Assignment 6 : Pretrain and Transfer Learning (20 pts)

Before working on the assignment please read papers as following

- SUPERVISED CONTRASTIVE LEARNING FOR PRE-TRAINED LANGUAGE MODEL FINE-TUNING
  - link: https://openreview.net/pdf?id=cu7IUiO
- Few-Shot Intent Detection via Contrastive Pre-Training and Fine-Tuning
  - link: https://arxiv.org/abs/2109.06349

Question 1: Why do we need transfer learning ? (1.5pts)

In [ ]:
```
#answer1
```

Question 2: When transfer learning makes sense ? (1.5pts)

In [ ]:
```
#answer2
```

In [ ]:
```
import os
import numpy as np
import torch
import torch.nn as nn
from torch.utils.data import Dataset, DataLoader
from transformers import RobertaConfig, RobertaModel, RobertaTokenizer, RobertaForSequenceClassification
from transformers import AdamW
import random
from IPython.display import clear_output
from utils import create_supervised_pair, supervised_contrasive_loss, Similarity

#comment this if you are not using puffer
os.environ['http_proxy'] = 'http://192.41.170.23:3128'
os.environ['https_proxy'] = 'http://192.41.170.23:3128'
```

In [ ]:
```

```

To download data from file directory both text samples and labels

In [ ]:
```
def load_examples(file_path, do_lower_case=True):
    examples = []

    with open('{}/seq.in'.format(file_path),'r',encoding="utf-8") as f_text, open('{}/label'.format(file_path),'r',encodin
        for text, label in zip(f_text, f_label):

            e = Inputexample(text.strip(),label=label.strip())
            examples.append(e)

    return examples
```

Each sample has a sentence and label format

In [ ]:
```

```

```
class Inputexample(object):
    def __init__(self,text_a,label = None):
        self.text = text_a
        self.label = label
```

Question3 : Write the code to be able to control batching data process for the sake of fine-tuning models with combining cross entropy and supervised contrastive loss in question 5, and only cross entropy in question 4. (7pts)

- assume : we have batch size = 4 but we have 64 classes, so sometime batching process will random sample in a batch, and then it has no any samples come from the same classes like below
    - samples_sentence = ['a','b','c','d'] : assume that one alphabet represent one sentence or one sample
    - labels = [0,1,2,3] ; Therefore, if a batch has unqiue classes equal to batch size, this batch will be skipped due to equation "1yi=yj" of supervised contrastive loss(equation in question 5) that's reason why we need to force like below buttlet.
    - you can see at least one pair that come from the same class.

      Therefore, we want dataloader to output like below

        - samples_sentence = ['a','b','c','f']
        - labels = [0,1,2,0] ; this batch will pass condition as "1yi=yj" because the label of y[0] = 0, y[3] = 0 in list of labels.

In [ ]:

```
# create custom dataset class
# ===  =  Hint =  ===
# can train on two condition
# 1.) trainig training with supervise contrastive loss and cross entropy loss using in question 5.)
#    when self.repeated_label == True:
# 2.) train only cross entropy loss use in question 4.)
#    when self.repeated_label == False:
class CustomTextDataset(Dataset):
    def __init__(self,labels,text,batch_size,repeated_label:bool=False):
        self.labels = labels
        self.text = text
        self.batch_size = batch_size
        self.count = 0
        self.repeated_label = repeated_label

        # to use when training with supervise contrastive loss
        if self.repeated_label == True:
            # write the code here
            pass


    def __len__(self):
        return len(self.labels)

    def __getitem__(self, idx):

        # write code here for 1)


        label = self.labels[idx]

        data = self.text[idx]

        sample = {"Class": label,"Text": data}
```

```
    return sample
```

What is Few-shot Learning ?

- few-shot learning is the process of train model on small amount of data in each class to guide model on specific taks, opposed to standard fine-tuning method which requires a large amount of training data for the pretrained model to adapt to the desired task with accuracy.

