.parameters(), lr=learning_rate)

# Freeze embedding Layer

#freeze embeddings
#model.embed.weight.requires_grad  = False

# STEP 7: TRAIN THE MODEL

train_losses= np.zeros(epochs)
valid_losses= np.zeros(epochs)


for epoch in range(epochs):

  t0= datetime.now()
  train_loss=[]

  model.train()
  for batch in train_dataloader:

    # forward pass
    output= model(batch[0].to(device))
    loss=criterion(output,batch[2].to(device))

    # set gradients to zero
    optimizer.zero_grad()

    # backward pass
    loss.backward()
    optimizer.step()
    train_loss.append(loss.item())

  train_loss=np.mean(train_loss)

  valid_loss=[]
  model.eval()
  with torch.no_grad():
    for batch in validation_dataloader:

      # forward pass
      output= model(batch[0].to(device))
      loss=criterion(output,batch[2].to(device))

      valid_loss.append(loss.item())
```

```
    valid_loss=np.mean(valid_loss)

  # save Losses
  train_losses[epoch]= train_loss
  valid_losses[epoch]= valid_loss
  dt= datetime.now()-t0
  print(f'Epoch {epoch+1}/{epochs}, Train Loss: {train_loss:.4f}    Valid Loss: {valid_los
```

```
Epoch 1/10, Train Loss: 3.0417    Valid Loss: 2.7780, Duration: 0:02:01.126623
Epoch 2/10, Train Loss: 2.9329    Valid Loss: 2.6847, Duration: 0:02:01.281187
Epoch 3/10, Train Loss: 2.9016    Valid Loss: 2.6381, Duration: 0:02:01.230411
Epoch 4/10, Train Loss: 2.8764    Valid Loss: 2.5830, Duration: 0:02:01.262106
Epoch 5/10, Train Loss: 2.8541    Valid Loss: 2.6120, Duration: 0:02:01.383775
Epoch 6/10, Train Loss: 2.8473    Valid Loss: 2.5413, Duration: 0:02:01.520749
Epoch 7/10, Train Loss: 2.8357    Valid Loss: 2.5198, Duration: 0:02:01.259472
Epoch 8/10, Train Loss: 2.8219    Valid Loss: 2.5013, Duration: 0:02:01.286779
Epoch 9/10, Train Loss: 2.8168    Valid Loss: 2.5052, Duration: 0:02:01.248354
Epoch 10/10, Train Loss: 2.8272    Valid Loss: 2.4822, Duration: 0:02:01.276187
```

```
# Accuracy- write a function to get accuracy
# use this function to get accuracy and print accuracy
def get_accuracy(data_iter, model):
  model.eval()
  with torch.no_grad():
    correct =0
    total =0

    for batch in data_iter:

      output=model(batch[0].to(device))
      _,indices = torch.max(output,dim=1)
      correct+= (batch[2].to(device)==indices).sum().item()
      total += batch[2].shape[0]

    acc= correct/total

    return acc
```

```
train_acc = get_accuracy(train_dataloader, model)
valid_acc = get_accuracy(validation_dataloader, model)
test_acc = get_accuracy(test_dataloader ,model)
print(f'Train acc: {train_acc:.4f},\t Valid acc: {valid_acc:.4f},\t Test acc: {test_acc:.4
```

```
Train acc: 0.2495,       Valid acc: 0.2412,      Test acc: 0.2211
```

```
# Write a function to get predictions

def get_predictions(test_iter, model):
  model.eval()
  with torch.no_grad():
    predictions= np.array([])
    y_test= np.array([])

    for batch in test_iter:
```

```
        output=model(batch[0].to(device))
        _,indices = torch.max(output,dim=1)
        predictions=np.concatenate((predictions,indices.cpu().numpy()))
        y_test = np.concatenate((y_test,batch[2].numpy()))

