Installing Modules

```
!pip install spacy==3
!python -m spacy download en_core_web_sm
!pip install pytorch_lightning torchmetrics tableprint
```

```
Requirement already satisfied: pydantic<1.8.0,>=1.7.1 in /usr/local/lib/pytl
Requirement already satisfied: setuptools in /usr/local/lib/python3.7/dist-p
Requirement already satisfied: cymem<2.1.0,>=2.0.2 in /usr/local/lib/python3
Requirement already satisfied: smart-open<4.0.0,>=2.2.0 in /usr/local/lib/py
Requirement already satisfied: zipp>=0.5; python_version < "3.8" in /usr/lo
Requirement already satisfied: click<7.2.0,>=7.1.1 in /usr/local/lib/python3
Requirement already satisfied: urllib3!=1.25.0,!=1.25.1,<1.26,>=1.21.1 in /u
Requirement already satisfied: chardet<4,>=3.0.2 in /usr/local/lib/python3.7
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3
Requirement already satisfied: idna<3,>=2.5 in /usr/local/lib/python3.7/dist
Requirement already satisfied: pyparsing>=2.0.2 in /usr/local/lib/python3.7/
Requirement already satisfied: MarkupSafe>=0.23 in /usr/local/lib/python3.7/
✔ Download and installation successful
You can now load the package via spacy.load('en_core_web_sm')
Requirement already satisfied: pytorch_lightning in /usr/local/lib/python3.7
Requirement already satisfied: torchmetrics in /usr/local/lib/python3.7/dist
Requirement already satisfied: tableprint in /usr/local/lib/python3.7/dist-p
Requirement already satisfied: torch>=1.4 in /usr/local/lib/python3.7/dist-p
Requirement already satisfied: future>=0.17.1 in /usr/local/lib/python3.7/di
Requirement already satisfied: numpy>=1.17.2 in /usr/local/lib/python3.7/dis
Requirement already satisfied: tqdm>=4.41.0 in /usr/local/lib/python3.7/dist
Requirement already satisfied: packaging in /usr/local/lib/python3.7/dist-pa
Requirement already satisfied: fsspec[http]!=2021.06.0,>=2021.05.0 in /usr/l
Requirement already satisfied: pyDeprecate==0.3.0 in /usr/local/lib/python3.
Requirement already satisfied: tensorboard!=2.5.0,>=2.2.0 in /usr/local/lib/
Requirement already satisfied: PyYAML<=5.4.1,>=5.1 in /usr/local/lib/python3
Requirement already satisfied: wcwidth in /usr/local/lib/python3.7/dist-pack
Requirement already satisfied: typing-extensions in /usr/local/lib/python3.7
Requirement already satisfied: pyparsing>=2.0.2 in /usr/local/lib/python3.7/
Requirement already satisfied: requests; extra == "http" in /usr/local/lib/p
Requirement already satisfied: aiohttp; extra == "http" in /usr/local/lib/py
Requirement already satisfied: markdown>=2.6.8 in /usr/local/lib/python3.7/d
Requirement already satisfied: google-auth<2,>=1.6.3 in /usr/local/lib/pytho
Requirement already satisfied: tensorboard-plugin-wit>=1.6.0 in /usr/local/l
Requirement already satisfied: setuptools>=41.0.0 in /usr/local/lib/python3.
Requirement already satisfied: wheel>=0.26; python_version >= "3" in /usr/lo
Requirement already satisfied: protobuf>=3.6.0 in /usr/local/lib/python3.7/d
Requirement already satisfied: six>=1.10.0 in /usr/local/lib/python3.7/dist-
Requirement already satisfied: grpcio>=1.24.3 in /usr/local/lib/python3.7/di
Requirement already satisfied: google-auth-oauthlib<0.5,>=0.4.1 in /usr/loca
Requirement already satisfied: absl-py>=0.4 in /usr/local/lib/python3.7/dist
Requirement already satisfied: werkzeug>=0.11.15 in /usr/local/lib/python3.7
Requirement already satisfied: urllib3!=1.25.0,!=1.25.1,<1.26,>=1.21.1 in /u
Requirement already satisfied: idna<3,>=2.5 in /usr/local/lib/python3.7/dist
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.
Requirement already satisfied: chardet<4,>=3.0.2 in /usr/local/lib/python3.7
Requirement already satisfied: attrs>=17.3.0 in /usr/local/lib/python3.7/dis
Requirement already satisfied: multidict<7.0,>=4.5 in /usr/local/lib/python3
Requirement already satisfied: yarl<2.0,>=1.0 in /usr/local/lib/python3.7/di
Requirement already satisfied: async-timeout<4.0,>=3.0 in /usr/local/lib/py
Requirement already satisfied: importlib-metadata; python_version < "3.8" in
```

```
Requirement already satisfied: pyasn1-modules>=0.2.1 in /usr/local/lib/pyth
Requirement already satisfied: rsa<5,>=3.1.4; python_version >= "3.6" in /u
Requirement already satisfied: cachetools<5.0,>=2.0.0 in /usr/local/lib/pyt
Requirement already satisfied: requests-oauthlib>=0.7.0 in /usr/local/lib/p
Requirement already satisfied: zipp>=0.5 in /usr/local/lib/python3.7/dist-pa
Requirement already satisfied: pyasn1<0.5.0,>=0.4.6 in /usr/local/lib/pytho
Requirement already satisfied: oauthlib>=3.0.0 in /usr/local/lib/python3.7/
```