source : https://huggingface.co/blog/few-shot-learning-gpt-neo-and-inference-api

Define Parameters

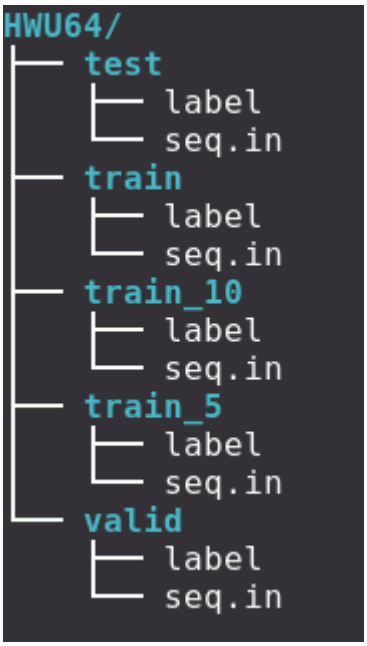
In [ ]:
```
N = 5
data = []
labels = []
train_samples = []
train_labels = []
embed_dim = 768
batch_size = 4
lr= 1e-5  # you can adjust
temp = 0.3  # you can adjust
lamda = 0.01  # you can adjust
skip_time = 0 # the number of time that yi not equal to yj in supervised contrastive loss equation
device = torch.device('cuda:2' if torch.cuda.is_available() else 'cpu')
```

The Aim of these training is to fine tuning on few shot setting on text classification task

Path example of train, validation and test

In [ ]:
```
path_5shot = f'./HWU64/train_5/'
path_test = f'./HWU64/test/'
path_valid = f'./HWU64/valid/'
```

Dataset Structure



In [ ]:
```
# !unzip HWU64.zip
```

In [ ]:
```
# https://downgit.github.io/#/home?url=https:%2F%2Fgithub.com%2Fjianguoz%2FFew-Shot-Intent-Detection%2Ft

# downloading training samples
train_samples = load_examples(path_5shot)

# write code here : for downloading validation samples

#write code here : for downloading test samples

# preprocess for training
for i in range(len(train_samples)):
    data.append(train_samples[i].text)
    labels.append(train_samples[i].label)

# write code here :preprocess validation samples

# write code here : preprocess test samples

# dataloader for training
train_data = CustomTextDataset(labels,data,batch_size=batch_size,repeated_label=True)
train_loader = DataLoader(train_data,batch_size=batch_size,shuffle=True)


# write code here : dataloader for validation


# write code here : dataloader for test


# got the number of unique classes from dataset
num_class = len(np.unique(np.array(labels)))

# get text label of uniqure classes
unique_label = np.unique(np.array(labels))

# map text label to index classes
label_maps = {unique_label[i]: i for i in range(len(unique_label))}

# Download tokenizer that use to tokenize sentence into words by using Pretrain from roberta-base
tokenizer = RobertaTokenizer.from_pretrained('roberta-base')
```

Download Pretrain Model

In [ ]:
```
# download config of Roberta config
config = RobertaConfig.from_pretrained("roberta-base",output_hidden_states=True)

#chnage modifying the number of classes
config.num_labels = num_class
# Download pretrain models weight
model = RobertaForSequenceClassification.from_pretrained('roberta-base')
# change from binary classification to muli-classification and loss automatically change to cross entropy loss
model.num_labels = config.num_labels
# change the output of last layer to num_class that we want to predict
model.classifier.out_proj = nn.Linear(in_features=embed_dim,out_features=num_class)
# move to model to device that we set
model = model.to(device)
```

Some weights of the model checkpoint at roberta-base were not used when initializing RobertaForSequenceClassification: ['roberta.pooler.dense.bias', 'lm_head.decoder.weight', 'lm_head.dense.bias', 'lm_head.layer_norm.bias', 'lm_head.dense.weight', 'lm_head.layer_norm.weight', 'lm_head.bias', 'roberta.pooler.dense.weight']
- This IS expected if you are initializing RobertaForSequenceClassification from the checkpoint of a model trained on another task or with another architecture (e.g. initializing a BertForSequenceClassification model from a BertForPreTrain

ing model).
- This IS NOT expected if you are initializing RobertaForSequenceClassification from the checkpoint of a model that you expect to be exactly identical (initializing a BertForSequenceClassification model from a BertForSequenceClassification model).
Some weights of RobertaForSequenceClassification were not initialized from the model checkpoint at roberta-base and are newly initialized: ['classifier.out_proj.weight', 'classifier.out_proj.bias', 'classifier.dense.bias', 'classifier.dense.weight']
You should probably TRAIN this model on a down-stream task to be able to use it for predictions and inference.

