Installing Modules

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

```
Requirement already satisfied: thinc<8.1.0,>=8.0.0 in /usr/local/lib/python
Requirement already satisfied: typer<0.4.0,>=0.3.0 in /usr/local/lib/python
Requirement already satisfied: preshed<3.1.0,>=3.0.2 in /usr/local/lib/pyth
Requirement already satisfied: wasabi<1.1.0,>=0.8.1 in /usr/local/lib/pytho
Requirement already satisfied: typing-extensions>=3.7.4; python_version < "
Requirement already satisfied: zipp>=0.5 in /usr/local/lib/python3.7/dist-p
Requirement already satisfied: smart-open<6.0.0,>=5.0.0 in /usr/local/lib/p
Requirement already satisfied: pyparsing>=2.0.2 in /usr/local/lib/python3.7
Requirement already satisfied: urllib3!=1.25.0,!=1.25.1,<1.26,>=1.21.1 in /
Requirement already satisfied: idna<3,>=2.5 in /usr/local/lib/python3.7/dis
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.
Requirement already satisfied: MarkupSafe>=0.23 in /usr/local/lib/python3.7
Requirement already satisfied: click<7.2.0,>=7.1.1 in /usr/local/lib/python
Installing collected packages: en-core-web-sm
  Found existing installation: en-core-web-sm 2.2.5
    Uninstalling en-core-web-sm-2.2.5:
      Successfully uninstalled en-core-web-sm-2.2.5
Successfully installed en-core-web-sm-3.0.0
✔ Download and installation successful
You can now load the package via spacy.load('en_core_web_sm')
2021-07-01 03:14:43.023277: I tensorflow/stream_executor/platform/default/d
Collecting de-core-news-sm==3.0.0
  Downloading https://github.com/explosion/spacy-models/releases/download/d
     |████████████████████████████████| 19.3MB 1.1MB/s
Requirement already satisfied: spacy<3.1.0,>=3.0.0 in /usr/local/lib/python
Requirement already satisfied: spacy-legacy<3.1.0,>=3.0.0 in /usr/local/lib
Requirement already satisfied: packaging>=20.0 in /usr/local/lib/python3.7/
Requirement already satisfied: tqdm<5.0.0,>=4.38.0 in /usr/local/lib/python

Requirement already satisfied: typing-extensions>=3.7.4; python_version < "
Requirement already satisfied: numpy>=1.15.0 in /usr/local/lib/python3.7/di
Requirement already satisfied: blis<0.8.0,>=0.4.0 in /usr/local/lib/python3
Requirement already satisfied: thinc<8.1.0,>=8.0.0 in /usr/local/lib/python
Requirement already satisfied: setuptools in /usr/local/lib/python3.7/dist-
Requirement already satisfied: typer<0.4.0,>=0.3.0 in /usr/local/lib/python
Requirement already satisfied: srsly<3.0.0,>=2.4.0 in /usr/local/lib/python
Requirement already satisfied: requests<3.0.0,>=2.13.0 in /usr/local/lib/py
Requirement already satisfied: jinja2 in /usr/local/lib/python3.7/dist-pack
Requirement already satisfied: preshed<3.1.0,>=3.0.2 in /usr/local/lib/pyth
Requirement already satisfied: catalogue<2.1.0,>=2.0.1 in /usr/local/lib/py
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Requirement already satisfied: pydantic<1.8.0,>=1.7.1 in /usr/local/lib/pyt
Requirement already satisfied: importlib-metadata>=0.20; python_version < "
Requirement already satisfied: murmurhash<1.1.0,>=0.28.0 in /usr/local/lib/
Requirement already satisfied: pathy in /usr/local/lib/python3.7/dist-packa
Requirement already satisfied: cymem<2.1.0,>=2.0.2 in /usr/local/lib/python
Requirement already satisfied: pyparsing>=2.0.2 in /usr/local/lib/python3.7
Requirement already satisfied: click<7.2.0,>=7.1.1 in /usr/local/lib/python
Requirement already satisfied: idna<3,>=2.5 in /usr/local/lib/python3.7/dis
Requirement already satisfied: chardet<4,>=3.0.2 in /usr/local/lib/python3.
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3
Requirement already satisfied: urllib3!=1.25.0,!=1.25.1,<1.26,>=1.21.1 in /
Requirement already satisfied: MarkupSafe>=0.23 in /usr/local/lib/python3.7/
Requirement already satisfied: zipp>=0.5; python_version < "3.8" in /usr/lo
Requirement already satisfied: smart-open<6.0.0,>=5.0.0 in /usr/local/lib/py
Installing collected packages: de-core-news-sm
Successfully installed de-core-news-sm-3.0.0
✔ Download and installation successful
```