Imports

```
# Import Library
import random
import torch, torchtext
from torchtext.legacy import data
import torch.nn as nn
import torch.nn.functional as F
import torch.optim as optim


import pandas as pd
import sys, os, pickle
import numpy as np
import math
import matplotlib.pyplot  as plt
import seaborn as sns

import spacy
nlp = spacy.load('en_core_web_sm')

import pytorch_lightning as pl
import torchmetrics

from pytorch_lightning.loggers import CSVLogger
from pytorch_lightning.callbacks import ModelCheckpoint
from sklearn.metrics import confusion_matrix
import tableprint as tp


# Manual Seed
SEED = 43
torch.manual_seed(SEED)
```

```
<torch._C.Generator at 0x7f5d9feb1af0>
```

Loading Data

Files have been saved to google drive for faster access!

```
!gdown --id 1nPiDRoGrc_-lQ0KiNJFR0IuAc4CXk_jQ
```

```
Downloading...
From: https://drive.google.com/uc?id=1nPiDRoGrc_-lQ0KiNJFR0IuAc4CXk_jQ
To: /content/quora_duplicate_questions.tsv
58.2MB [00:00, 221MB/s]
```

```
df = pd.read_csv('quora_duplicate_questions.tsv', sep="\t", engine='python')
print(len(df))
```

```
404290
```

```
df.head()
```

	id	qid1	qid2	question1	question2	is_duplicate
0	0	1	2	What is the step by step guide to invest in sh...	What is the step by step guide to invest in sh...	0
1	1	3	4	What is the story of Kohinoor (Koh-i-Noor) Dia...	What would happen if the Indian government sto...	0
2	2	5	6	How can I increase the speed of my internet co...	How can Internet speed be increased by hacking...	0
3	3	7	8	Why am I mentally very	Find the remainder when	0

We are only interested in the rows where `is_duplicate ==1`

```
df = df.loc[df['is_duplicate'] == 1]
df.drop(['id','qid1', 'qid2'], inplace=True, axis=1)
df.reset_index(drop=True, inplace=True)
```

```
df.head()
```

	question1	question2	is_duplicate
0	Astrology: I am a Capricorn Sun Cap moon and c...	I'm a triple Capricorn (Sun, Moon and ascendan...	1
1	How can I be a good geologist?	What should I do to be a great geologist?	1
2	How do I read and find my YouTube comments?	How can I see all my Youtube comments?	1
3	What can make Physics easy to learn?	How can you make physics easy to	1

There are no null values in our data

```
df.isnull().sum()
```

```
question1       0
question2       0
is_duplicate    0
dtype: int64
```

Defining Fields

Now we shall be defining the SRC and TRG fields.

```
def tokenize_inp(text):
  return [tok.text for tok in nlp.tokenizer(text)][::-1]

def tokenize_out(text):
  return [tok.text for tok in nlp.tokenizer(text)]


SRC= data.Field(sequential = True, tokenize = tokenize_inp, init_token='<sos>',
            eos_token='<eos>',
            lower=True)
TRG = data.Field(sequential = True, tokenize = tokenize_out, init_token='<sos>',
            eos_token='<eos>',
            lower=True)
```

