

SageMaker Project

July 8, 2020

1 Creating a Sentiment Analysis Web App

1.1 Using PyTorch and SageMaker

Deep Learning Nanodegree Program | Deployment

Now that we have a basic understanding of how SageMaker works we will try to use it to construct a complete project from end to end. Our goal will be to have a simple web page which a user can use to enter a movie review. The web page will then send the review off to our deployed model which will predict the sentiment of the entered review.

1.2 Instructions

Some template code has already been provided for you, and you will need to implement additional functionality to successfully complete this notebook. You will not need to modify the included code beyond what is requested. Sections that begin with '**TODO**' in the header indicate that you need to complete or implement some portion within them. Instructions will be provided for each section and the specifics of the implementation are marked in the code block with a # **TODO**: ... comment. Please be sure to read the instructions carefully!

In addition to implementing code, there will be questions for you to answer which relate to the task and your implementation. Each section where you will answer a question is preceded by a '**Question:**' header. Carefully read each question and provide your answer below the '**Answer:**' header by editing the Markdown cell.

Note: Code and Markdown cells can be executed using the **Shift+Enter** keyboard shortcut. In addition, a cell can be edited by typically clicking it (double-click for Markdown cells) or by pressing **Enter** while it is highlighted.

1.3 General Outline

Recall the general outline for SageMaker projects using a notebook instance.

1. Download or otherwise retrieve the data.
2. Process / Prepare the data.
3. Upload the processed data to S3.
4. Train a chosen model.

5. Test the trained model (typically using a batch transform job).
6. Deploy the trained model.
7. Use the deployed model.

For this project, you will be following the steps in the general outline with some modifications.

First, you will not be testing the model in its own step. You will still be testing the model, however, you will do it by deploying your model and then using the deployed model by sending the test data to it. One of the reasons for doing this is so that you can make sure that your deployed model is working correctly before moving forward.

In addition, you will deploy and use your trained model a second time. In the second iteration you will customize the way that your trained model is deployed by including some of your own code. In addition, your newly deployed model will be used in the sentiment analysis web app.

1.4 Step 1: Downloading the data

As in the XGBoost in SageMaker notebook, we will be using the [IMDb dataset](#)

Maas, Andrew L., et al. [Learning Word Vectors for Sentiment Analysis](#). In *Proceedings of the 49th Annual Meeting of the Association for Computational Linguistics: Human Language Technologies*. Association for Computational Linguistics, 2011.

```
[ ]: %mkdir ../data
!wget -O ../data/aclImdb_v1.tar.gz http://ai.stanford.edu/~amaas/data/sentiment/
→aclImdb_v1.tar.gz
!tar -zxvf ../data/aclImdb_v1.tar.gz -C ../data
```

```
mkdir: cannot create directory ../data: File exists
--2020-07-07 10:11:52--
http://ai.stanford.edu/~amaas/data/sentiment/aclImdb_v1.tar.gz
Resolving ai.stanford.edu (ai.stanford.edu)... 171.64.68.10
Connecting to ai.stanford.edu (ai.stanford.edu)|171.64.68.10|:80... connected.
HTTP request sent, awaiting response... 200 OK
Length: 84125825 (80M) [application/x-gzip]
Saving to: ../data/aclImdb_v1.tar.gz

../data/aclImdb_v1. 100%[=====>] 80.23M 23.4MB/s in 3.9s

2020-07-07 10:11:57 (20.5 MB/s) - ../data/aclImdb_v1.tar.gz saved
[84125825/84125825]
```

1.5 Step 2: Preparing and Processing the data

Also, as in the XGBoost notebook, we will be doing some initial data processing. The first few steps are the same as in the XGBoost example. To begin with, we will read in each of the reviews and combine them into a single input structure. Then, we will split the dataset into a training set and a testing set.

```
[2]: import os
import glob

def read_imdb_data(data_dir='../data/aclImdb'):
    data = {}
    labels = {}

    for data_type in ['train', 'test']:
        data[data_type] = {}
        labels[data_type] = {}

        for sentiment in ['pos', 'neg']:
            data[data_type][sentiment] = []
            labels[data_type][sentiment] = []

            path = os.path.join(data_dir, data_type, sentiment, '*.txt')
            files = glob.glob(path)

            for f in files:
                with open(f) as review:
                    data[data_type][sentiment].append(review.read())
                    # Here we represent a positive review by '1' and a negative
→review by '0'
                    labels[data_type][sentiment].append(1 if sentiment == 'pos'
→else 0)

            assert len(data[data_type][sentiment]) ==
→len(labels[data_type][sentiment]), \
                "{}/{ } data size does not match labels size".
→format(data_type, sentiment)

    return data, labels
```

```
[3]: data, labels = read_imdb_data()
print("IMDB reviews: train = { } pos / { } neg, test = { } pos / { } neg".format(
    len(data['train']['pos']), len(data['train']['neg']),
    len(data['test']['pos']), len(data['test']['neg'])))
```

