

# Application of Deep Learning to Text and Image Data

## Module 2, Lab 5: Finetuning BERT

BERT stands for **B**idirectional **E**ncoder **R**epresentations from **T**ransformers. To learn how BERT works, let's fine-tune the **BERT** model to classify product reviews. You will use a new library called **transformers** to download a pre-trained BERT model.

You will learn:

- How to load and format the dataset
- How to load the pre-trained model
- How to train and test the model

**BERT and its variants use more resources than the other models you have used so far. This may cause your instance to run out of memory. If that happens:**

- Restart the kernel (Kernel->Restart from the top menu)
- Reduce the batch size
- Then re-run the code

**Note:** In this walkthrough, you will use a light version of the original BERT implementation called "**DistilBert**". You can checkout [the paper](#) about it for more details.

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This lab uses a dataset derived from a small sample of Amazon product reviews.

**Review dataset schema:**

- **reviewText:** Text of the review
  - **summary:** Summary of the review
  - **verified:** Whether the purchase was verified (True or False)
  - **time:** UNIX timestamp for the review
  - **log\_votes:** Logarithm-adjusted votes  $\log(1+\text{votes})$
  - **isPositive:** Whether the review is positive or negative (1 or 0)
- 

You will be presented with two kinds of exercises throughout the notebook: activities and challenges.

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No coding is needed for an activity. You try to      Challenges are where you can practice your

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understand a concept, answer questions, or coding skills.  
run a code cell.

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```
%%capture
```

```
!pip install -U -q -r requirements.txt
```

## Reading and formatting the dataset

First, you need to read in the product review dataset and prepare it for the BERT model. To keep the training time down, you will only use the first 2000 data points from the dataset. If you want to improve your model after you understand how to train, you can use more data to train a new model.

```
%%capture
```

```
import os
import sys
import time
import torch
import pandas as pd
from sklearn.model_selection import train_test_split
from transformers import DistilBertForSequenceClassification,
DistilBertTokenizerFast
from torch.utils.data import DataLoader

# Import system library and append path
sys.path.insert(1, '..')

# Setting tokenizer parallelism to false
os.environ["TOKENIZERS_PARALLELISM"] = "false"

# Import utility functions that provide answers to challenges
from MLUDTI_EN_M2_Lab5_quiz_questions import *
```

Read the dataset.

```
df = pd.read_csv("data/NLP-REVIEW-DATA-CLASSIFICATION-TRAINING.csv")
```

Print the dataset information to see the field types.

```
df.info()

<class 'pandas.core.frame.DataFrame'>
RangeIndex: 56000 entries, 0 to 55999
Data columns (total 7 columns):
#   Column          Non-Null Count  Dtype  
---  -
0   ID               56000 non-null  int64  
1   reviewText       55989 non-null  object  
2   summary          55987 non-null  object  
3   verified         56000 non-null  bool    
4   time             56000 non-null  int64  
5   log_votes        56000 non-null  float64 
6   isPositive       56000 non-null  int64  
dtypes: bool(1), float64(1), int64(3), object(2)
memory usage: 2.6+ MB
```

You do not need any of the rows that do not have **reviewText**, so drop them.

```
df.dropna(subset=["reviewText"], inplace=True)

question_1

<MLU DTI_EN_M2_Lab5_quiz_questions.Quiz at 0x7f941cb124d0>
```

BERT requires a lot of compute power for large datasets. To reduce the amount of time it takes to train the model, you will only use the first 2,000 data points for this lab.

```
df = df.head(2000)
```

Now split the dataset into training and validation data sets, keeping 10% of the data for validation.

```
# This separates 10% of the entire dataset into validation dataset.
train_texts, val_texts, train_labels, val_labels = train_test_split(
    df["reviewText"].tolist(),
    df["isPositive"].tolist(),
    test_size=0.10,
    shuffle=True,
    random_state=324,
    stratify = df["isPositive"].tolist(),
)
```

You need to tokenize the data. To do this, use a special tokenizer built for the DistilBERT model to tokenize the training and validation texts.

```
tokenizer = DistilBertTokenizerFast.from_pretrained('distilbert-base-uncased')
```

```

train_encodings = tokenizer(train_texts,
                             truncation=True,
                             padding=True)
val_encodings = tokenizer(val_texts,
                          truncation=True,
                          padding=True)

```

Create a new `ReviewDataset` class to use with the BERT model. Later, you use the training and validation encoding-label pairs with this new class.

```

class ReviewDataset(torch.utils.data.Dataset):
    def __init__(self, encodings, labels):
        self.encodings = encodings
        self.labels = labels

    def __getitem__(self, idx):
        item = {key: torch.tensor(val[idx]).to(device) for key, val in
self.encodings.items()}
        item["labels"] = torch.tensor(self.labels[idx]).to(device)
        return item

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

train_dataset = ReviewDataset(train_encodings, train_labels)
val_dataset = ReviewDataset(val_encodings, val_labels)

```

## Loading the pre-trained model

Now, you need to load the model. When you do this, several warnings will print that are related to the last classification layer of BERT where you are using a randomly initialized layer. You can ignore the warnings as they are not relevant to the type of training you are doing.

```

model =
DistilBertForSequenceClassification.from_pretrained("distilbert-base-
uncased",
num_labels=2)

```

The last step is to freeze all weights until the very last classification layer in the BERT model. This helps accelerate the training process. Training the weights of the whole network (66 million weights) takes a long time. Additionally, 2000 data points would not be enough for that task. Instead, the code below freezes all the weights until the last classification layer. This means only a small portion of the weights gets updated (rest stays the same). This is a common practice with large language models.

```

# Freeze the encoder weights until the classifier
for name, param in model.named_parameters():

```

```
if "classifier" not in name:
    param.requires_grad = False
```

## Training and testing the model

Now that your data is ready and you have configured your model, its time to start the fine-tuning process. This code will take **a long time** (30+ minutes) to complete with large datasets, that is why you are running it on a subset of the full review dataset.

First, define the accuracy function.

```
def calculate_accuracy(output, label):
    """Calculate the accuracy of the trained network.
    output: (batch_size, num_output) float32 tensor
    label: (batch_size, ) int32 tensor """

    return (output.argmax(axis=1) == label.float()).float().mean()
```

Now you need to create the training and validation loop. This loop will be similar to the previous train/validation loops, however there are a few extra parameters needed due to the transformer architecture.

You need to use the `attention_mask` and get the loss from the output of the model with `loss = output[0]`

```
# Hyperparameters
num_epochs = 20
learning_rate = 0.005

# Get the compute device
device = torch.device("cuda" if torch.cuda.is_available() else "cpu")

# Create data loaders
train_loader = DataLoader(train_dataset, shuffle=True,
                           batch_size=16, drop_last=True)
validation_loader = DataLoader(val_dataset, batch_size=8,
                               drop_last=True)

# Setup the optimizer
optimizer = torch.optim.SGD(model.parameters(), lr=learning_rate)

model = model.to(device)

for epoch in range(num_epochs):

    train_loss, val_loss, train_acc, valid_acc = 0., 0., 0., 0.

    start = time.time()
    # Training loop starts
```

```

model.train() # put the model in training mode
for batch in train_loader:
    # Zero the parameter gradients
    optimizer.zero_grad()
    # Put data, label and attention mask to the correct device
    data = batch["input_ids"].to(device)
    attention_mask = batch['attention_mask'].to(device)
    label = batch["labels"].to(device)

    # Make forward pass
    output = model(data, attention_mask=attention_mask,
labels=label)

    # Calculate the loss (this comes from the output)
    loss = output[0]
    # Make backwards pass (calculate gradients)
    loss.backward()
    # Accumulate training accuracy and loss
    train_acc += calculate_accuracy(output.logits, label).item()
    train_loss += loss.item()
    # Update weights
    optimizer.step()

