Assignment 05

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Assignment 5.1

Implement the movie review classifier found in section 3.4 of Deep Learning with Python.

In [27]:
```
# Load all the required libraries
import numpy as np
from tensorflow import keras
from tensorflow.keras import layers
import matplotlib.pyplot as plt
```

In [28]:
```
## Import models and layers from keras
from keras import models
from keras import layers
from keras.utils import to_categorical
```

Load the dataset

In [3]:
```
# Load the IMDB dataset
from keras.datasets import imdb
# split train / test data
(train_data, train_labels), (test_data, test_labels) = imdb.load_data(
    num_words=10000)
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datas
ets/imdb.npz
17464789/17464789 [==============================] - 1s 0us/step
```

Prepare data

In [4]:
```
# Encode the integer sequences via multi-hot encoding
def vectorize_sequences(sequences, dimension=10000):
    results = np.zeros((len(sequences), dimension))
    for i, sequence in enumerate(sequences):
        results[i, sequence] = 1.
    return results
```

In [5]:
```
# Vectorize the data
x_train = vectorize_sequences(train_data)
x_test = vectorize_sequences(test_data)
```

In [6]:
```
# Vectorize the labels
y_train = np.asarray(train_labels).astype("float32")
y_test = np.asarray(test_labels).astype("float32")
```

Model Building

In [8]:
```
## Define keras model as sequential
model = models.Sequential()
model.add(layers.Dense(16, activation='relu', input_shape=(10000,)))
model.add(layers.Dense(16, activation='relu'))
model.add(layers.Dense(1, activation='sigmoid'))
```

In [9]:
```
# Compile the model
model.compile(optimizer="rmsprop",
              loss="binary_crossentropy",
              metrics=["accuracy"])
```

Model Validation

In [10]:
```
## Set aside a validation set (10,000 samples)
# Data
x_val = x_train[:10000]
partial_x_train = x_train[10000:]
# Labels
y_val = y_train[:10000]
partial_y_train = y_train[10000:]
```

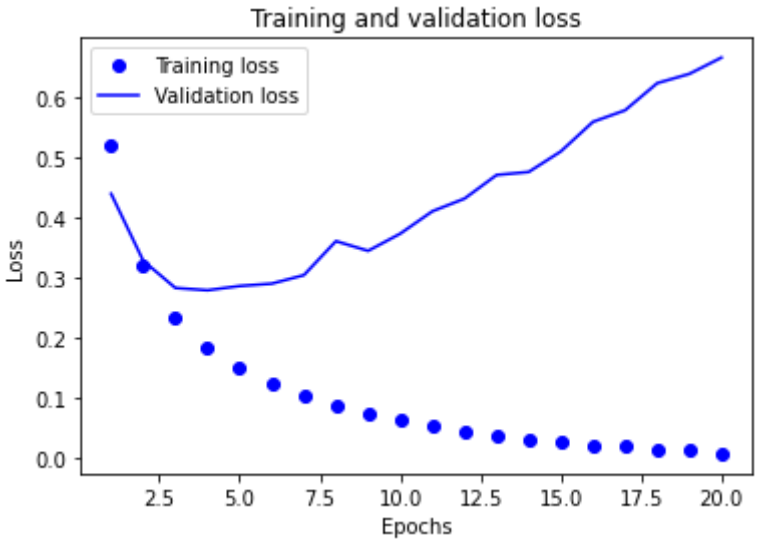
Model Training

In [11]:
```
# Train the model
history = model.fit(partial_x_train,
                    partial_y_train,
                    epochs=20,
                    batch_size=512,
                    validation_data=(x_val, y_val))
```

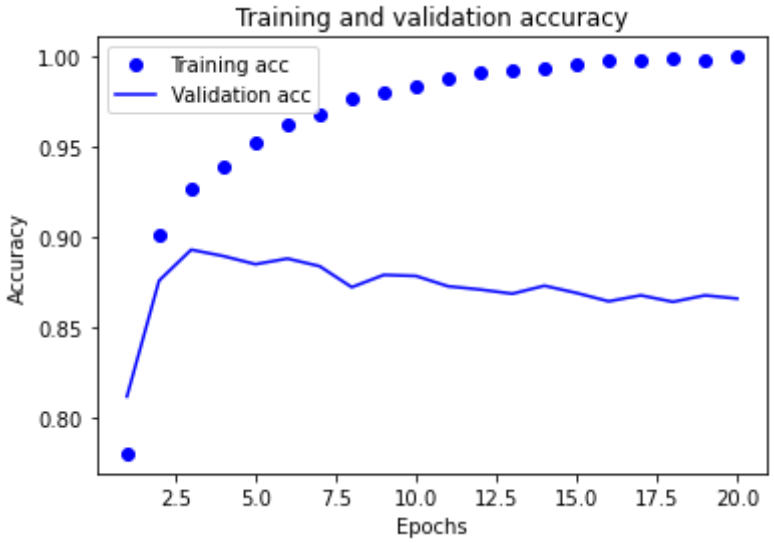
```
Epoch 1/20
30/30 [==============================] - 4s 110ms/step - loss: 0.5206 - accura
cy: 0.7805 - val_loss: 0.4386 - val_accuracy: 0.8120
Epoch 2/20
30/30 [==============================] - 1s 29ms/step - loss: 0.3208 - accurac
y: 0.9011 - val_loss: 0.3271 - val_accuracy: 0.8760
Epoch 3/20
30/30 [==============================] - 1s 32ms/step - loss: 0.2340 - accurac
y: 0.9273 - val_loss: 0.2819 - val_accuracy: 0.8931
Epoch 4/20
30/30 [==============================] - 1s 29ms/step - loss: 0.1840 - accurac
y: 0.9394 - val_loss: 0.2781 - val_accuracy: 0.8896
Epoch 5/20
30/30 [==============================] - 1s 27ms/step - loss: 0.1494 - accurac
y: 0.9529 - val_loss: 0.2852 - val_accuracy: 0.8851
Epoch 6/20
30/30 [==============================] - 1s 27ms/step - loss: 0.1233 - accurac
y: 0.9626 - val_loss: 0.2891 - val_accuracy: 0.8882
Epoch 7/20
30/30 [==============================] - 2s 54ms/step - loss: 0.1040 - accurac
y: 0.9683 - val_loss: 0.3032 - val_accuracy: 0.8840
Epoch 8/20
30/30 [==============================] - 1s 34ms/step - loss: 0.0852 - accurac
y: 0.9762 - val_loss: 0.3599 - val_accuracy: 0.8724
Epoch 9/20
30/30 [==============================] - 1s 41ms/step - loss: 0.0734 - accurac
y: 0.9798 - val_loss: 0.3437 - val_accuracy: 0.8792
Epoch 10/20
30/30 [==============================] - 1s 29ms/step - loss: 0.0622 - accurac
y: 0.9831 - val_loss: 0.3723 - val_accuracy: 0.8786
Epoch 11/20
30/30 [==============================] - 1s 33ms/step - loss: 0.0520 - accurac
y: 0.9875 - val_loss: 0.4095 - val_accuracy: 0.8729
Epoch 12/20
30/30 [==============================] - 1s 27ms/step - loss: 0.0417 - accurac
y: 0.9911 - val_loss: 0.4306 - val_accuracy: 0.8711
Epoch 13/20
30/30 [==============================] - 1s 30ms/step - loss: 0.0363 - accurac
y: 0.9927 - val_loss: 0.4700 - val_accuracy: 0.8688
Epoch 14/20
30/30 [==============================] - 1s 39ms/step - loss: 0.0306 - accurac
y: 0.9935 - val_loss: 0.4750 - val_accuracy: 0.8732
Epoch 15/20
30/30 [==============================] - 1s 28ms/step - loss: 0.0244 - accurac
y: 0.9956 - val_loss: 0.5092 - val_accuracy: 0.8692
Epoch 16/20
30/30 [==============================] - 1s 28ms/step - loss: 0.0182 - accurac
y: 0.9976 - val_loss: 0.5584 - val_accuracy: 0.8646
Epoch 17/20
30/30 [==============================] - 1s 27ms/step - loss: 0.0176 - accurac
y: 0.9975 - val_loss: 0.5776 - val_accuracy: 0.8679
Epoch 18/20
30/30 [==============================] - 1s 28ms/step - loss: 0.0128 - accurac
y: 0.9987 - val_loss: 0.6228 - val_accuracy: 0.8643
Epoch 19/20
30/30 [==============================] - 1s 27ms/step - loss: 0.0135 - accurac
y: 0.9979 - val_loss: 0.6382 - val_accuracy: 0.8679
Epoch 20/20
30/30 [==============================] - 1s 28ms/step - loss: 0.0062 - accurac
y: 0.9997 - val_loss: 0.6653 - val_accuracy: 0.8661
```

Plot Model Output and Loss

In [12]:
```
# Plot the training and validation LOSS
history_dict = history.history
loss_values = history_dict["loss"]
val_loss_values = history_dict["val_loss"]
epochs = range(1, len(loss_values) + 1)
plt.plot(epochs, loss_values, "bo", label="Training loss") # 'bo' blue dot
plt.plot(epochs, val_loss_values, "b", label="Validation loss") # 'b' blue line
plt.title("Training and validation loss")
plt.xlabel("Epochs")
plt.ylabel("Loss")
plt.legend()
plt.show()
```



In [13]:
```
# Plot the training and validation ACCURACY
plt.clf()  # clear the figure
acc = history_dict["accuracy"]
val_acc = history_dict["val_accuracy"]
plt.plot(epochs, acc, "bo", 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()
plt.show()
```



Model Fitting

In [14]:
```
# Fit model
model.fit(x_train, y_train, epochs=4, batch_size=512)
```

```
Epoch 1/4
49/49 [==============================] - 2s 30ms/step - loss: 0.2287 - accurac
y: 0.9454
Epoch 2/4
49/49 [==============================] - 1s 18ms/step - loss: 0.1411 - accurac
y: 0.9585
Epoch 3/4
49/49 [==============================] - 1s 18ms/step - loss: 0.1156 - accurac
y: 0.9653
Epoch 4/4
49/49 [==============================] - 1s 18ms/step - loss: 0.0947 - accurac
y: 0.9704
```

Out[14]:
```
<keras.callbacks.History at 0x7fce6fa21f10>
```

In [15]:
```
# Evaluate model
results = model.evaluate(x_test, y_test)
```

```
782/782 [==============================] - 2s 3ms/step - loss: 0.4833 - accura
cy: 0.8586
```

In [16]:
```
# Show results
print(f'Test loss: {results[0]:0.3f}\nTest accuracy: {results[1]:0.3f}')
```

```
Test loss: 0.483
Test accuracy: 0.859
```

Generate predictions

In [17]:
```
# Predict test data
model.predict(x_test)
```

```
782/782 [==============================] - 3s 4ms/step
```

Out[17]:
```
array([[0.01214925],
       [0.99996805],
       [0.71127635],
       ...,
       [0.03993864],
       [0.04501442],
       [0.7804223 ]], dtype=float32)
```

Assignment 5.2

Implement the news classifier found in section 3.5 of Deep Learning with Python.

Load the data

In [51]:
```
# Load the Reuters dataset
from tensorflow.keras.datasets import reuters
# split train / test data
(train_data, train_labels), (test_data, test_labels) = reuters.load_data(
    num_words=10000)
```

In [52]:
```
print("The length of traning dataset: {}".format(len(train_data)))
print("The length of test dataset: {}".format(len(test_data)))
```

```
The length of traning dataset: 8982
The length of test dataset: 2246
```

Data Preparation

In [53]:
```
# Encode the integer sequences via multi-hot encoding
def vectorize_sequences(sequences, dimension=10000):
    results = np.zeros((len(sequences), dimension))
    for i, sequence in enumerate(sequences):
        results[i, sequence] = 1.
    return results
```

In [54]:
```
# Vectorize the input data
x_train = vectorize_sequences(train_data)
x_test = vectorize_sequences(test_data)
```

In [55]:
```
# Vectorize the labels
y_train = np.asarray(train_labels).astype("float32")
y_test = np.asarray(test_labels).astype("float32")
```

In [56]:
```
# Set up one-hot encoding
def to_one_hot(labels, dimension=46):
    results = np.zeros((len(labels), dimension))
    for i, label in enumerate(labels):
        results[i, label] = 1.
    return results
```

In [57]:
```
# One-hot encode the labels
one_hot_train_labels = to_one_hot(train_labels)
one_hot_test_labels = to_one_hot(test_labels)
```

Model Building

In [58]:
```
# Define the model
model = models.Sequential()
model.add(layers.Dense(64, activation='relu', input_shape=(10000,)))
model.add(layers.Dense(64, activation='relu'))
model.add(layers.Dense(46, activation='softmax'))
```

In [59]:
```
# Compile the model
model.compile(optimizer="rmsprop",
              loss="categorical_crossentropy",
              metrics=["accuracy"])
```

Model Validation

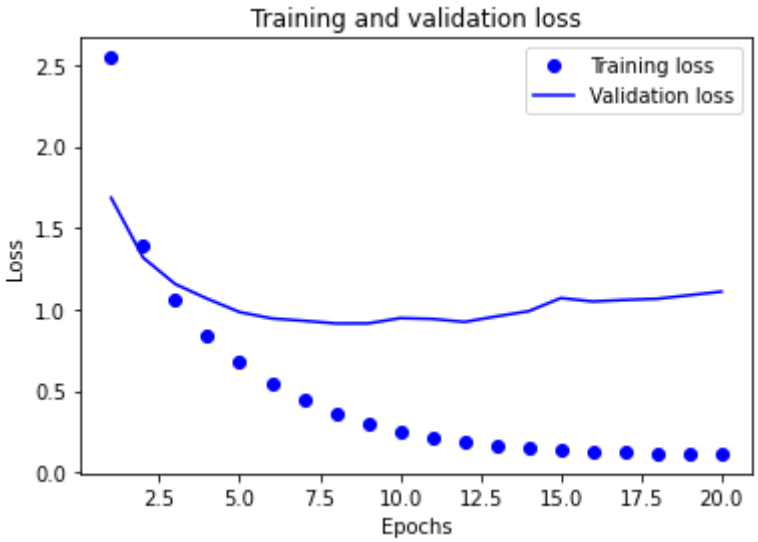
In [60]:
```
## Set aside a validation set (1000 samples)
# Data
x_val = x_train[:1000]
partial_x_train = x_train[1000:]
# Labels
y_val = one_hot_train_labels[:1000]
partial_y_train = one_hot_train_labels[1000:]
```

In [61]:
```
# Train the model
history = model.fit(partial_x_train,
                    partial_y_train,
                    epochs=20,
                    batch_size=512,
                    validation_data=(x_val, y_val))
```

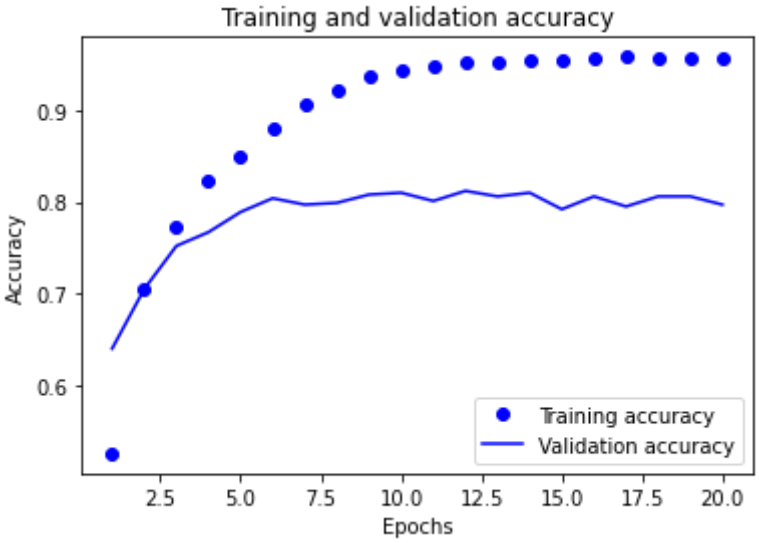
```
Epoch 1/20
16/16 [==============================] - 2s 58ms/step - loss: 2.5454 - accurac
y: 0.5256 - val_loss: 1.6854 - val_accuracy: 0.6400
Epoch 2/20
16/16 [==============================] - 1s 40ms/step - loss: 1.3972 - accurac
y: 0.7050 - val_loss: 1.3175 - val_accuracy: 0.7050
Epoch 3/20
16/16 [==============================] - 1s 41ms/step - loss: 1.0585 - accurac
y: 0.7720 - val_loss: 1.1556 - val_accuracy: 0.7520
Epoch 4/20
16/16 [==============================] - 1s 48ms/step - loss: 0.8413 - accurac
y: 0.8239 - val_loss: 1.0654 - val_accuracy: 0.7670
Epoch 5/20
16/16 [==============================] - 1s 56ms/step - loss: 0.6772 - accurac
y: 0.8502 - val_loss: 0.9840 - val_accuracy: 0.7890
Epoch 6/20
16/16 [==============================] - 1s 47ms/step - loss: 0.5454 - accurac
y: 0.8806 - val_loss: 0.9450 - val_accuracy: 0.8040
Epoch 7/20
16/16 [==============================] - 1s 57ms/step - loss: 0.4404 - accurac
y: 0.9067 - val_loss: 0.9305 - val_accuracy: 0.7970
Epoch 8/20
16/16 [==============================] - 1s 51ms/step - loss: 0.3559 - accurac
y: 0.9222 - val_loss: 0.9143 - val_accuracy: 0.7990
Epoch 9/20
16/16 [==============================] - 1s 47ms/step - loss: 0.2952 - accurac
y: 0.9362 - val_loss: 0.9145 - val_accuracy: 0.8080
Epoch 10/20
16/16 [==============================] - 1s 65ms/step - loss: 0.2463 - accurac
y: 0.9442 - val_loss: 0.9470 - val_accuracy: 0.8100
Epoch 11/20
16/16 [==============================] - 1s 76ms/step - loss: 0.2120 - accurac
y: 0.9481 - val_loss: 0.9420 - val_accuracy: 0.8010
Epoch 12/20
16/16 [==============================] - 1s 54ms/step - loss: 0.1840 - accurac
y: 0.9514 - val_loss: 0.9235 - val_accuracy: 0.8120
Epoch 13/20
16/16 [==============================] - 1s 58ms/step - loss: 0.1689 - accurac
y: 0.9531 - val_loss: 0.9579 - val_accuracy: 0.8060
Epoch 14/20
16/16 [==============================] - 1s 44ms/step - loss: 0.1535 - accurac
y: 0.9536 - val_loss: 0.9896 - val_accuracy: 0.8100
Epoch 15/20
16/16 [==============================] - 1s 70ms/step - loss: 0.1403 - accurac
y: 0.9553 - val_loss: 1.0700 - val_accuracy: 0.7920
Epoch 16/20
16/16 [==============================] - 1s 43ms/step - loss: 0.1324 - accurac
y: 0.9558 - val_loss: 1.0491 - val_accuracy: 0.8060
Epoch 17/20
16/16 [==============================] - 1s 68ms/step - loss: 0.1261 - accurac
y: 0.9584 - val_loss: 1.0587 - val_accuracy: 0.7950
Epoch 18/20
16/16 [==============================] - 1s 41ms/step - loss: 0.1196 - accurac
y: 0.9568 - val_loss: 1.0656 - val_accuracy: 0.8060
Epoch 19/20
16/16 [==============================] - 1s 59ms/step - loss: 0.1155 - accurac
y: 0.9564 - val_loss: 1.0875 - val_accuracy: 0.8060
Epoch 20/20
16/16 [==============================] - 1s 61ms/step - loss: 0.1154 - accurac
y: 0.9575 - val_loss: 1.1097 - val_accuracy: 0.7970
```

Plot the result

In [62]:
```
# Plot the training and validation LOSS
loss = history.history["loss"]
val_loss = history.history["val_loss"]
epochs = range(1, len(loss) + 1)
plt.plot(epochs, loss, "bo", label="Training loss")
plt.plot(epochs, val_loss, "b", label="Validation loss")
plt.title("Training and validation loss")
plt.xlabel("Epochs")
plt.ylabel("Loss")
plt.legend()
plt.show()
```



In [63]:
```
# Plot the training and validation ACCURACY
plt.clf()
acc = history.history["accuracy"]
val_acc = history.history["val_accuracy"]
plt.plot(epochs, acc, "bo", label="Training accuracy")
plt.plot(epochs, val_acc, "b", label="Validation accuracy")
plt.title("Training and validation accuracy")
plt.xlabel("Epochs")
plt.ylabel("Accuracy")
plt.legend()
plt.show()
```