IMDB reviews: train = 12500 pos / 12500 neg, test = 12500 pos / 12500 neg

Now that we've read the raw training and testing data from the downloaded dataset, we will combine the positive and negative reviews and shuffle the resulting records.

```
[4]: from sklearn.utils import shuffle

def prepare_imdb_data(data, labels):
    """Prepare training and test sets from IMDB movie reviews."""
```

```

#Combine positive and negative reviews and labels
data_train = data['train']['pos'] + data['train']['neg']
data_test = data['test']['pos'] + data['test']['neg']
labels_train = labels['train']['pos'] + labels['train']['neg']
labels_test = labels['test']['pos'] + labels['test']['neg']

#Shuffle reviews and corresponding labels within training and test sets
data_train, labels_train = shuffle(data_train, labels_train)
data_test, labels_test = shuffle(data_test, labels_test)

# Return a unified training data, test data, training labels, test labels
return data_train, data_test, labels_train, labels_test

```

```

[5]: train_X, test_X, train_y, test_y = prepare_imdb_data(data, labels)
print("IMDb reviews (combined): train = {}, test = {}".format(len(train_X),
→len(test_X)))

```

IMDb reviews (combined): train = 25000, test = 25000

Now that we have our training and testing sets unified and prepared, we should do a quick check and see an example of the data our model will be trained on. This is generally a good idea as it allows you to see how each of the further processing steps affects the reviews and it also ensures that the data has been loaded correctly.

```

[6]: print(train_X[100])
print(train_y[100])

```

I never watched the 'Next Action Hero' show, and until reading the other comments here, did not know that this movie was the 'prize' from that competition. I was just flipping channels and came across this, and found myself watching, dare eagerly, all the way to the end.

Yes, the plot's been done (The Most Dangerous Game, etc.) but I was hoping for, and almost received, the 'gotcha' - how the protagonist was going to beat the hunter in the end. I think the high-tech was overdone (GPS's) and gave me cold-sweat flashbacks of Night Rider, but it nevertheless was not too overdone.

The basic problem I had with this movie was the degree of SOD (Suspension of Disbelief) that was required of the viewer. Do we really think that someone flying in a helicopter could lob countless incendiary grenades at a public bridge and NO COPS show up to investigate? Could a limousine do countless donuts in a Las Vegas intersection and NO COPS show up? Pleeese. Way too much of that type of thing - fun to watch, but keep it at least plausible, thank you very much.

The final solution was good, but the ending was disappointing, with the after taste of a bad Star Trek episode. At least now I understand why the acting was so cheesy - except for Zane, who doesn't get near as much work as he deserves IMHO - they were winners from a reality show.

Knock me out.

1

The first step in processing the reviews is to make sure that any html tags that appear should be removed. In addition we wish to tokenize our input, that way words such as *entertained* and *entertaining* are considered the same with regard to sentiment analysis.

```
[7]: import nltk
from nltk.corpus import stopwords
from nltk.stem.porter import *

import re
from bs4 import BeautifulSoup

def review_to_words(review):
    nltk.download("stopwords", quiet=True)
    stemmer = PorterStemmer()

    text = BeautifulSoup(review, "html.parser").get_text() # Remove HTML tags
    text = re.sub(r"[^a-zA-Z0-9]", " ", text.lower()) # Convert to lower case
    words = text.split() # Split string into words
    words = [w for w in words if w not in stopwords.words("english")] # Remove stopwords
    words = [PorterStemmer().stem(w) for w in words] # stem

    return words
```

The `review_to_words` method defined above uses BeautifulSoup to remove any html tags that appear and uses the nltk package to tokenize the reviews. As a check to ensure we know how everything is working, try applying `review_to_words` to one of the reviews in the training set.

```
[8]: # TODO: Apply review_to_words to a review (train_X[100] or any other review)
review = train_X[100]
review_to_words(review)
```

```
[8]: ['never',
      'watch',
      'next',
      'action',
      'hero',
      'show',
      'read',
      'comment',
      'know',
      'movi',
      'prize',
      'competit',
      'flip',
      'channel',
      'came',
      'across',
      'found',
      'watch',
      'dare',
      'eagerli',
```

'way',
'end',
'ye',
'plot',
'done',
'danger',
'game',
'etc',
'hope',
'almost',
'receiv',
'gotcha',
'protagonist',
'go',
'beat',
'hunter',
'end',
'think',
'high',
'tech',
'overdon',
'gp',
'gave',
'cold',
'sweat',
'flashback',
'night',
'rider',
'nevertheless',
'overdon',
'basic',
'problem',
'movi',
'degre',
'sod',
'suspens',
'disbelief',
'requir',
'viewer',
'realli',
'think',
'someone',
'fli',
'helicopt',
'could',
'lob',
'countless',

'incendiari',
'grenad',
'public',
'bridg',
'cop',
'show',
'investig',
'could',
'limousin',
'countless',
'donut',
'la',
'vega',
'intersect',
'cop',
'show',
'pleeeas',
'way',
'much',
'type',
'thing',
'fun',
'watch',
'keep',
'least',
'plausibl',
'thank',
'much',
'final',
'solut',
'good',
'end',
'disappoint',
'tast',
'bad',
'star',
'trek',
'episod',
'least',
'understand',
'act',
'cheesi',
'except',
'zane',
'get',
'near',
'much',

```
'work',  
'deserv',  
'imho',  
'winner',  
'realiti',  
'show',  
'knock']
```

Question: Above we mentioned that `review_to_words` method removes html formatting and allows us to tokenize the words found in a review, for example, converting *entertained* and *entertaining* into *entertain* so that they are treated as though they are the same word. What else, if anything, does this method do to the input?