# Validation loop:
# This loop tests the trained network on validation dataset
# No weight updates here
# torch.no_grad() reduces memory usage when not training the
network
model.eval() # Activate evaluation mode
with torch.no_grad():
    for batch in validation_loader:
        data = batch["input_ids"].to(device)
        attention_mask = batch['attention_mask'].to(device)
        label = batch["labels"].to(device)
        # Make forward pass with the trained model so far
        output = model(data, attention_mask=attention_mask,
labels=label)
        # Accumulate validation accuracy and loss
        valid_acc += calculate_accuracy(output.logits,
label).item()
        val_loss += output[0].item()

# Take averages
train_loss /= len(train_loader)
train_acc /= len(train_loader)
val_loss /= len(validation_loader)
valid_acc /= len(validation_loader)

end = time.time()

```

```
print("Epoch %d: train loss %.3f, train acc %.3f, val loss %.3f,  
val acc %.3f, seconds % .3f " % (  
    epoch+1, train_loss, train_acc, val_loss, valid_acc, end-  
start))
```

```
Epoch 1: train loss 0.660, train acc 0.615, val loss 0.641, val acc  
0.620, seconds 30.084  
Epoch 2: train loss 0.631, train acc 0.633, val loss 0.618, val acc  
0.640, seconds 30.026  
Epoch 3: train loss 0.609, train acc 0.650, val loss 0.589, val acc  
0.630, seconds 29.999  
Epoch 4: train loss 0.585, train acc 0.691, val loss 0.566, val acc  
0.645, seconds 30.058  
Epoch 5: train loss 0.564, train acc 0.717, val loss 0.540, val acc  
0.710, seconds 30.054  
Epoch 6: train loss 0.540, train acc 0.743, val loss 0.517, val acc  
0.730, seconds 30.094  
Epoch 7: train loss 0.519, train acc 0.766, val loss 0.492, val acc  
0.780, seconds 30.055  
Epoch 8: train loss 0.501, train acc 0.784, val loss 0.472, val acc  
0.795, seconds 30.079  
Epoch 9: train loss 0.484, train acc 0.791, val loss 0.460, val acc  
0.845, seconds 30.076  
Epoch 10: train loss 0.467, train acc 0.800, val loss 0.436, val acc  
0.840, seconds 30.064  
Epoch 11: train loss 0.458, train acc 0.799, val loss 0.421, val acc  
0.800, seconds 30.086  
Epoch 12: train loss 0.429, train acc 0.818, val loss 0.402, val acc  
0.845, seconds 30.067  
Epoch 13: train loss 0.428, train acc 0.814, val loss 0.399, val acc  
0.815, seconds 30.101  
Epoch 14: train loss 0.415, train acc 0.815, val loss 0.389, val acc  
0.875, seconds 30.065  
Epoch 15: train loss 0.410, train acc 0.820, val loss 0.373, val acc  
0.870, seconds 30.094  
Epoch 16: train loss 0.402, train acc 0.821, val loss 0.362, val acc  
0.860, seconds 30.061  
Epoch 17: train loss 0.390, train acc 0.836, val loss 0.354, val acc  
0.880, seconds 30.088  
Epoch 18: train loss 0.393, train acc 0.828, val loss 0.360, val acc  
0.880, seconds 30.061  
Epoch 19: train loss 0.386, train acc 0.826, val loss 0.342, val acc  
0.885, seconds 30.066  
Epoch 20: train loss 0.384, train acc 0.825, val loss 0.341, val acc  
0.870, seconds 30.087
```

## Looking at what's going on

The fine-tuned BERT model is able to correctly classify the sentiment of the most of the records in the validation set. Let's observe in more detail how the sentences are tokenized and encoded. You can do this by picking one sentence as example to look at.

```
st = val_texts[19]
print(f"Sentence: {st}")
tok = tokenizer(st, truncation=True, padding=True)
print(f"Encoded Sentence: {tok['input_ids']}")
```

```
Sentence: An excellent resource for all scanner owners. Seems to be
up to date and all inclusive. I highly recommend this product!
Encoded Sentence: [101, 2019, 6581, 7692, 2005, 2035, 26221, 5608,
1012, 3849, 2000, 2022, 2039, 2000, 3058, 1998, 2035, 18678, 1012,
1045, 3811, 16755, 2023, 4031, 999, 102]
```

Print the vocabulary size.

```
# The mapped vocabulary is stored in tokenizer.vocab
tokenizer.vocab_size

30522
```

Use the encoded sentence with the tokenizer to recover the original sentence.

```
# Methods convert_ids_to_tokens and convert_tokens_to_ids allow to see
how sentences are tokenized
print(tokenizer.convert_ids_to_tokens(tok["input_ids"]))

['[CLS]', 'an', 'excellent', 'resource', 'for', 'all', 'scanner',
'owners', '.', 'seems', 'to', 'be', 'up', 'to', 'date', 'and', 'all',
'inclusive', '.', 'i', 'highly', 'recommend', 'this', 'product', '!',
'[SEP]']
```

## Getting predictions on the test data

After the model is trained, you can focus on getting test data to make predictions with. Do this by:

- Reading and format the test dataset
- Passing the test data to your trained model and make predictions

```
# Read the test data (It doesn't have the isPositive label)
df_test = pd.read_csv("data/NLP-REVIEW-DATA-CLASSIFICATION-TEST.csv")
df_test.head()
```

	ID	reviewText \
0	33276	I've been using greeting card software for wel...
1	20859	This version worked well for me, have upgraded...



```

2  63500                                     Great!
3   4950  I can assure you that any five star review was...
4  26509  Overall the product really seems the same but ...

                                summary  verified
time \
0                                Absolutely awful.  False
1300233600
1                                Good for virtual machine on a mac  True
1448755200
2                                Five Stars  True
1456963200
3                                SCAM  False
1400803200
4  Has potential but many glitches and really the...  False
1419206400

log_votes
0  0.000000
1  0.000000
2  0.000000
3  2.197225
4  0.000000

```

Just as before, drop the rows that don't have the **reviewText**.

```
df_test.dropna(subset=["reviewText"], inplace=True)
```

Making predictions will also take a long time with this model. To get results quickly, start by only making predictions with 15 datapoints from the test set.

```

test_texts = df_test["reviewText"].tolist()[0:15]
test_encodings = tokenizer(test_texts,
                           truncation=True,
                           padding=True)

```

Create labels for the test dataset to pass zeros using `[0]*len(test_texts)`.

```
test_dataset = ReviewDataset(test_encodings, [0]*len(test_texts))
```

Then, create a dataloader for the test set and record the corresponding predictions.

```

test_loader = DataLoader(test_dataset, batch_size=4)
test_predictions = []
model.eval()

with torch.no_grad():

```

```

for batch in test_loader:
    data = batch["input_ids"].to(device)
    attention_mask = batch['attention_mask'].to(device)
    label = batch["labels"].to(device)
    output = model(data, attention_mask=attention_mask,
labels=label)
    predictions = torch.argmax(output.logits, dim=-1)
    test_predictions.extend(predictions.cpu().numpy())

```

Finally, pick an example sentence and examine the prediction. Does the prediction look correct?

Remember

- 1->positive class
- 0->negative class

```

k = 13
print(f'Text: {test_texts[k]}')
print(f'Prediction: {test_predictions[k]}')

```

Text: I have been using this product for five or six years. This purchase was my annual subscription renewal. It has the features that I need, and seems to protect the three PC's that we have while using the internet. I will be looking at the mobile apps for a tablet and smart phone.  
Prediction: 1

---

## Conclusion

In this lab you learned how to import a pre-trained Transformer model and fine-tune it for a specific task. Although you used a lighter version of the BERT model, these types of models tend to use large amounts of compute power. For that reason, you only worked with the first 2000 datapoints of the dataset. To see more general results, you need to spend more time training while using the whole dataset.

## Next Lab: Reading and plotting images

In the next lab you will learn how to read images and plot them as you start to learn about computer vision problems.