In [ ]:
```
import os
import shutil

import tensorflow as tf
import tensorflow_hub as hub
import tensorflow_text as text
from official.nlp import optimization  # to create AdamW optimizer

import matplotlib.pyplot as plt

tf.get_logger().setLevel('ERROR')
```

In [ ]:
```
# url = 'https://ai.stanford.edu/~amaas/data/sentiment/aclImdb_v1.tar.gz'

# dataset = tf.keras.utils.get_file('aclImdb_v1.tar.gz', url,
#                                   untar=True, cache_dir='.',
#                                   cache_subdir='')

# dataset_dir = os.path.join(os.path.dirname(dataset), 'aclImdb')

# train_dir = os.path.join(dataset_dir, 'train')

# # remove unused folders to make it easier to load the data
# remove_dir = os.path.join(train_dir, 'unsup')
# shutil.rmtree(remove_dir)
```

In [ ]:
```
AUTOTUNE = tf.data.AUTOTUNE
batch_size = 64
seed = 42

raw_train_ds = tf.keras.utils.text_dataset_from_directory(
    'aclImdb/train',
    batch_size=batch_size,
    validation_split=0.2,
    subset='training',
    seed=seed)

class_names = raw_train_ds.class_names
train_ds = raw_train_ds.cache().prefetch(buffer_size=AUTOTUNE)

val_ds = tf.keras.utils.text_dataset_from_directory(
    'aclImdb/train',
    batch_size=batch_size,
    validation_split=0.2,
    subset='validation',
    seed=seed)

val_ds = val_ds.cache().prefetch(buffer_size=AUTOTUNE)

test_ds = tf.keras.utils.text_dataset_from_directory(
    'aclImdb/test',
    batch_size=batch_size)

test_ds = test_ds.cache().prefetch(buffer_size=AUTOTUNE)
```

Let's take a look at a few reviews.