Answer:

The method below applies the `review_to_words` method to each of the reviews in the training and testing datasets. In addition it caches the results. This is because performing this processing step can take a long time. This way if you are unable to complete the notebook in the current session, you can come back without needing to process the data a second time.

```
[9]: import pickle  
  
cache_dir = os.path.join("../cache", "sentiment_analysis") # where to store  
→ cache files  
os.makedirs(cache_dir, exist_ok=True) # ensure cache directory exists  
  
def preprocess_data(data_train, data_test, labels_train, labels_test,  
                    cache_dir=cache_dir, cache_file="preprocessed_data.pkl"):  
    """Convert each review to words; read from cache if available."""  
  
    # If cache_file is not None, try to read from it first  
    cache_data = None  
    if cache_file is not None:  
        try:  
            with open(os.path.join(cache_dir, cache_file), "rb") as f:  
                cache_data = pickle.load(f)  
            print("Read preprocessed data from cache file:", cache_file)  
        except:  
            pass # unable to read from cache, but that's okay  
  
    # If cache is missing, then do the heavy lifting  
    if cache_data is None:  
        # Preprocess training and test data to obtain words for each review  
        # words_train = list(map(review_to_words, data_train))  
        # words_test = list(map(review_to_words, data_test))  
        words_train = [review_to_words(review) for review in data_train]  
        words_test = [review_to_words(review) for review in data_test]  
  
        # Write to cache file for future runs  
        if cache_file is not None:
```



```

        cache_data = dict(words_train=words_train, words_test=words_test,
                           labels_train=labels_train,
→labels_test=labels_test)
        with open(os.path.join(cache_dir, cache_file), "wb") as f:
            pickle.dump(cache_data, f)
        print("Wrote preprocessed data to cache file:", cache_file)
    else:
        # Unpack data loaded from cache file
        words_train, words_test, labels_train, labels_test =
→(cache_data['words_train'],
        cache_data['words_test'], cache_data['labels_train'],
→cache_data['labels_test'])

    return words_train, words_test, labels_train, labels_test

```

```

[10]: # Preprocess data
train_X, test_X, train_y, test_y = preprocess_data(train_X, test_X, train_y,
→test_y)

```

Read preprocessed data from cache file: preprocessed_data.pkl

1.6 Transform the data

In the XGBoost notebook we transformed the data from its word representation to a bag-of-words feature representation. For the model we are going to construct in this notebook we will construct a feature representation which is very similar. To start, we will represent each word as an integer. Of course, some of the words that appear in the reviews occur very infrequently and so likely don't contain much information for the purposes of sentiment analysis. The way we will deal with this problem is that we will fix the size of our working vocabulary and we will only include the words that appear most frequently. We will then combine all of the infrequent words into a single category and, in our case, we will label it as 1.

Since we will be using a recurrent neural network, it will be convenient if the length of each review is the same. To do this, we will fix a size for our reviews and then pad short reviews with the category 'no word' (which we will label 0) and truncate long reviews.

1.6.1 (TODO) Create a word dictionary

To begin with, we need to construct a way to map words that appear in the reviews to integers. Here we fix the size of our vocabulary (including the 'no word' and 'infrequent' categories) to be 5000 but you may wish to change this to see how it affects the model.

TODO: Complete the implementation for the `build_dict()` method below. Note that even though the `vocab_size` is set to 5000, we only want to construct a mapping for the most frequently appearing 4998 words. This is because we want to reserve the special labels 0 for 'no word' and 1 for 'infrequent word'.

```

[11]: #train_X[:1]
def word_counter(data):

```

```

#flatten all words in single list
flat = [words for reviews in data for words in reviews]
# A dict storing the words that appear in the reviews along with how often
→they occur
word_count = Counter(flat)
return word_count

```

```

[12]: import numpy as np

from collections import Counter
def build_dict(data, vocab_size = 5000):
    """Construct and return a dictionary mapping each of the most frequently
    →appearing words to a unique integer."""

    # TODO: Determine how often each word appears in `data`. Note that `data`
    →is a list of sentences and that a
    #         sentence is a list of words.

    word_count = word_counter(data)

    #Sort the words found in `data` so that sorted_words[0] is the most
    →frequently appearing word and
    #sorted_words[-1] is the least frequently appearing word.

    #sort the counter and convert to dict
    sorted_words = dict(word_count.most_common())
    sorted_words = list(sorted_words.keys())

    word_dict = {} # This is what we are building, a dictionary that translates
    →words into integers
    for idx, word in enumerate(sorted_words[:vocab_size - 2]): # The -2 is so
    →that we save room for the 'no word'
        word_dict[word] = idx + 2 # 'infrequent'
    →labels

    return word_dict

```

```

[13]: word_dict = build_dict(train_X)

```

```

[14]: print(word_dict)

```

```

{'movi': 2, 'film': 3, 'one': 4, 'like': 5, 'time': 6, 'good': 7, 'make': 8,
'charact': 9, 'get': 10, 'see': 11, 'watch': 12, 'stori': 13, 'even': 14,
'would': 15, 'realli': 16, 'well': 17, 'scene': 18, 'look': 19, 'show': 20,
'much': 21, 'end': 22, 'peopl': 23, 'bad': 24, 'go': 25, 'great': 26, 'also':
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'made': 34, 'thing': 35, 'could': 36, 'know': 37, 'say': 38, 'seem': 39, 'work':
40, 'plot': 41, 'two': 42, 'actor': 43, 'year': 44, 'come': 45, 'mani': 46,

```

'seen': 47, 'take': 48, 'want': 49, 'life': 50, 'never': 51, 'littl': 52,
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```

Question: What are the five most frequently appearing (tokenized) words in the training set? Does it makes sense that these words appear frequently in the training set?

Answer:

```
[15]: # TODO: Use this space to determine the five most frequently appearing words in
      ↪ the training set.
word_count = word_counter(train_X)
most_words = dict(word_count.most_common(5))
print("The five most frequently appearing words in the training set are:\n ",
      ↪ most_words)
```

The five most frequently appearing words in the training set are:

```
{'movi': 51695, 'film': 48190, 'one': 27741, 'like': 22799, 'time': 16191}
```

1.6.2 Save word_dict

Later on when we construct an endpoint which processes a submitted review we will need to make use of the word_dict which we have created. As such, we will save it to a file now for future use.

```
[16]: data_dir = '../data/pytorch' # The folder we will use for storing data
      if not os.path.exists(data_dir): # Make sure that the folder exists
          os.makedirs(data_dir)
```

```
[17]: with open(os.path.join(data_dir, 'word_dict.pkl'), "wb") as f:
      pickle.dump(word_dict, f)
```

1.6.3 Transform the reviews

Now that we have our word dictionary which allows us to transform the words appearing in the reviews into integers, it is time to make use of it and convert our reviews to their integer sequence representation, making sure to pad or truncate to a fixed length, which in our case is 500.

```
[18]: def convert_and_pad(word_dict, sentence, pad=500):
        NOWORD = 0 # We will use 0 to represent the 'no word' category
        INFREQ = 1 # and we use 1 to represent the infrequent words, i.e., words
        ↪not appearing in word_dict

        working_sentence = [NOWORD] * pad

        for word_index, word in enumerate(sentence[:pad]):
            if word in word_dict:
                working_sentence[word_index] = word_dict[word]
            else:
                working_sentence[word_index] = INFREQ

        return working_sentence, min(len(sentence), pad)

def convert_and_pad_data(word_dict, data, pad=500):
    result = []
    lengths = []

    for sentence in data:
        converted, leng = convert_and_pad(word_dict, sentence, pad)
        result.append(converted)
        lengths.append(leng)

    return np.array(result), np.array(lengths)

[19]: train_X, train_X_len = convert_and_pad_data(word_dict, train_X)
    test_X, test_X_len = convert_and_pad_data(word_dict, test_X)
```

As a quick check to make sure that things are working as intended, check to see what one of the reviews in the training set looks like after having been processed. Does this look reasonable? What is the length of a review in the training set?

```
[20]: # Use this cell to examine one of the processed reviews to make sure everything
        ↪is working as intended.
    train_X[:20]

[20]: array([[ 173,  259,  236, ...,  0,  0,  0],
           [   4, 1723,  267, ...,  0,  0,  0],
           [ 443,   44,  536, ...,  0,  0,  0],
           ...,
           [ 249,  618,   18, ...,  0,  0,  0],
           [3416,    1,    1, ...,  0,  0,  0],
           [ 385,  581,   52, ...,  0,  0,  0]])
```


Question: In the cells above we use the `preprocess_data` and `convert_and_pad_data` methods to process both the training and testing set. Why or why not might this be a problem?

Answer:

The `preprocess_data` method applies the `review_to_words` method to each of the reviews in the training and testing datasets. The `convert_and_pad_data` process by fixing the length, which in our case is 500. The first will taking time, but the second one can miss some information.

1.7 Step 3: Upload the data to S3

As in the XGBoost notebook, we will need to upload the training dataset to S3 in order for our training code to access it. For now we will save it locally and we will upload to S3 later on.

1.7.1 Save the processed training dataset locally

It is important to note the format of the data that we are saving as we will need to know it when we write the training code. In our case, each row of the dataset has the form `label, length, review[500]` where `review[500]` is a sequence of 500 integers representing the words in the review.

```
[21]: import pandas as pd

pd.concat([pd.DataFrame(train_y), pd.DataFrame(train_X_len), pd.
↳ DataFrame(train_X)], axis=1) \
    .to_csv(os.path.join(data_dir, 'train.csv'), header=False, index=False)
```

1.7.2 Uploading the training data

Next, we need to upload the training data to the SageMaker default S3 bucket so that we can provide access to it while training our model.

```
[22]: import sagemaker

sagemaker_session = sagemaker.Session()

bucket = sagemaker_session.default_bucket()
prefix = 'sagemaker/sentiment_rnn'

role = sagemaker.get_execution_role()

[23]: input_data = sagemaker_session.upload_data(path=data_dir, bucket=bucket,
↳ key_prefix=prefix)
```

NOTE: The cell above uploads the entire contents of our data directory. This includes the `word_dict.pkl` file. This is fortunate as we will need this later on when we create an endpoint that accepts an arbitrary review. For now, we will just take note of the fact that it resides in the data directory (and so also in the S3 training bucket) and that we will need to make sure it gets saved in the model directory.