In [ ]:
```
# Using adam optimizer
optimizer= AdamW(model.parameters(), lr=lr)
```

Question3: write function to freeze model (3pts)

In [ ]:
```
def freeze_layers(model,freeze_layers_count:int):

    """
    model : model object that we create
    freeze_layers_count : the number of layers to freeze
    """
    # write the code here


    return model
```

Question4: Training on text classification task on CrossEntropy loss (3.5 pts)

- Using API of hugging face of RobertaForSequenceClassification
  - source : https://huggingface.co/transformers/v3.0.2/model_doc/roberta.html#robertaforsequenceclassification
- report performance of models (test acc) with differrent experiement of unfreezing of bottom layers and compare the result of each
  - 4.1. freeze weight from pretrain model all layer except classifier

```
RobertaClassificationHead(
  (dense): Linear(in_features=768, out_features=768, bias=True)
  (dropout): Dropout(p=0.1, inplace=False)
  (out_proj): Linear(in_features=768, out_features=64, bias=True)
)
```

  -

- 4.2. freeze all from top embeddings to encoder layers (9)
  - embeddings
    - ![image.png](attachment:2a69ebe1-6893-45ca-b7ea-38f9715b8c9a.png)
  - layer 9
    - ![image.png](attachment:ef8674dc-7743-40d4-bde4-21a3819e62fb.png)
- 4.3 add code to collect loss and accuracy of training history of (4.1 and 4.2)
- 4.4 add the code in below in training loop collect validation loss and accuracy history of (4.1 and 4.2)

- hint: for this training on Cross entropy loss no need to control the outcome of class in each batch using code below to train model base on how many layers that you freeze
  - to see whole architecture look like you can use mode.eval()

In [ ]:
```
# this code training models on Cross entropy loss
for epoch in range(30):  # loop over the dataset multiple times
```

```
running_loss = 0.0

for (idx, batch) in enumerate(train_loader):
    sentence = batch["Text"]
    inputs = tokenizer(sentence,padding=True,truncation=True,return_tensors="pt")

    # move parameter to device
    inputs = {k:v.to(device) for k,v in inputs.items()}

    # map string labels to class idex
    labels = [label_maps[stringtoId] for stringtoId in (batch['Class'])]

    #print("show out: ",np.unique(labels, return_counts=True))
    # convert list to tensor
    labels = torch.tensor(labels).unsqueeze(0)
    labels = labels.to(device)


    #(batch_size, seq_len)
    #print(inputs["input_ids"].shape)

     # zero the parameter gradients
    optimizer.zero_grad()

    outputs = model(**inputs,labels=labels)
    # you can check
    loss, logits = outputs[:2]

    loss.backward()
    optimizer.step()

    # write code here
    # to save model eg. model.pth look at pytorch document how to save model

    print(f'[{epoch + 1}, {idx}] loss: {loss.item()}')
    print(running_loss)
    clear_output(wait=True)
```

- 4.5 write code to plot both loss and accuracy for training and validation repectively.
- 4.6 write test function to get test accuracy for (4.1,4.2)

In [ ]:
```
# write code here for 4.5 and 4.6
```

Question 5: Training on text classification task on combine two losses Cross Entropy and Supervised Contrastive. (3.5 pts)

- Cross Entropy loss

$$\mathcal{L}_{\text{CE}} = -\frac{1}{m}\sum_{i=1}^{m} yi \cdot log(\hat{yi})$$

- Supervised Contrastive learning loss

$$\mathcal{L}_{\text{S\_cl}} = -\frac{1}{T}\sum_{i=1}^{N}\sum_{j=1}^{N} \mathbf{1}_{yi=yj} \ log\frac{e^{sim(hi,hj)/\tau}}{\sum_{n=1}^{N} e^{sim(hi,hn)/\tau}}$$

  - detail

- ui ~ sentence i
- hi ~ BERT(ui) in our case using Roberta as a encoder
- hi : (batch_size,sequence_len,embed_size)
- hi is the output of model which is last hidden layers before classifier head in the model architecture
- 1yi=yj ~ we select only the sample that come from the same class to compute in each i and j
- T ~ the number of pairs that come from the same classes
- τ ~ temperature parameter
- Sim(x1,x2) : cosine similarity [-1, 1]
- λ' is just weighted of cross entropy loss
- Sim function is the cosine similarity
- N ~ the number of samples in a batch

$$sim(A, B) = \cos(\theta) = \frac{A \cdot B}{\|A\|\|B\|}$$

- Loss total

$$\mathcal{L}_{\text{total}} = \mathcal{L}_{\text{s\_cl}} + \lambda' \mathcal{L}_{CE}$$

- you can get cross entropy loss like below
  - outputs = model(input_ids, labels=labels)
  - loss, logits = outputs[:2]
  - loss : this is cross entropy loss
- hint : for this question you will utilize the function CustomTextDataset to force dataloader to have at least one pair that come from the same class
  - eg. batch_size = 4
  - the labels in a batch should be like [0, 21, 43, 0]