The `SRC` and `TRG` fields are mapped to the `Question` and `Answer` columns respectively.

```
fields = [('question1', SRC),('question2',TRG)]
```

```
example = [data.Example.fromlist([df.question1[i],df.question2[i]], fields) for i
```

Create the dataset...

```
QA = data.Dataset(example, fields)
```

Split into train and test sets

```
(train, test) = QA.split(split_ratio=[0.70, 0.30], random_state=random.seed(SEED))
```

Double-click (or enter) to edit

```
(len(train), len(test))
```

```
(104484, 44779)
```

An example from the dataset:

```
vars(train.examples[10])
```

```
{'question1': ['?', 'election', 'the', 'win', 'trump', 'donald', 'did', 'why'
```

```
 'question2': ['how',
  'did',
  'donald',
  'trump',
  'win',
  'despite',
  'projections',
  'that',
  'he',
  'would',
  'fail',
  '?']}
```

```
" ".join((vars(train.examples[10]))['question1'])
```

```
'? election the win trump donald did why'
```

Building Vocabulary

We will build vocabulary only using the `train` dataset and not the `test` dataset

```
SRC.build_vocab(train)
TRG.build_vocab(train)
```

By default, torchtext will add two more special tokens, for unknown words and , a padding token that will be used to pad all our text to roughly the same size to help with efficient batching on the GPU.

```
print('Size of input vocab : ', len(SRC.vocab))
print('Size of label vocab : ', len(TRG.vocab))
print('Top 10 words appreared repeatedly :', list(SRC.vocab.freqs.most_common(10))
```

```
Size of input vocab :  23815
Size of label vocab :  23805
Top 10 words appreared repeatedly : [('?', 108745), ('the', 46724), ('what',
```

Initializing GPU as the device

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

The Train/Test iterators are initialized here

```
train_iterator, test_iterator = data.BucketIterator.splits((train, test), batch_si
                                                           sort_key = lambda x: l
                                                           sort_within_batch=True
```

Save the vocabulary for later use

```
with open('tokenizer.pkl', 'wb') as tokens:
    pickle.dump(SRC.vocab.stoi, tokens)
```

Defining Our Model

Boilerplate code

```
# Define the model

class TL(pl.LightningModule):
    def __init__(self):
        super(TL, self).__init__()

        self.train_acc =  torch.tensor(0.)
        self.avg_train_loss = torch.tensor(0.)
        self.table_context = None


    def training_step(self, batch, batch_idx):
        src = batch.question1
        trg = batch.question2
        output = self(src, trg)
        output_dim = output.shape[-1]
        output = output[1:].view(-1, output_dim)
        trg = trg[1:].view(-1)
        loss_train = self.loss(output, trg)
        return loss_train

    def validation_step(self, batch, batch_idx):
        src = batch.question1
        trg = batch.question2
        output = self(src, trg, 0)
        output_dim = output.shape[-1]
        output = output[1:].view(-1, output_dim)
        trg = trg[1:].view(-1)
        loss_valid = self.loss(output, trg)
        return {"loss": loss_valid}

    def training_epoch_end(self, outputs):
        self.avg_train_loss = torch.stack([x['loss'] for x in outputs]).mean()

    def validation_epoch_end(self, outputs):
        if trainer.running_sanity_check:
            return
        avg_valid_loss = torch.stack([x['loss'] for x in outputs]).mean()
        metrics = {'epoch': self.current_epoch+1, 'Train PPL': math.exp(self.avg_t
        if self.table_context is None:
```

```
            self.table_context = tp.TableContext(headers=['epoch', 'Train PPL', 'T
            self.table_context.__enter__()
        self.table_context([self.current_epoch+1, math.exp(self.avg_train_loss.ite
        self.logger.log_metrics(metrics)
        if self.current_epoch == self.trainer.max_epochs - 1:
            self.validation_end(outputs)

    def validation_end(self, outputs):
        self.table_context.__exit__()
```

Encoder

```
class Encoder(pl.LightningModule):
    def __init__(self, input_dim, emb_dim, hid_dim, n_layers, dropout):
        super().__init__()

        self.hid_dim = hid_dim
        self.n_layers = n_layers

        self.embedding = nn.Embedding(input_dim, emb_dim)
        self.rnn = nn.LSTM(emb_dim, hid_dim, n_layers, dropout = dropout)
        self.dropout = nn.Dropout(dropout)

    def forward(self, src):


        embedded = self.dropout(self.embedding(src))
        output, (hidden,cell) = self.rnn(embedded)

        return hidden,cell
```

Decoder

```
class Decoder(pl.LightningModule):
    def __init__(self, emb_dim, hid_dim, n_layers, dropout, output_dim):
        super().__init__()

        self.hid_dim = hid_dim
        self.n_layers = n_layers
        self.output_dim = output_dim
        self.embedding = nn.Embedding(output_dim, emb_dim)
        self.rnn = nn.LSTM(emb_dim, hid_dim, n_layers, dropout = dropout)
        self.fc_out = nn.Linear(hid_dim, output_dim)
        self.dropout = nn.Dropout(dropout)

    def forward(self, input, hidden, cell):

        input = input.unsqueeze(0)

        embedded = self.dropout(self.embedding(input))
```

```
        output, (hidden,cell) = self.rnn(embedded, (hidden,cell))
        prediction = self.fc_out(output.squeeze(0))

        return prediction, hidden, cell
```

Seq2Seq Model

```
# Define the model

class Seq2Seq(TL):
    def __init__(self, encoder, decoder, device):
        super(Seq2Seq, self).__init__()

        TRG_PAD_IDX = TRG.vocab.stoi[TRG.pad_token]
        self.loss = nn.CrossEntropyLoss(ignore_index=TRG_PAD_IDX)
        self.lr = 1e-3

        self.encoder = encoder
        self.decoder = decoder
        # self.device = device # Doesn't work in PyTorchLightning since it is alre

        assert encoder.hid_dim == decoder.hid_dim, "Hidden Dimensions of Encoder a
        assert encoder.n_layers == decoder.n_layers, "Encoder and Decoder must hav

    def forward(self, src, trg, teacher_forcing_ratio = 0.5):

        batch_size = trg.shape[1]
        trg_len = trg.shape[0]
        trg_vocab_size = self.decoder.output_dim

        outputs = torch.zeros(trg_len, batch_size, trg_vocab_size).to(self.device)

        hidden, cell = self.encoder(src)

        input = trg[0,:]

        for t in range(1, trg_len):

            output, hidden,cell = self.decoder(input, hidden, cell)

            outputs[t] = output

            teacher_force = random.random() < teacher_forcing_ratio

            top1 = output.argmax(1)

            input = trg[t] if teacher_force else top1

        return outputs

    def configure_optimizers(self):
        optim = torch.optim.Adam(self.parameters())
```

```
        return optim
```

```
device
```

```
    device(type='cuda')
```

```
INPUT_DIM = len(SRC.vocab)
OUTPUT_DIM = len(TRG.vocab)
ENC_EMB_DIM = 256
DEC_EMB_DIM = 256
HID_DIM = 512
N_LAYERS = 2
ENC_DROPOUT = 0.5
DEC_DROPOUT = 0.5

enc = Encoder(INPUT_DIM, ENC_EMB_DIM, HID_DIM, N_LAYERS, ENC_DROPOUT)
dec = Decoder(DEC_EMB_DIM, HID_DIM, N_LAYERS, DEC_DROPOUT, OUTPUT_DIM)

model = Seq2Seq(enc, dec, device).to(device)
```

Model Checkpoint

This saves the best model (best => model with lowest val loss)

```
checkpoint_callback = ModelCheckpoint(
    monitor='val_loss',
    dirpath='/content',
    filename='sst-{epoch:02d}-{val_loss:.2f}',
    mode='min'
)
```

```
!rm -rf csv_logs
csvlogger = CSVLogger('csv_logs', name='END2 Assign 7_2_TL', version=0)
trainer = pl.Trainer(max_epochs=20, num_sanity_val_steps=1, logger=csvlogger, gpus=
trainer.fit(model, train_dataloader=train_iterator, val_dataloaders=test_iterator)
checkpoint_callback.best_model_path
```

```
GPU available: True, used: True
TPU available: False, using: 0 TPU cores
LOCAL_RANK: 0 - CUDA_VISIBLE_DEVICES: [0]

  | Name    | Type             | Params
-------------------------------------------
0 | loss    | CrossEntropyLoss | 0
1 | encoder | Encoder          | 9.8 M
2 | decoder | Decoder          | 22.0 M
-------------------------------------------
31.8 M    Trainable params
0         Non-trainable params
31.8 M    Total params
127.036   Total estimated model params size (MB)
```