Imports

```
# Import Libraries
import random
from typing import Iterable, List, Tuple
import pandas as pd
import sys, os, pickle
import numpy as np
import math
import matplotlib.pyplot  as plt
import spacy

# PyTorch related
import torch, torchtext
import torch.nn as nn
import torch.nn.functional as F
import torch.optim as optim
from torch import Tensor
from torchtext.data.utils import get_tokenizer
from torchtext.vocab import build_vocab_from_iterator
from torchtext.datasets import Multi30k
from torch.nn.utils.rnn import pad_sequence
from torch.utils.data import DataLoader

# My Custom Code
import pytorch_lightning as pl
import torchmetrics
from pytorch_lightning.loggers import CSVLogger
from pytorch_lightning.callbacks import ModelCheckpoint
import tableprint as tp
```

```
/usr/local/lib/python3.7/dist-packages/pytorch_lightning/metrics/__init__.py:
  "`pytorch_lightning.metrics.*` module has been renamed to `torchmetrics.*`
```

```
# Manual Seed
SEED = 1234

random.seed(SEED)
np.random.seed(SEED)
torch.manual_seed(SEED)
torch.cuda.manual_seed(SEED)
torch.backends.cudnn.deterministic = True


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

Language Definitions

```
SRC_LANGUAGE = 'de'
TGT_LANGUAGE = 'en'

# Place-holders
token_transform = {}
vocab_transform = {}
```

Tokenizers

```
token_transform[SRC_LANGUAGE]  = get_tokenizer('spacy', language='de_core_news_sm'
token_transform[TGT_LANGUAGE] = get_tokenizer('spacy', language='en_core_web_sm')
```

Yield Function

This yields the tokens for the texts and will be used to build the vocab

```
def yield_tokens(data_iter: Iterable, language: str) -> List[str]:
    language_index = {SRC_LANGUAGE: 0, TGT_LANGUAGE: 1}

    for data_sample in data_iter:
        yield token_transform[language](data_sample[language_index[language]])
```

Special Tokens

```
# Define special symbols and indices
UNK_IDX, PAD_IDX, BOS_IDX, EOS_IDX = 0, 1, 2, 3
# Make sure the tokens are in order of their indices to properly insert them in vo
special_symbols = ['<unk>', '<pad>', '<bos>', '<eos>']
```

Build the vocab here

```
for ln in [SRC_LANGUAGE, TGT_LANGUAGE]:
  # Training data Iterator
  train_iter = Multi30k(split='train', language_pair=(SRC_LANGUAGE, TGT_LANGUAGE))
  # Create torchtext's Vocab object
  vocab_transform[ln] = build_vocab_from_iterator(yield_tokens(train_iter, ln),
                                                  min_freq=1,
                                                    specials=special_symbols,
                                                    special_first=True)
```

```
training.tar.gz: 100%|██████████| 1.21M/1.21M [00:00<00:00, 1.61MB/s]
```

Setting the default index as the token

```
# Set UNK_IDX as the default index. This index is returned when the token is not fo
# If not set, it throws RuntimeError when the queried token is not found in the Voc
for ln in [SRC_LANGUAGE, TGT_LANGUAGE]:
  vocab_transform[ln].set_default_index(UNK_IDX)
```

```
len(vocab_transform['de'])
```

```
19215
```

```
len(vocab_transform['en'])
```

```
10838
```

Collator

```
# helper function to club together sequential operations
def sequential_transforms(*transforms):
    def func(txt_input):
        for transform in transforms:
            txt_input = transform(txt_input)
        return txt_input
    return func

# function to add BOS/EOS and create tensor for input sequence indices
def tensor_transform(token_ids: List[int]):
    return torch.cat((torch.tensor([BOS_IDX]),
                      torch.tensor(token_ids),
                      torch.tensor([EOS_IDX])))

# src and tgt language text transforms to convert raw strings into tensors indices
text_transform = {}
for ln in [SRC_LANGUAGE, TGT_LANGUAGE]:
    text_transform[ln] = sequential_transforms(token_transform[ln], #Tokenization
                                               vocab_transform[ln], #Numericalizati
                                               tensor_transform) # Add BOS/EOS and
```

```
# function to collate data samples into batch tesors
def collate_fn(batch):
    src_batch, tgt_batch = [], []
    for src_sample, tgt_sample in batch:
        src_batch.append(text_transform[SRC_LANGUAGE](src_sample.rstrip("\n")))
        tgt_batch.append(text_transform[TGT_LANGUAGE](tgt_sample.rstrip("\n")))

    src_batch = pad_sequence(src_batch, padding_value=PAD_IDX)
    tgt_batch = pad_sequence(tgt_batch, padding_value=PAD_IDX)
    return src_batch, tgt_batch
```

DataLoader

```
BATCH_SIZE = 32
train_iter = Multi30k(split='train', language_pair=(SRC_LANGUAGE, TGT_LANGUAGE))
train_loader = DataLoader(train_iter, batch_size=BATCH_SIZE, collate_fn=collate_fn

val_iter = Multi30k(split='valid', language_pair=(SRC_LANGUAGE, TGT_LANGUAGE))
val_loader = DataLoader(val_iter, batch_size=BATCH_SIZE, collate_fn=collate_fn, nu

test_iter = Multi30k(split='test', language_pair=(SRC_LANGUAGE, TGT_LANGUAGE))
test_loader = DataLoader(test_iter, batch_size=BATCH_SIZE, collate_fn=collate_fn,
```

```
    validation.tar.gz: 100%|██████████| 46.3k/46.3k [00:00<00:00, 279kB/s]
    mmt16_task1_test.tar.gz: 100%|██████████| 43.9k/43.9k [00:00<00:00, 262kB/s]
```

Model

Boilerplate Code for PyTorch Lightning

```
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, trg = batch
        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, trg = batch
        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.sanity_checking:
          print('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', 'Tra
          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, dropout):
        super().__init__()

        self.hid_dim = hid_dim

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

    def forward(self, src):
        embedded = self.dropout(self.embedding(src))
        output, hidden = self.rnn(embedded)

        return hidden
```

Decoder

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

        self.hid_dim = hid_dim
        self.output_dim = output_dim
        self.embedding = nn.Embedding(output_dim, emb_dim)
        self.rnn = nn.GRU(emb_dim + hid_dim, hid_dim)
        self.fc_out = nn.Linear(emb_dim + hid_dim * 2, output_dim)
        self.dropout = nn.Dropout(dropout)

    def forward(self, input, hidden, context):
        input = input.unsqueeze(0)
        embedded = self.dropout(self.embedding(input))
        emb_con = torch.cat((embedded, context), dim = 2)
        output, hidden = self.rnn(emb_con, hidden)
        output = torch.cat((embedded.squeeze(0), hidden.squeeze(0), context.squeeze
        prediction = self.fc_out(output)
        return prediction, hidden
```

Seq2Seq Model

```
# Define the model

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

        self.loss = nn.CrossEntropyLoss(ignore_index=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

    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)

        context = self.encoder(src)
        hidden = context

        input = trg[0,:]

        for t in range(1, trg_len):

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

            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
```

Model Initialization and Summary

```
INPUT_DIM = len(vocab_transform[SRC_LANGUAGE])
OUTPUT_DIM = len(vocab_transform[TGT_LANGUAGE])


ENC_EMB_DIM = 256
DEC_EMB_DIM = 256
HID_DIM = 512
ENC_DROPOUT = 0.5
DEC_DROPOUT = 0.5

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

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

Model Checkpoint

```
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_8', version=0)
trainer = pl.Trainer(max_epochs=20, num_sanity_val_steps=1, logger=csvlogger, gpus
trainer.fit(model, train_dataloader=train_loader, val_dataloaders=val_loader)
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          | 6.1 M
2 | decoder | Decoder          | 18.6 M
---------------------------------------------
24.7 M    Trainable params
0         Non-trainable params
24.7 M    Total params
98.916    Total estimated model params size (MB)
```

Validation sanity check: 0% 0/1 [10:53<?, ?it/s]

```
/usr/local/lib/python3.7/dist-packages/pytorch_lightning/utilities/data.py:42
  'Your `IterableDataset` has `__len__` defined.'
sanity check
```

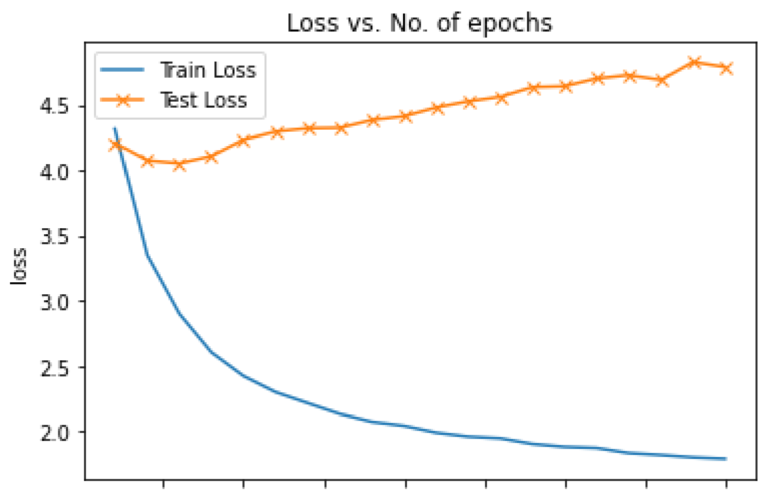
Epoch 19: 100% 939/939 [01:33<00:00, 10.06it/s, loss=1.77, v_num=0]

epoch	Train PPL	Train Loss	Valid PPL	Valid Loss
1	74.902	4.3162	67.223	4.208
2	28.447	3.3481	58.845	4.0749
3	18.158	2.8991	57.574	4.0531
4	13.507	2.6032	60.827	4.108
5	11.272	2.4223	68.96	4.2335
6	9.9687	2.2994	73.399	4.2959
7	9.1678	2.2157	75.213	4.3203
8	8.4415	2.1332	75.475	4.3238
9	7.9434	2.0723	80.1	4.3833
10	7.7005	2.0413	82.483	4.4126
11	7.3105	1.9893	88.19	4.4795
12	7.0949	1.9594	92.416	4.5263
13	7.0039	1.9465	95.617	4.5604
14	6.7083	1.9033	103.06	4.6353
15	6.5609	1.8811	103.76	4.642
16	6.5058	1.8727	110.09	4.7013
20	5.9891	1.7899	120.28	4.7898

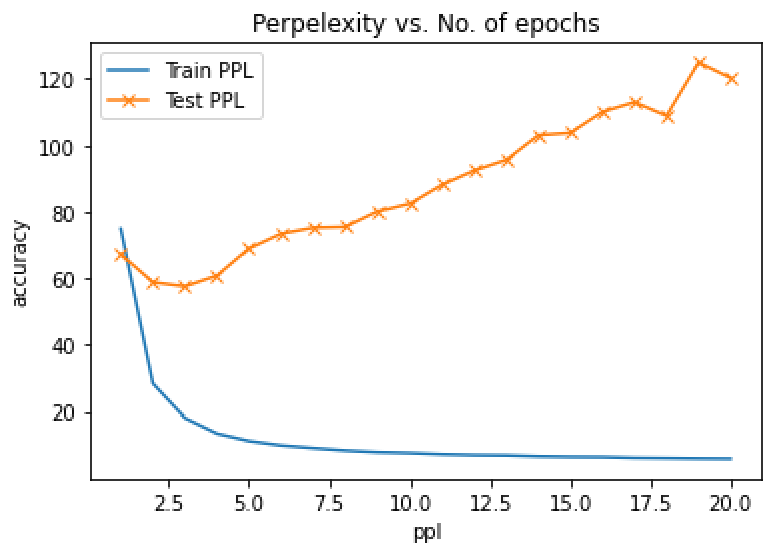
Training Log

```
root='./csv_logs/' + 'END2_Assign_8' + '/'
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');
```



Inference on Random Samples from Test Data