1. training this model in the code below on loss_total by do experiment the same as question 4.1, 4.2, 4.3, 4.4, 4.5, 4.6

In [ ]:

```
for epoch in range(30):  # loop over the dataset multiple times

    running_loss = 0.0

    for (idx, batch) in enumerate(train_loader):
        sentence = batch["Text"]
        inputs = tokenizer(sentence,padding=True,truncation=True,return_tensors="pt")
        inputs = {k:v.to(device) for k,v in inputs.items()}

        # map string labels to class idex
        labels = [label_maps[stringtoId] for stringtoId in (batch['Class'])]


        # convert list to tensor
        labels = torch.tensor(labels).unsqueeze(0)
        labels = labels.to(device)


        #(batch_size, seq_len)
        #print(inputs["input_ids"].shape)

         # zero the parameter gradients
        optimizer.zero_grad()

        outputs = model(**inputs,labels=labels,output_hidden_states=True)
```

```
        hidden_states = outputs.hidden_states

        last_hidden_states = hidden_states[12]

        # https://stackoverflow.com/questions/63040954/how-to-extract-and-use-bert-encodings-of-sentences-for-text-
        # (batch_size,seq_len,embed_dim)
        h = last_hidden_states[:,0,:]

        # create pair samples
        T, h_i, h_j, idx_yij = create_supervised_pair(h,batch['Class'],debug=False)

        if h_i is None:
            print("skip this batch")
            skip_time +=1
            continue

        # supervised contrastive loss
        loss_s_cl = supervised_contrasive_loss(h_i, h_j, h, T,temp=temp,idx_yij=idx_yij,debug=False)

        # cross entropy loss
        loss_classify, logits = outputs[:2]

        # loss total
        loss = loss_s_cl + (lamda * loss_classify)

        loss.backward()
        optimizer.step()


        print(f'[{epoch + 1}, {idx}] loss_total: {loss.item()}, loss_s_cl:{loss_s_cl.item()}, loss_classify:{lamda * loss_cla

        clear_output(wait=True)
```

```
[2, 62] loss_total: 1.4274049997329712, loss_s_cl:1.3862911462783813, loss_classify:0.04111388683319092
---------------------------------------------------------------------------
KeyboardInterrupt                         Traceback (most recent call last)
/tmp/ipykernel_1233/4103665026.py in <module>
     57         print(f'[{epoch + 1}, {idx}] loss_total: {loss.item()}, loss_s_cl:{loss_s_cl.item()}, loss_classify:{lamda * l
oss_classify.item()}')
     58
---> 59         clear_output(wait=True)
     60

/opt/conda/lib/python3.9/site-packages/IPython/core/display.py in clear_output(wait)
   1469     from IPython.core.interactiveshell import InteractiveShell
   1470     if InteractiveShell.initialized():
-> 1471         InteractiveShell.instance().display_pub.clear_output(wait)
   1472     else:
   1473         print('\033[2K\r', end='')

/opt/conda/lib/python3.9/site-packages/ipykernel/zmqshell.py in clear_output(self, wait)
    152         """
    153         content = dict(wait=wait)
--> 154         self._flush_streams()
    155         self.session.send(
    156             self.pub_socket, 'clear_output', content,

/opt/conda/lib/python3.9/site-packages/ipykernel/zmqshell.py in _flush_streams(self)
     70     def _flush_streams(self):
     71         """flush IO Streams prior to display"""
---> 72         sys.stdout.flush()
     73         sys.stderr.flush()
     74

/opt/conda/lib/python3.9/site-packages/ipykernel/iostream.py in flush(self)
    464                 self.pub_thread.schedule(evt.set)
    465                 # and give a timeout to avoid
--> 466                 if not evt.wait(self.flush_timeout):
```

```
    467                 # write directly to __stderr__ instead of warning because
    468                 # if this is happening sys.stderr may be the problem.

/opt/conda/lib/python3.9/threading.py in wait(self, timeout)
    572         signaled = self._flag
    573         if not signaled:
--> 574             signaled = self._cond.wait(timeout)
    575         return signaled
    576

/opt/conda/lib/python3.9/threading.py in wait(self, timeout)
    314         else:
    315             if timeout > 0:
--> 316                 gotit = waiter.acquire(True, timeout)
    317             else:
    318                 gotit = waiter.acquire(False)

KeyboardInterrupt:
```

In [ ]:

In [ ]:

In [ ]:

In [ ]: