



```
os.environ['TOKENIZERS_PARALLELISM'] = 'false'
# Import utility functions that provide answers to challenges
from MLUDTI_EN_M2_Lab5_quiz_questions import *
```

Read the dataset.

```
In [3]: df = pd.read_csv("data/NLP-REVIEW-DATA-CLASSIFICATION-TRAINING.csv")
```

Print the dataset information to see the field types.

```
In [4]: 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.

```
In [5]: df.dropna(subset=["reviewText"], inplace=True)
```

### Try it Yourself!



#### Activity

Answer the question below to test your understanding of epochs and learning rate.

```
In [6]: question_1
```

```
Out[6]:
```

Why did you drop all rows where `reviewText` is empty?

This action makes the dataset the correct size for training.

If `reviewText` is empty for a row, then the model doesn't have anything to train on for that row.

The `reviewText` feature isn't used in this model, so rows with `reviewText` can be dropped.

**Submit**

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.

```
In [7]: df = df.head(2000)
```

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

```
In [8]: # 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.

```
In [9]: 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)
```

tokenizer\_config.json: 100% 

28.0/28.0 [00:00<00:00, 3.32kB/s]

vocab.txt: 100% 

232k/232k [00:00<00:00, 9.29MB/s]

tokenizer.json: 100% 

466k/466k [00:00<00:00, 27.9MB/s]

config.json: 100% 

483/483 [00:00<00:00, 51.3kB/s]

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.

```
In [10]: 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["label"] = torch.tensor(self.labels[idx])
        return item
```

```

        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.

```
In [11]: model = DistilBertForSequenceClassification.from_pretrained("distilbert-base-uncased",
                                                               num_labels=2)
```

model.safetensors: 100% 268M/268M [00:00<00:00, 385MB/s]

Some weights of DistilBertForSequenceClassification were not initialized from the model checkpoint at distilbert-base-uncased and are newly initialized: ['classifier.bias', 'classifier.weight', 'pre\_classifier.bias', 'pre\_classifier.weight']  
You should probably TRAIN this model on a down-stream task to be able to use it for predictions and inference.

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.

```
In [12]: # 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.

```
In [13]: 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]`

```
In [14]: # Hyperparameters
num_epochs = 10
learning_rate = 0.01

# 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
```

```

# 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 0.647, train acc 0.621, val loss 0.610, val acc 0.630, seconds 29.258  
Epoch 2: train loss 0.601, train acc 0.663, val loss 0.575, val acc 0.625, seconds 28.882  
Epoch 3: train loss 0.557, train acc 0.734, val loss 0.514, val acc 0.700, seconds 29.201  
Epoch 4: train loss 0.511, train acc 0.767, val loss 0.473, val acc 0.765, seconds 29.393  
Epoch 5: train loss 0.471, train acc 0.797, val loss 0.434, val acc 0.860, seconds 29.526  
Epoch 6: train loss 0.447, train acc 0.805, val loss 0.405, val acc 0.885, seconds 29.483  
Epoch 7: train loss 0.426, train acc 0.810, val loss 0.377, val acc 0.855, seconds 29.253  
Epoch 8: train loss 0.413, train acc 0.812, val loss 0.382, val acc 0.820, seconds 29.272  
Epoch 9: train loss 0.410, train acc 0.816, val loss 0.365, val acc 0.850, seconds 29.276  
Epoch 10: train loss 0.400, train acc 0.819, val loss 0.335, val acc 0.880, seconds 29.283

## 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.

```

In [15]: 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.

```

In [16]: # The mapped vocabulary is stored in tokenizer.vocab
tokenizer.vocab_size

Out[16]: 30522

```

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

```

In [17]: # 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', 'an', '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

```

In [18]: # Read the test data (it doesn't have the isPositive label)
df_test = pd.read_csv("data/NLP-REVIEW-CLASSIFICATION-TEST.csv")
df_test.head()

Out[18]:
   ID      reviewText      summary  verified      time  log_votes
0  33276  I've been using greeting card software for wel...  Absolutely awful.  False  1300233600  0.000000
1  20859  This version worked well for me, have upgraded...  Good for virtual machine on a mac  True  1448755200  0.000000
2  63500        Great!      Five Stars  True  1456963200  0.000000
3   4950  I can assure you that any five star review was...       SCAM  False  1400803200  2.197225
4  26509  Overall the product really seems the same but ...  Has potential but many glitches and really the...  False  1419206400  0.000000

```

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

```
In [19]: 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.

```
In [20]: test_texts = df_test["reviewText"].tolist()[0:15]
```

```
In [21]: test_encodings = tokenizer(test_texts,
                               truncation=True,
                               padding=True)
```

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

```
In [22]: test_dataset = ReviewDataset(test_encodings, [0]*len(test_texts))
```

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

```

In [23]: 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

```
In [24]: 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

### Try it Yourself!



### Challenge

You trained the model for 10 epochs. Would you get better results from the validation dataset if the model trained longer?

Make a note of your last `val_loss` result.

Then, in the [Training and testing the model](#) section, change the `num_epochs` parameter to `20`.

Finally, re-run the code blocks to load the pre-trained model, and train your model.

Did `val_loss` improve?

## 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.