```
model.to(device)
model.eval()
```

```
    Seq2Seq(
      (loss): CrossEntropyLoss()
      (encoder): Encoder(
        (embedding): Embedding(19215, 256)
        (rnn): GRU(256, 512)
        (dropout): Dropout(p=0.5, inplace=False)
      )
      (decoder): Decoder(
        (embedding): Embedding(10838, 256)
        (rnn): GRU(768, 512)
        (fc_out): Linear(in_features=1280, out_features=10838, bias=True)
        (dropout): Dropout(p=0.5, inplace=False)
        )
      )
```

```
for i in np.random.randint(0,32, 10):
  src_sent_i = next(iter(test_loader))[0][:,i]
  trg_sent_i = next(iter(test_loader))[1][:,i]
  stop_ind_src = (src_sent_i==3).nonzero()[0].item() # stop when <eos> token is fou
  stop_ind_trg = (trg_sent_i==3).nonzero()[0].item() # stop when <eos> token is fou
  src_sent_tok = [vocab_transform['de'].lookup_token(word_i) for word_i in src_sent
  trg_sent_tok = [vocab_transform['en'].lookup_token(word_i) for word_i in trg_sent
  src_sent = " ".join(src_sent_tok[1:]) # skip the initial <bos> token
  trg_sent = " ".join(trg_sent_tok[1:]) # skip the initial <bos> token
  src_sent_tensor = src_sent_i.clone().detach().unsqueeze(1).to(device)
  trg_sent_tensor = trg_sent_i.clone().detach().unsqueeze(1).to(device)
  with torch.no_grad():
        output = model(src_sent_tensor, trg_sent_tensor, 1)
        out = output.squeeze(1)
        out = torch.argmax(out,dim=1)
        stop_ind_pred = (out==3).nonzero()[0].item() # stop when <eos> token is fou
        trans = []
        pred_sent_tok = [vocab_transform['en'].lookup_token(word_i) for word_i in o
        pred_sent = " ".join(pred_sent_tok[1:stop_ind_pred])
        start = "\033[1m"
        end = "\033[0;0m"
        print(f'{start}Source Sentence: {end}{src_sent}')
        print(f'{start}Target Sentence: {end}{trg_sent}')
        print(f'{start}Translated Sentence: {end}{pred_sent}')
        print()
```

```
Source Sentence: Ein Mädchen in einem Jeanskleid läuft über einen erhöhten Sc
Target Sentence: A girl in a jean dress is walking along a raised balance bea
Translated Sentence: A girl in a a walks walks walking across a fence . . .

Source Sentence: Zwei Männer tun so als seien sie Statuen , während Frauen ih
Target Sentence: Two men pretend to be <unk> while women look on .
Translated Sentence: Two men are as as preparing as preparing look on them

Source Sentence: Eine Gruppe von Menschen steht vor einem Iglu .
Target Sentence: A group of people standing in front of an igloo .
Translated Sentence: A group of people standing in front of a airport .

Source Sentence: Eine Teenagerin spielt bei einem Spiel Trompete auf dem Feld
Target Sentence: A teenager plays her trumpet on the field at a game .
Translated Sentence: A soccer game soccer game game a field . a game game

Source Sentence: Eine Frau , die in einer Küche eine Schale mit Essen hält .
Target Sentence: A woman holding a bowl of food in a kitchen .
Translated Sentence: A woman is a food of food . a kitchen .

Source Sentence: Leute , die vor einem Gebäude stehen .
Target Sentence: People standing outside of a building .
Translated Sentence: People standing outside front building building .

Source Sentence: Eine Frau verwendet eine Bohrmaschine während ein Mann sie f
Target Sentence: A woman uses a drill while another man takes her picture .
Translated Sentence: A woman is a picture while a man takes photographs pictu
```

```
Source Sentence: Eine Frau in einem pinken Pulli und einer Schürze putzt eine
Target Sentence: A woman in a pink sweater and an apron , cleaning a table wi
Translated Sentence: A woman in a apron apron and apron apron is is a table w

Source Sentence: Ein Mädchen in einem Jeanskleid läuft über einen erhöhten Sc
Target Sentence: A girl in a jean dress is walking along a raised balance bea
Translated Sentence: A girl in a a walks walks walking across a fence . . .

Source Sentence: Eine Frau in einem <unk> Pulli und mit einer schwarzen Baseb
Target Sentence: A woman in a gray sweater and black baseball cap is standing
Translated Sentence: A woman in a black winter and black apron cap stands sta
```

✓ 1s completed at 8:46 AM