Validation sanity check: 0% 0/1 [00:00<?, ?it/s]

Epoch 19: 100% 584/584 [06:34<00:00, 1.48it/s, loss=2.24, v_num=0]

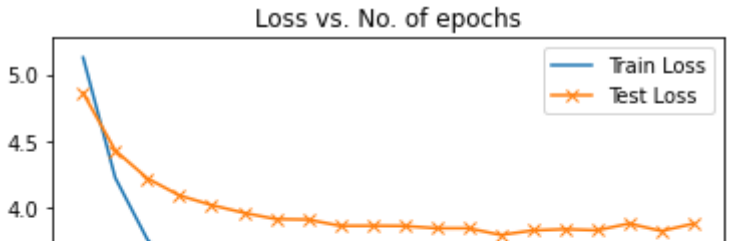
epoch	Train PPL	Train Loss	Valid PPL	Valid Loss
1	168.34	5.126	129.11	4.8607
2	68.464	4.2263	84.001	4.4308
3	43.166	3.765	68.202	4.2225
4	32.583	3.4838	59.996	4.0943
5	26.535	3.2785	55.842	4.0225
6	22.678	3.1214	52.708	3.9648
7	19.708	2.981	50.279	3.9176
8	18.061	2.8938	50.096	3.9139
13	11.972	2.4826	46.952	3.8491
16	10.314	2.3335	46.604	3.8417

Model Training and Evaluation

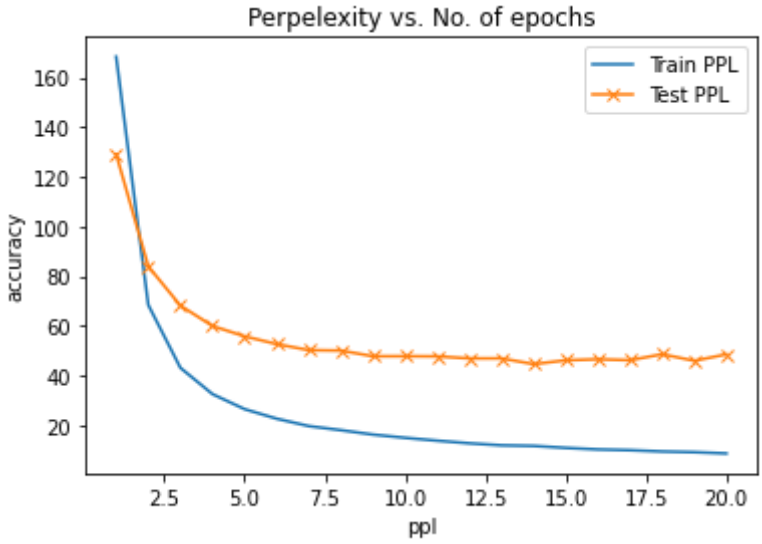
First define the optimizer and loss functions

```
root='./csv_logs/' + 'END2 Assign 7_2_TL' + '/'
dirlist = [ item for item in os.listdir(root) if os.path.isdir(os.path.join(root, 
metricfile = root + dirlist[-1:][0] + '/metrics.csv'
metrics = pd.read_csv(metricfile)


plt.plot(metrics['epoch'], metrics['Train Loss'], label="Train Loss")
plt.plot(metrics['epoch'], metrics['Valid Loss'], '-x', label="Test Loss")
plt.xlabel('epoch')
plt.ylabel('loss')
plt.legend()
plt.title('Loss vs. No. of epochs');
```




```
plt.plot(metrics['epoch'], metrics['Train PPL'], label="Train PPL")
plt.plot(metrics['epoch'], metrics['Valid PPL'], '-x', label="Test PPL")
plt.xlabel('ppl')
plt.ylabel('accuracy')
plt.legend()
plt.title('Perpelexity vs. No. of epochs');
```



✓ 0s completed at 3:07 PM