In [ ]:
```
#@title Choose a BERT model to fine-tune

bert_model_name = 'small_bert/bert_en_uncased_L-4_H-512_A-8'  #@param ["bert_e

map_name_to_handle = {
    'bert_en_uncased_L-12_H-768_A-12':
        'https://tfhub.dev/tensorflow/bert_en_uncased_L-12_H-768_A-12/3',
    'bert_en_cased_L-12_H-768_A-12':
        'https://tfhub.dev/tensorflow/bert_en_cased_L-12_H-768_A-12/3',
    'bert_multi_cased_L-12_H-768_A-12':
        'https://tfhub.dev/tensorflow/bert_multi_cased_L-12_H-768_A-12/3',
    'small_bert/bert_en_uncased_L-2_H-128_A-2':
        'https://tfhub.dev/tensorflow/small_bert/bert_en_uncased_L-2_H-128_A-2
    'small_bert/bert_en_uncased_L-2_H-256_A-4':
        'https://tfhub.dev/tensorflow/small_bert/bert_en_uncased_L-2_H-256_A-4
    'small_bert/bert_en_uncased_L-2_H-512_A-8':
        'https://tfhub.dev/tensorflow/small_bert/bert_en_uncased_L-2_H-512_A-8
    'small_bert/bert_en_uncased_L-2_H-768_A-12':
        'https://tfhub.dev/tensorflow/small_bert/bert_en_uncased_L-2_H-768_A-1
    'small_bert/bert_en_uncased_L-4_H-128_A-2':
        'https://tfhub.dev/tensorflow/small_bert/bert_en_uncased_L-4_H-128_A-2
    'small_bert/bert_en_uncased_L-4_H-256_A-4':
        'https://tfhub.dev/tensorflow/small_bert/bert_en_uncased_L-4_H-256_A-4
    'small_bert/bert_en_uncased_L-4_H-512_A-8':
        'https://tfhub.dev/tensorflow/small_bert/bert_en_uncased_L-4_H-512_A-8
    'small_bert/bert_en_uncased_L-4_H-768_A-12':
        'https://tfhub.dev/tensorflow/small_bert/bert_en_uncased_L-4_H-768_A-1
    'small_bert/bert_en_uncased_L-6_H-128_A-2':
        'https://tfhub.dev/tensorflow/small_bert/bert_en_uncased_L-6_H-128_A-2
    'small_bert/bert_en_uncased_L-6_H-256_A-4':
        'https://tfhub.dev/tensorflow/small_bert/bert_en_uncased_L-6_H-256_A-4
    'small_bert/bert_en_uncased_L-6_H-512_A-8':
        'https://tfhub.dev/tensorflow/small_bert/bert_en_uncased_L-6_H-512_A-8
    'small_bert/bert_en_uncased_L-6_H-768_A-12':
        'https://tfhub.dev/tensorflow/small_bert/bert_en_uncased_L-6_H-768_A-1
    'small_bert/bert_en_uncased_L-8_H-128_A-2':
        'https://tfhub.dev/tensorflow/small_bert/bert_en_uncased_L-8_H-128_A-2
    'small_bert/bert_en_uncased_L-8_H-256_A-4':
        'https://tfhub.dev/tensorflow/small_bert/bert_en_uncased_L-8_H-256_A-4
    'small_bert/bert_en_uncased_L-8_H-512_A-8':
        'https://tfhub.dev/tensorflow/small_bert/bert_en_uncased_L-8_H-512_A-8
    'small_bert/bert_en_uncased_L-8_H-768_A-12':
        'https://tfhub.dev/tensorflow/small_bert/bert_en_uncased_L-8_H-768_A-1
    'small_bert/bert_en_uncased_L-10_H-128_A-2':
        'https://tfhub.dev/tensorflow/small_bert/bert_en_uncased_L-10_H-128_A-
    'small_bert/bert_en_uncased_L-10_H-256_A-4':
        'https://tfhub.dev/tensorflow/small_bert/bert_en_uncased_L-10_H-256_A-
    'small_bert/bert_en_uncased_L-10_H-512_A-8':
        'https://tfhub.dev/tensorflow/small_bert/bert_en_uncased_L-10_H-512_A-
    'small_bert/bert_en_uncased_L-10_H-768_A-12':
        'https://tfhub.dev/tensorflow/small_bert/bert_en_uncased_L-10_H-768_A-
    'small_bert/bert_en_uncased_L-12_H-128_A-2':
        'https://tfhub.dev/tensorflow/small_bert/bert_en_uncased_L-12_H-128_A-
    'small_bert/bert_en_uncased_L-12_H-256_A-4':
        'https://tfhub.dev/tensorflow/small_bert/bert_en_uncased_L-12_H-256_A-
    'small_bert/bert_en_uncased_L-12_H-512_A-8':
        'https://tfhub.dev/tensorflow/small_bert/bert_en_uncased_L-12_H-512_A-
    'small_bert/bert_en_uncased_L-12_H-768_A-12':
        'https://tfhub.dev/tensorflow/small_bert/bert_en_uncased_L-12_H-768_A-
    'albert_en_base':
```

```
        'https://tfhub.dev/tensorflow/albert_en_base/2',
    'electra_small':
        'https://tfhub.dev/google/electra_small/2',
    'electra_base':
        'https://tfhub.dev/google/electra_base/2',
    'experts_pubmed':
        'https://tfhub.dev/google/experts/bert/pubmed/2',
    'experts_wiki_books':
        'https://tfhub.dev/google/experts/bert/wiki_books/2',
    'talking-heads_base':
        'https://tfhub.dev/tensorflow/talkheads_ggelu_bert_en_base/1',
}

map_model_to_preprocess = {
    'bert_en_uncased_L-12_H-768_A-12':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
    'bert_en_cased_L-12_H-768_A-12':
        'https://tfhub.dev/tensorflow/bert_en_cased_preprocess/3',
    'small_bert/bert_en_uncased_L-2_H-128_A-2':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
    'small_bert/bert_en_uncased_L-2_H-256_A-4':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
    'small_bert/bert_en_uncased_L-2_H-512_A-8':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
    'small_bert/bert_en_uncased_L-2_H-768_A-12':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
    'small_bert/bert_en_uncased_L-4_H-128_A-2':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
    'small_bert/bert_en_uncased_L-4_H-256_A-4':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
    'small_bert/bert_en_uncased_L-4_H-512_A-8':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
    'small_bert/bert_en_uncased_L-4_H-768_A-12':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
    'small_bert/bert_en_uncased_L-6_H-128_A-2':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
    'small_bert/bert_en_uncased_L-6_H-256_A-4':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
    'small_bert/bert_en_uncased_L-6_H-512_A-8':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
    'small_bert/bert_en_uncased_L-6_H-768_A-12':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
    'small_bert/bert_en_uncased_L-8_H-128_A-2':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
    'small_bert/bert_en_uncased_L-8_H-256_A-4':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
    'small_bert/bert_en_uncased_L-8_H-512_A-8':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
    'small_bert/bert_en_uncased_L-8_H-768_A-12':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
    'small_bert/bert_en_uncased_L-10_H-128_A-2':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
    'small_bert/bert_en_uncased_L-10_H-256_A-4':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
    'small_bert/bert_en_uncased_L-10_H-512_A-8':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
    'small_bert/bert_en_uncased_L-10_H-768_A-12':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
    'small_bert/bert_en_uncased_L-12_H-128_A-2':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
```

```
    'small_bert/bert_en_uncased_L-12_H-256_A-4':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
    'small_bert/bert_en_uncased_L-12_H-512_A-8':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
    'small_bert/bert_en_uncased_L-12_H-768_A-12':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
    'bert_multi_cased_L-12_H-768_A-12':
        'https://tfhub.dev/tensorflow/bert_multi_cased_preprocess/3',
    'albert_en_base':
        'https://tfhub.dev/tensorflow/albert_en_preprocess/3',
    'electra_small':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
    'electra_base':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
    'experts_pubmed':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
    'experts_wiki_books':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
    'talking-heads_base':
        'https://tfhub.dev/tensorflow/bert_en_uncased_preprocess/3',
}

tfhub_handle_encoder = map_name_to_handle[bert_model_name]
tfhub_handle_preprocess = map_model_to_preprocess[bert_model_name]

print(f'BERT model selected           : {tfhub_handle_encoder}')
print(f'Preprocess model auto-selected: {tfhub_handle_preprocess}')
```

In [ ]:
```
bert_preprocess_model = hub.KerasLayer(tfhub_handle_preprocess)
```

In [ ]:
```
text_test = ['this is such an amazing movie!']
text_preprocessed = bert_preprocess_model(text_test)

print(f'Keys       : {list(text_preprocessed.keys())}')
print(f'Shape      : {text_preprocessed["input_word_ids"].shape}')
print(f'Word Ids   : {text_preprocessed["input_word_ids"][0, :12]}')
print(f'Input Mask : {text_preprocessed["input_mask"][0, :12]}')
print(f'Type Ids   : {text_preprocessed["input_type_ids"][0, :12]}')
```

In [ ]:
```
bert_model = hub.KerasLayer(tfhub_handle_encoder)
```

In [ ]:
```
bert_results = bert_model(text_preprocessed)

print(f'Loaded BERT: {tfhub_handle_encoder}')
print(f'Pooled Outputs Shape:{bert_results["pooled_output"].shape}')
print(f'Pooled Outputs Values:{bert_results["pooled_output"][0, :12]}')
print(f'Sequence Outputs Shape:{bert_results["sequence_output"].shape}')
print(f'Sequence Outputs Values:{bert_results["sequence_output"][0, :12]}')
```

In [ ]:
```
def build_classifier_model():
  text_input = tf.keras.layers.Input(shape=(), dtype=tf.string, name='text')
  preprocessing_layer = hub.KerasLayer(tfhub_handle_preprocess, name='preproce
  encoder_inputs = preprocessing_layer(text_input)
  encoder = hub.KerasLayer(tfhub_handle_encoder, trainable=True, name='BERT_en
  outputs = encoder(encoder_inputs)
  net = outputs['pooled_output']
  net = tf.keras.layers.Dropout(0.5)(net)
```

```
  net = tf.keras.layers.Dense(1, activation=None, name='classifier')(net)
  return tf.keras.Model(text_input, net)
```

In [ ]:
```
classifier_model = build_classifier_model()
bert_raw_result = classifier_model(tf.constant(text_test))
print(tf.sigmoid(bert_raw_result))
```

In [ ]:
```
tf.keras.utils.plot_model(classifier_model)
```

In [ ]:
```
loss = tf.keras.losses.BinaryCrossentropy(from_logits=True)
metrics = tf.metrics.BinaryAccuracy()
```

In [34]:
```
epochs = 5
steps_per_epoch = tf.data.experimental.cardinality(train_ds).numpy()
num_train_steps = steps_per_epoch * epochs
num_warmup_steps = int(0.1*num_train_steps)

init_lr = 1e-4
optimizer = optimization.create_optimizer(init_lr=init_lr,
                                          num_train_steps=num_train_steps,
                                          num_warmup_steps=num_warmup_steps,
                                          optimizer_type='lamb')
```

In [35]:
```
classifier_model.compile(optimizer=optimizer,
                         loss=loss,
                         metrics=metrics)
```

In [36]:
```
print(f'Training model with {tfhub_handle_encoder}')
history = classifier_model.fit(x=train_ds,
                               validation_data=val_ds,
                               epochs=epochs)
```

```
Training model with https://tfhub.dev/tensorflow/small_bert/bert_en_uncased_L-4_H-512_A-8/1
Epoch 1/5
313/313 [==============================] - 153s 470ms/step - loss: 0.5819 - binary_accuracy: 0.6697 - val_loss: 0.4091 - val_binary_accuracy: 0.7914
Epoch 2/5
313/313 [==============================] - 147s 471ms/step - loss: 0.3996 - binary_accuracy: 0.8148 - val_loss: 0.3660 - val_binary_accuracy: 0.8232
Epoch 3/5
313/313 [==============================] - 147s 471ms/step - loss: 0.3421 - binary_accuracy: 0.8494 - val_loss: 0.3620 - val_binary_accuracy: 0.8324
Epoch 4/5
313/313 [==============================] - 147s 471ms/step - loss: 0.2983 - binary_accuracy: 0.8716 - val_loss: 0.3676 - val_binary_accuracy: 0.8462
Epoch 5/5
313/313 [==============================] - 147s 471ms/step - loss: 0.2728 - binary_accuracy: 0.8861 - val_loss: 0.3692 - val_binary_accuracy: 0.8432
```

Evaluate the model

Let's see how the model performs. Two values will be returned. Loss (a number which represents the error, lower values are better), and accuracy.

In [37]:
```
loss, accuracy = classifier_model.evaluate(test_ds)
```

```
print(f'Loss: {loss}')
print(f'Accuracy: {accuracy}')
```

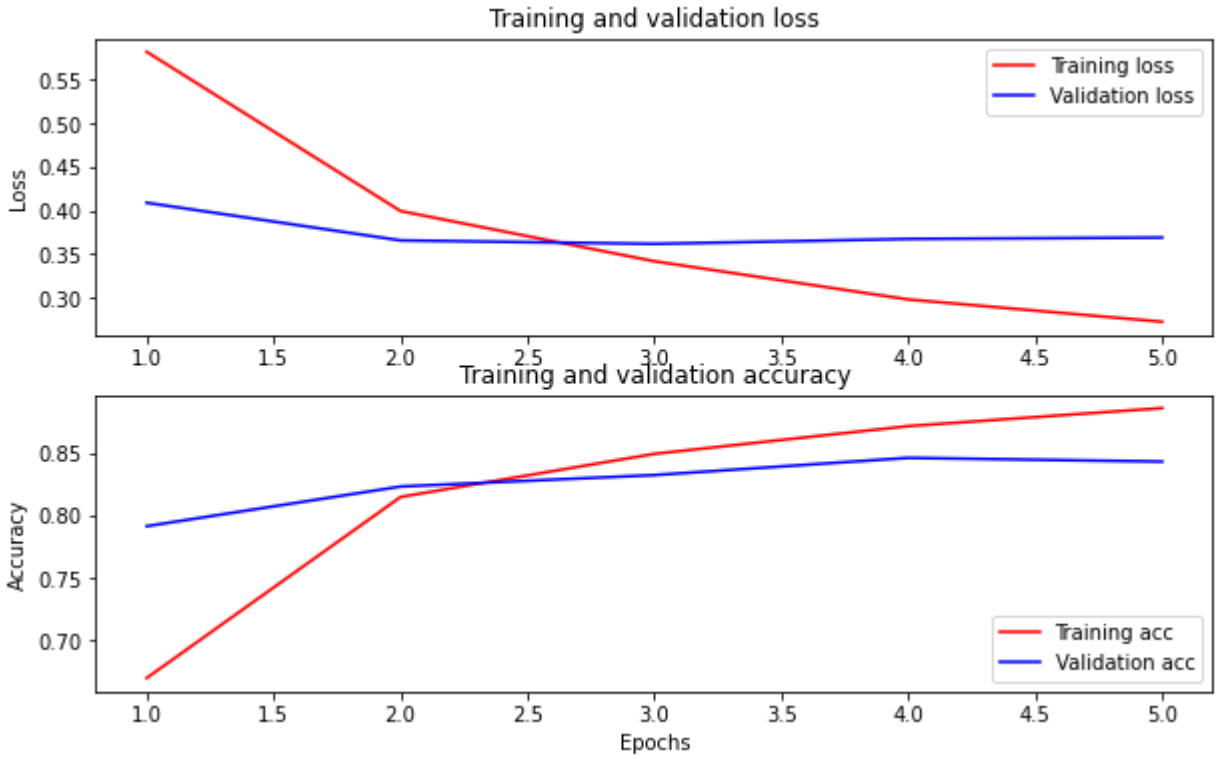
```
391/391 [==============================] - 78s 198ms/step - loss: 0.3588 - bin
ary_accuracy: 0.8464
Loss: 0.35883429646492004
Accuracy: 0.8464000225067139
```

Plot the accuracy and loss over time

Based on the `History` object returned by `model.fit()`. You can plot the training and validation loss for comparison, as well as the training and validation accuracy:

In [43]:
```
history_dict = history.history
print(history_dict.keys())

acc = history_dict['binary_accuracy']
val_acc = history_dict['val_binary_accuracy']
loss = history_dict['loss']
val_loss = history_dict['val_loss']

epochs = range(1, len(acc) + 1)
fig = plt.figure(figsize=(10, 6))
fig.tight_layout()

plt.subplot(2, 1, 1)
# r is for "solid red line"
plt.plot(epochs, loss, 'r', label='Training loss')
# b is for "solid blue line"
plt.plot(epochs, val_loss, 'b', label='Validation loss')
plt.title('Training and validation loss')
# plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.legend()

plt.subplot(2, 1, 2)
plt.plot(epochs, acc, 'r', label='Training acc')
plt.plot(epochs, val_acc, 'b', label='Validation acc')
plt.title('Training and validation accuracy')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.legend(loc='lower right')
```

Out[43]:
```
dict_keys(['loss', 'binary_accuracy', 'val_loss', 'val_binary_accuracy'])
<matplotlib.legend.Legend at 0x7fb118ae0f40>
```



In [44]:
```
dataset_name = 'imdb'
saved_model_path = './{}_bert'.format(dataset_name.replace('/', '_'))

classifier_model.save(saved_model_path, include_optimizer=False)
```

```
WARNING:absl:Found untraced functions such as restored_function_body, restored
_function_body, restored_function_body, restored_function_body, restored_funct
ion_body while saving (showing 5 of 124). These functions will not be directly
callable after loading.
```

In [45]:
```
reloaded_model = tf.saved_model.load(saved_model_path)
```

In [46]:
```
def print_my_examples(inputs, results):
  result_for_printing = \
    [f'input: {inputs[i]:<30} : score: {results[i][0]:.6f}'
                          for i in range(len(inputs))]
  print(*result_for_printing, sep='\n')
  print()


examples = [
    'this is such an amazing movie!',  # this is the same sentence tried earli
    'The movie was great!',
    'The movie was meh.',
    'The movie was okish.',
    'The movie was terrible...'
]

reloaded_results = tf.sigmoid(reloaded_model(tf.constant(examples)))
original_results = tf.sigmoid(classifier_model(tf.constant(examples)))

print('Results from the saved model:')
print_my_examples(examples, reloaded_results)
```

```
print('Results from the model in memory:')
print_my_examples(examples, original_results)
```

```
Results from the saved model:
input: this is such an amazing movie! : score: 0.998092
input: The movie was great!           : score: 0.986202
input: The movie was meh.             : score: 0.849131
input: The movie was okish.           : score: 0.179548
input: The movie was terrible...      : score: 0.012731

Results from the model in memory:
input: this is such an amazing movie! : score: 0.998092
input: The movie was great!           : score: 0.986202
input: The movie was meh.             : score: 0.849131
input: The movie was okish.           : score: 0.179548
input: The movie was terrible...      : score: 0.012731
```

In [47]:
```
serving_results = reloaded_model \
            .signatures['serving_default'](tf.constant(examples))

serving_results = tf.sigmoid(serving_results['classifier'])

print_my_examples(examples, serving_results)
```

```
input: this is such an amazing movie! : score: 0.998092
input: The movie was great!           : score: 0.986202
input: The movie was meh.             : score: 0.849131
input: The movie was okish.           : score: 0.179548
input: The movie was terrible...      : score: 0.012731
```

In [ ]:
```

```