  return y_test, predictions
```

+ Code + Text

```
y_test, predictions=get_predictions(test_dataloader, model)
```

```
# Confusion Matrix
cm=confusion_matrix(y_test,predictions)
cm
```

```
array([[ 35,   0,   0,   0,   0,   0,   7,   1,   0,  23,   0,   1,   0,
          3,   0,   9,   0, 212,  22,   6],
       [  0,  30,   5,  38,   1,   3,  41,   0,   1,  18,   3,   4,   6,
          5,   5,   0,   0, 221,   8,   0],
       [  0,   5,  15,  81,   1,   6,  25,   0,   0,  30,   1,   4,   4,
          4,   3,   0,   0, 210,   5,   0],
       [  0,   2,   4, 113,   4,   2,  24,   1,   0,  20,   0,   4,   4,
          1,   0,   0,   0, 212,   1,   0],
       [  0,   1,   1,  76,   8,   0,  27,   2,   2,  25,   3,   0,   9,
          3,   0,   0,   0, 224,   4,   0],
       [  1,   6,   9,  82,   0,  32,  40,   1,   0,  15,   2,   7,   7,
          3,   1,   0,   0, 187,   2,   0],
       [  0,   2,   0,  13,   1,   0, 223,   6,   0,  18,   3,   1,   0,
          1,   0,   0,   0, 118,   4,   0],
       [  0,   0,   0,   7,   0,   0,  29,  80,   0,  35,   1,   1,   3,
          2,   0,   0,   0, 235,   3,   0],
       [  0,   1,   0,  10,   0,   1,  34,  47,   7,  37,   1,   0,   3,
          1,   1,   0,   0, 249,   6,   0],
       [  1,   0,   0,   4,   0,   0,  16,   0,   0, 125,  43,   1,   0,
          1,   0,   0,   0, 198,   8,   0],
       [  1,   0,   0,   2,   0,   0,  13,   0,   0,  28, 154,   0,   0,
          0,   0,   0,   0, 197,   4,   0],
       [  1,   0,   0,  17,   0,   1,  14,   1,   0,  25,   0,  61,   5,
          0,   2,   0,   1, 254,  14,   0],
       [  0,   3,   2,  35,   2,   0,  34,   4,   0,  18,   1,   8,  25,
          1,   3,   0,   0, 255,   2,   0],
       [  1,   1,   0,   8,   0,   0,  13,   1,   0,  23,   1,   0,   3,
         97,   0,   1,   0, 243,   4,   0],
       [  1,   1,   1,   3,   0,   0,  17,   2,   0,  22,   0,   0,   2,
          4,  78,   0,   1, 248,  14,   0],
       [ 11,   0,   0,   0,   0,   0,   9,   1,   0,  17,   0,   0,   0,
          4,   0, 137,   0, 192,   9,  18],
       [  0,   0,   0,   0,   0,   0,  15,   1,   0,  21,   0,   3,   0,
          1,   0,   1,  32, 259,  31,   0],
       [  1,   0,   0,   0,   0,   0,   4,   0,   0,  17,   1,   0,   0,
          0,   0,   1,   0, 343,   9,   0],
       [  1,   0,   0,   1,   0,   0,   4,   0,   0,  15,   0,   1,   1,
          3,   4,   1,   9, 206,  63,   1],
       [ 10,   1,   0,   1,   0,   0,   4,   0,   0,  18,   0,   0,   0,
          4,   2,  21,   4, 168,  11,   7]])
```

```
# Write a function to print confusion matrix
# plot confusion matrix
```

```
# need to import confusion_matrix from sklearn for this function to work
# need to import seaborn as sns
# import seaborn as sns
# import matplotlib.pyplot as plt
# from sklearn.metrics import confusion_matrix

def plot_confusion_matrix(y_true,y_pred,normalize=None):
  cm=confusion_matrix(y_true,y_pred,normalize=normalize)
  fig, ax = plt.subplots(figsize=(6,5))
  if normalize == None:
    fmt='d'
    fig.suptitle('Confusion matrix without Normalization', fontsize=12)

  else :
    fmt='0.2f'
    fig.suptitle('Normalized confusion matrix', fontsize=12)

  ax=sns.heatmap(cm,cmap=plt.cm.Blues,annot=True,fmt=fmt)
  ax.axhline(y=0, color='k',linewidth=1)
  ax.axhline(y=cm.shape[1], color='k',linewidth=2)
  ax.axvline(x=0, color='k',linewidth=1)
  ax.axvline(x=cm.shape[0], color='k',linewidth=2)

  ax.set_xlabel('Predicted label', fontsize=12)
  ax.set_ylabel('True label', fontsize=12)


plot_confusion_matrix(y_test,predictions)
```