1.8 Step 4: Build and Train the PyTorch Model

In the XGBoost notebook we discussed what a model is in the SageMaker framework. In particular, a model comprises three objects

- Model Artifacts,
- Training Code, and
- Inference Code,

each of which interact with one another. In the XGBoost example we used training and inference code that was provided by Amazon. Here we will still be using containers provided by Amazon with the added benefit of being able to include our own custom code.

We will start by implementing our own neural network in PyTorch along with a training script. For the purposes of this project we have provided the necessary model object in the `model.py` file, inside of the `train` folder. You can see the provided implementation by running the cell below.

```
[24]: !pygmentize train/model.py
```

```
import
torch.nn
as nn

class LSTMClassifier(nn.Module):
    """
    This is the simple RNN model we will be using to perform Sentiment
    Analysis.
    """

    def __init__(self,
embedding_dim, hidden_dim, vocab_size):
        """
        Initialize the model by setting up the various layers.
        """
        super(LSTMClassifier,
self).__init__()

        self.embedding = nn.Embedding(vocab_size, embedding_dim,
padding_idx=0)
        self.lstm = nn.LSTM(embedding_dim, hidden_dim)
        self.dense = nn.Linear(in_features=hidden_dim,
out_features=1)
        self.sig = nn.Sigmoid()

        self.word_dict = None

    def forward(self, x):
        """
        Perform a forward pass of our model on some input.
        """
```

```

x = x.t()
lengths = x[0,:]
reviews = x[1,:]
embeds = self.embedding(reviews)
lstm_out, _ = self.lstm(embeds)
out = self.dense(lstm_out)
out = out[lengths - 1,
range(len(lengths))]
return self.sig(out.squeeze())

```

The important takeaway from the implementation provided is that there are three parameters that we may wish to tweak to improve the performance of our model. These are the embedding dimension, the hidden dimension and the size of the vocabulary. We will likely want to make these parameters configurable in the training script so that if we wish to modify them we do not need to modify the script itself. We will see how to do this later on. To start we will write some of the training code in the notebook so that we can more easily diagnose any issues that arise.

First we will load a small portion of the training data set to use as a sample. It would be very time consuming to try and train the model completely in the notebook as we do not have access to a gpu and the compute instance that we are using is not particularly powerful. However, we can work on a small bit of the data to get a feel for how our training script is behaving.

```

[25]: import torch
import torch.utils.data

# Read in only the first 250 rows
train_sample = pd.read_csv(os.path.join(data_dir, 'train.csv'), header=None,
names=None, nrows=250)

# Turn the input pandas dataframe into tensors
train_sample_y = torch.from_numpy(train_sample[[0]].values).float().squeeze()
train_sample_X = torch.from_numpy(train_sample.drop([0], axis=1).values).long()

# Build the dataset
train_sample_ds = torch.utils.data.TensorDataset(train_sample_X, train_sample_y)
# Build the dataloader
train_sample_dl = torch.utils.data.DataLoader(train_sample_ds, batch_size=50)

```

1.8.1 (TODO) Writing the training method

Next we need to write the training code itself. This should be very similar to training methods that you have written before to train PyTorch models. We will leave any difficult aspects such as model saving / loading and parameter loading until a little later.

```

[26]: def train(model, train_loader, epochs, optimizer, loss_fn, device):
    for epoch in range(1, epochs + 1):
        model.train()
        total_loss = 0
        for batch in train_loader:
            batch_X, batch_y = batch

```

```

        batch_X = batch_X.to(device)
        batch_y = batch_y.to(device)

        # TODO: Complete this train method to train the model provided.
        optimizer.zero_grad()
        output = model.forward(batch_X)
        loss = loss_fn(output, batch_y)
        loss.backward()
        optimizer.step()
        total_loss += loss.data.item()
        print("Epoch: {}, BCELoss: {}".format(epoch, total_loss /
        →len(train_loader)))

```

Supposing we have the training method above, we will test that it is working by writing a bit of code in the notebook that executes our training method on the small sample training set that we loaded earlier. The reason for doing this in the notebook is so that we have an opportunity to fix any errors that arise early when they are easier to diagnose.

```

[27]: import torch.optim as optim
      from train.model import LSTMClassifier

      device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
      model = LSTMClassifier(32, 100, 5000).to(device)
      optimizer = optim.Adam(model.parameters())
      loss_fn = torch.nn.BCELoss()

      train(model, train_sample_dl, 5, optimizer, loss_fn, device)

```

```

Epoch: 1, BCELoss: 0.6971158146858215
Epoch: 2, BCELoss: 0.6852663993835449
Epoch: 3, BCELoss: 0.6755394220352173
Epoch: 4, BCELoss: 0.665908932685852
Epoch: 5, BCELoss: 0.6556065559387207

```

In order to construct a PyTorch model using SageMaker we must provide SageMaker with a training script. We may optionally include a directory which will be copied to the container and from which our training code will be run. When the training container is executed it will check the uploaded directory (if there is one) for a `requirements.txt` file and install any required Python libraries, after which the training script will be run.

1.8.2 (TODO) Training the model

When a PyTorch model is constructed in SageMaker, an entry point must be specified. This is the Python file which will be executed when the model is trained. Inside of the `train` directory is a file called `train.py` which has been provided and which contains most of the necessary code to train our model. The only thing that is missing is the implementation of the `train()` method which you wrote earlier in this notebook.

TODO: Copy the `train()` method written above and paste it into the `train/train.py` file where required.

The way that SageMaker passes hyperparameters to the training script is by way of arguments. These arguments can then be parsed and used in the training script. To see how this is done take a look at the provided `train/train.py` file.

```
[28]: from sagemaker.pytorch import PyTorch

estimator = PyTorch(entry_point="train.py",
                    source_dir="train",
                    role=role,
                    framework_version='0.4.0',
                    train_instance_count=1,
                    train_instance_type='ml.p2.xlarge',
                    hyperparameters={
                        'epochs': 10,
                        'hidden_dim': 200,
                    })
```

```
[29]: estimator.fit({'training': input_data})
```

'create_image_uri' will be deprecated in favor of 'ImageURIProvider' class in SageMaker Python SDK v2.

's3_input' class will be renamed to 'TrainingInput' in SageMaker Python SDK v2.

'create_image_uri' will be deprecated in favor of 'ImageURIProvider' class in SageMaker Python SDK v2.

2020-07-07 10:14:59 Starting - Starting the training job...

2020-07-07 10:15:00 Starting - Launching requested ML instances...

2020-07-07 10:16:06 Starting - Preparing the instances for training...

2020-07-07 10:17:27 Downloading - Downloading input data...

2020-07-07 10:18:04 Training - Downloading the training image..`bash: cannot set terminal process group (-1): Inappropriate ioctl for device`

`bash: no job control in this shell`

2020-07-07 10:18:35,484 sagemaker-containers INFO Imported framework
`sagemaker_pytorch_container.training`

2020-07-07 10:18:35,508 sagemaker_pytorch_container.training INFO Block
until all host DNS lookups succeed.

2020-07-07 10:18:36,927 sagemaker_pytorch_container.training INFO
Invoking user training script.

2020-07-07 10:18:37,157 sagemaker-containers INFO Module train does not
provide a `setup.py`.

Generating `setup.py`

2020-07-07 10:18:37,157 sagemaker-containers INFO Generating
`setup.cfg`

2020-07-07 10:18:37,158 sagemaker-containers INFO Generating
`MANIFEST.in`

2020-07-07 10:18:37,158 sagemaker-containers INFO Installing module
with the following command:

```

/usr/bin/python -m pip install -U . -r requirements.txt
Processing /opt/ml/code
Collecting pandas (from -r requirements.txt (line 1))
  Downloading https://files.pythonhosted.org/packages/74/24/0cdbf8907e1e3bc5a8da03345c23cbcd7044330bb8f73bb12e711a640a00/pandas-0.24.2-cp35-cp35m-manylinux1_x86_64.whl (10.0MB)
Collecting numpy (from -r requirements.txt (line 2))
  Downloading https://files.pythonhosted.org/packages/b5/36/88723426b4ff576809fec7d73594fe17a35c27f8d01f93637637a29ae25b/numpy-1.18.5-cp35-cp35m-manylinux1_x86_64.whl (19.9MB)
Collecting nltk (from -r requirements.txt (line 3))
  Downloading https://files.pythonhosted.org/packages/92/75/ce35194d8e3022203cca0d2f896dbb88689f9b3fce8e9f9cff942913519d/nltk-3.5.zip (1.4MB)
Collecting beautifulsoup4 (from -r requirements.txt (line 4))
  Downloading https://files.pythonhosted.org/packages/66/25/ff030e2437265616a1e9b25ccc864e0371a0bc3adb7c5a404fd661c6f4f6/beautifulsoup4-4.9.1-py3-none-any.whl (115kB)
Collecting html5lib (from -r requirements.txt (line 5))
  Downloading https://files.pythonhosted.org/packages/6c/dd/a834df6482147d48e225a49515aabc28974ad5a4ca3215c18a882565b028/html5lib-1.1-py2.py3-none-any.whl (112kB)
Collecting pytz>=2011k (from pandas->-r requirements.txt (line 1))
  Downloading https://files.pythonhosted.org/packages/4f/a4/879454d49688e2fad93e59d7d4efda580b783c745fd2ec2a3adf87b0808d/pytz-2020.1-py2.py3-none-any.whl (510kB)
Requirement already satisfied, skipping upgrade: python-dateutil>=2.5.0 in /usr/local/lib/python3.5/dist-packages (from pandas->-r requirements.txt (line 1)) (2.7.5)
Requirement already satisfied, skipping upgrade: click in /usr/local/lib/python3.5/dist-packages (from nltk->-r requirements.txt (line 3)) (7.0)
Collecting joblib (from nltk->-r requirements.txt (line 3))
  Downloading https://files.pythonhosted.org/packages/28/5c/cf6a2b65a321c4a209efcdf64c2689efae2cb62661f8f6f4bb28547cf1bf/joblib-0.14.1-py2.py3-none-any.whl (294kB)
Collecting regex (from nltk->-r requirements.txt (line 3))
  Downloading https://files.pythonhosted.org/packages/b8/7b/01510a6229c2176425bda54d15fba05a4b3df169b87265b008480261d2f9/regex-2020.6.8.tar.gz (690kB)
Collecting tqdm (from nltk->-r requirements.txt (line 3))
  Downloading https://files.pythonhosted.org/packages/46/62/7663894f67ac5a41a0d8812d78d9d2a9404124051885af9d77dc526fb399/tqdm-4.47.0-py2.py3-none-any.whl (66kB)
Collecting soupsieve>1.2 (from beautifulsoup4->-r requirements.txt (line 4))
  Downloading https://files.pythonhosted.org/packages/6f/8f/457f4a5390eeae1cc3aeab89deb7724c965be841ffca6cfca9197482e470/soupsieve-2.0.1-py3-none-any.whl

```

```

Collecting webencodings (from html5lib->-r requirements.txt (line 5))
  Downloading https://files.pythonhosted.org/packages/f4/24/2a3e3df732393fed8b3e
bf2ec078f05546de641fe1b667ee316ec1dcf3b7/webencodings-0.5.1-py2.py3-none-
any.whl
Requirement already satisfied, skipping upgrade: six>=1.9 in
/usr/local/lib/python3.5/dist-packages (from html5lib->-r requirements.txt (line
5)) (1.11.0)
Building wheels for collected packages: nltk, train, regex
  Running setup.py bdist_wheel for nltk: started
  Running setup.py bdist_wheel for nltk: finished with status 'done'
  Stored in directory: /root/.cache/pip/wheels/ae/8c/3f/b1fe0ba04555b08b57ab52ab
7f86023639a526d8bc8d384306
  Running setup.py bdist_wheel for train: started
  Running setup.py bdist_wheel for train: finished with status 'done'
  Stored in directory: /tmp/pip-ephem-wheel-cache-e969t08r/wheels/35/24/16/37574
d11bf9bde50616c67372a334f94fa8356bc7164af8ca3
  Running setup.py bdist_wheel for regex: started

2020-07-07 10:18:34 Training - Training image download completed. Training in
progress.  Running setup.py bdist_wheel for regex: finished with status
'done'
  Stored in directory: /root/.cache/pip/wheels/9c/e2/cf/246ad8c87bcd3c3ba1ec95fa
89bc205c9037aa8f4d2e26fdad
Successfully built nltk train regex
Installing collected packages: numpy, pytz, pandas, joblib, regex, tqdm,
nltk, soupsieve, beautifulsoup4, webencodings, html5lib, train
  Found existing installation: numpy 1.15.4
  Uninstalling numpy-1.15.4:
    Successfully uninstalled numpy-1.15.4
Successfully installed beautifulsoup4-4.9.1 html5lib-1.1 joblib-0.14.1
nltk-3.5 numpy-1.18.5 pandas-0.24.2 pytz-2020.1 regex-2020.6.8 soupsieve-2.0.1
tqdm-4.47.0 train-1.0.0 webencodings-0.5.1
You are using pip version 18.1, however version 20.2b1 is available.
You should consider upgrading via the 'pip install --upgrade pip'
command.
2020-07-07 10:18:58,814 sagemaker-containers INFO      Invoking user script

```

Training Env:

```

{
  "input_data_config": {
    "training": {
      "S3DistributionType": "FullyReplicated",
      "RecordWrapperType": "None",
      "TrainingInputMode": "File"
    }
  },
  "output_data_dir": "/opt/ml/output/data",
  "current_host": "algo-1",
  "user_entry_point": "train.py",
  "input_dir": "/opt/ml/input",
  "output_intermediate_dir": "/opt/ml/output/intermediate",
  "resource_config": {
    "network_interface_name": "eth0",
    "current_host": "algo-1",
    "hosts": [
      "algo-1"
    ]
  },
  "module_dir": "s3://sagemaker-us-east-2-298679783816/sagemaker-
pytorch-2020-07-07-10-14-58-513/source/sourcedir.tar.gz",
  "channel_input_dirs": {
    "training": "/opt/ml/input/data/training"
  },
  "log_level": 20,
  "module_name": "train",
  "num_gpus": 1,
  "hyperparameters": {
    "epochs": 10,
    "hidden_dim": 200
  },
  "hosts": [
    "algo-1"
  ],
  "input_config_dir": "/opt/ml/input/config",
  "model_dir": "/opt/ml/model",
  "job_name": "sagemaker-pytorch-2020-07-07-10-14-58-513",
  "additional_framework_parameters": {},
  "framework_module": "sagemaker_pytorch_container.training:main",
  "network_interface_name": "eth0",
  "num_cpus": 4,
  "output_dir": "/opt/ml/output"
}

```

Environment variables:


```

SM_HP_HIDDEN_DIM=200
SM_CURRENT_HOST=algo-1
SM_OUTPUT_INTERMEDIATE_DIR=/opt/ml/output/intermediate
SM_NUM_GPUS=1
SM_NETWORK_INTERFACE_NAME=eth0
SM_HP_EPOCHS=10
SM_USER_ARGS=["--epochs", "10", "--hidden_dim", "200"]
SM_CHANNELS=["training"]
SM_OUTPUT_DATA_DIR=/opt/ml/output/data
SM_INPUT_CONFIG_DIR=/opt/ml/input/config
SM_MODULE_NAME=train
SM_RESOURCE_CONFIG={"current_host": "algo-1", "hosts": ["algo-1"], "network_interface_name": "eth0"}
SM_HOSTS=["algo-1"]
SM_HPS={"epochs": 10, "hidden_dim": 200}
SM_NUM_CPUS=4
SM_MODULE_DIR=s3://sagemaker-us-east-2-298679783816/sagemaker-pytorch-2020-07-07-10-14-58-513/source/sourcedir.tar.gz
SM_INPUT_DIR=/opt/ml/input
SM_MODEL_DIR=/opt/ml/model
SM_FRAMEWORK_PARAMS={}
SM_CHANNEL_TRAINING=/opt/ml/input/data/training
SM_TRAINING_ENV={"additional_framework_parameters": {}, "channel_input_dirs": {"training": "/opt/ml/input/data/training"}, "current_host": "algo-1", "framework_module": "sagemaker_pytorch_container.training:main", "hosts": ["algo-1"], "hyperparameters": {"epochs": 10, "hidden_dim": 200}, "input_config_dir": "/opt/ml/input/config", "input_data_config": {"training": {"RecordWrapperType": "None", "S3DistributionType": "FullyReplicated", "TrainingInputMode": "File"}}, "input_dir": "/opt/ml/input", "job_name": "sagemaker-pytorch-2020-07-07-10-14-58-513", "log_level": 20, "model_dir": "/opt/ml/model", "module_dir": "s3://sagemaker-us-east-2-298679783816/sagemaker-pytorch-2020-07-07-10-14-58-513/source/sourcedir.tar.gz", "module_name": "train", "network_interface_name": "eth0", "num_cpus": 4, "num_gpus": 1, "output_data_dir": "/opt/ml/output/data", "output_dir": "/opt/ml/output", "output_intermediate_dir": "/opt/ml/output/intermediate", "resource_config": {"current_host": "algo-1", "hosts": ["algo-1"], "network_interface_name": "eth0"}, "user_entry_point": "train.py"}
SM_FRAMEWORK_MODULE=sagemaker_pytorch_container.training:main
SM_USER_ENTRY_POINT=train.py
SM_OUTPUT_DIR=/opt/ml/output
SM_LOG_LEVEL=20
SM_INPUT_DATA_CONFIG={"training": {"RecordWrapperType": "None", "S3DistributionType": "FullyReplicated", "TrainingInputMode": "File"}}
PYTHONPATH=/usr/local/bin:/usr/lib/python3.5.zip:/usr/lib/python3.5:/usr/lib/python3.5/plat-x86_64-linux-gnu:/usr/lib/python3.5/lib-dynload:/usr/local/lib/python3.5/dist-packages:/usr/lib/python3/dist-packages

```

Invoking script with the following command:

```
/usr/bin/python -m train --epochs 10 --hidden_dim 200
```

```
Using device cuda.
```

```
Get train data loader.
```

```
Model loaded with embedding_dim 32, hidden_dim 200, vocab_size 5000.
```

```
Epoch: 1, BCELoss: 0.6712005856085796
```

```
Epoch: 2, BCELoss: 0.5953703887608587
```

```
Epoch: 3, BCELoss: 0.5104189691494923
```

```
Epoch: 4, BCELoss: 0.4380725275497047
```

```
Epoch: 5, BCELoss: 0.39914565913531247
```

```
Epoch: 6, BCELoss: 0.3496779708229766
```

```
Epoch: 7, BCELoss: 0.3259902219383084
```

```
Epoch: 8, BCELoss: 0.30550962078328037
```

```
Epoch: 9, BCELoss: 0.28697240535093815
```

```
2020-07-07 10:21:57 Uploading - Uploading generated training modelEpoch:
10, BCELoss: 0.26640932839743947
```

```
2020-07-07 10:21:56,217 sagemaker-containers INFO      Reporting training
SUCCESS
```

```
2020-07-07 10:22:04 Completed - Training job completed
```

```
Training seconds: 277
```

```
Billable seconds: 277
```

1.9 Step 5: Testing the model

As mentioned at the top of this notebook, we will be testing this model by first deploying it and then sending the testing data to the deployed endpoint. We will do this so that we can make sure that the deployed model is working correctly.

1.10 Step 6: Deploy the model for testing

Now that we have trained our model, we would like to test it to see how it performs. Currently our model takes input of the form `review_length, review[500]` where `review[500]` is a sequence of 500 integers which describe the words present in the review, encoded using `word_dict`. Fortunately for us, SageMaker provides built-in inference code for models with simple inputs such as this.

There is one thing that we need to provide, however, and that is a function which loads the saved model. This function must be called `model_fn()` and takes as its only parameter a path to the directory where the model artifacts are stored. This function must also be present in the python file which we specified as the entry point. In our case the model loading function has been provided and so no changes need to be made.

NOTE: When the built-in inference code is run it must import the `model_fn()` method from the `train.py` file. This is why the training code is wrapped in a main guard (ie, if `__name__ == '__main__':`)

Since we don't need to change anything in the code that was uploaded during training, we can simply deploy the current model as-is.