Model Fitting

In [64]:
```
# Fit model
model.fit(x_train,
          y_train,
          epochs=9,
          batch_size=512)
```

```
Epoch 1/9
2023-04-16 23:10:36.980548: W tensorflow/core/common_runtime/forward_type_infe
rence.cc:231] Type inference failed. This indicates an invalid graph that esca
ped type checking. Error message: INVALID_ARGUMENT: expected compatible input
types, but input 1:
type_id: TFT_OPTIONAL
args {
  type_id: TFT_PRODUCT
  args {
    type_id: TFT_TENSOR
    args {
      type_id: TFT_BOOL
    }
  }
}
 is neither a subtype nor a supertype of the combined inputs preceding it:
type_id: TFT_OPTIONAL
args {
  type_id: TFT_PRODUCT
  args {
    type_id: TFT_TENSOR
    args {
      type_id: TFT_LEGACY_VARIANT
    }
  }
}

        while inferring type of node 'categorical_crossentropy/cond/output/_1
0'
```

```
---------------------------------------------------------------------------
InvalidArgumentError                      Traceback (most recent call last)
Input In [64], in <cell line: 2>()
      1 # Fit model
----> 2 model.fit(x train,
      3           y_train,
      4           epochs=9,
      5           batch_size=512)

File ~/opt/anaconda3/lib/python3.9/site-packages/keras/utils/traceback_utils.p
y:67, in filter_traceback.<locals>.error_handler(*args, **kwargs)
     65 except Exception as e:  # pylint: disable=broad-except
     66   filtered_tb = _process_traceback_frames(e.__traceback__)
---> 67   raise e.with_traceback(filtered_tb) from None
     68 finally:
     69   del filtered_tb

File ~/opt/anaconda3/lib/python3.9/site-packages/tensorflow/python/eager/execu
te.py:54, in quick_execute(op_name, num_outputs, inputs, attrs, ctx, name)
     52 try:
     53   ctx.ensure_initialized()
---> 54   tensors = pywrap_tfe.TFE_Py_Execute(ctx._handle, device_name, op_nam
e,
     55                                       inputs, attrs, num_outputs)
     56 except core._NotOkStatusException as e:
     57   if name is not None:

InvalidArgumentError: Graph execution error:

Detected at node 'gradient_tape/categorical_crossentropy/mul/BroadcastGradient
Args' defined at (most recent call last):
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/runpy.py", line 197,
in _run_module_as_main
      return _run_code(code, main_globals, None,
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/runpy.py", line 87, i
n _run_code
      exec(code, run_globals)
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/site-packages/ipykern
el_launcher.py", line 16, in <module>
      app.launch_new_instance()
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/site-packages/traitle
ts/config/application.py", line 846, in launch_instance
      app.start()
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/site-packages/ipykern
el/kernelapp.py", line 677, in start
      self.io_loop.start()
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/site-packages/tornad
o/platform/asyncio.py", line 199, in start
      self.asyncio_loop.run_forever()
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/asyncio/base_events.p
y", line 596, in run_forever
      self._run_once()
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/asyncio/base_events.p
y", line 1890, in _run_once
      handle._run()
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/asyncio/events.py", l
ine 80, in _run
      self._context.run(self._callback, *self._args)
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/site-packages/ipykern
el/kernelbase.py", line 471, in dispatch_queue
```

```
      await self.process_one()
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/site-packages/ipykern
el/kernelbase.py", line 460, in process_one
      await dispatch(*args)
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/site-packages/ipykern
el/kernelbase.py", line 367, in dispatch_shell
      await result
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/site-packages/ipykern
el/kernelbase.py", line 662, in execute_request
      reply_content = await reply_content
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/site-packages/ipykern
el/ipkernel.py", line 360, in do_execute
      res = shell.run_cell(code, store_history=store_history, silent=silent)
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/site-packages/ipykern
el/zmqshell.py", line 532, in run_cell
      return super().run_cell(*args, **kwargs)
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/site-packages/IPytho
n/core/interactiveshell.py", line 2880, in run_cell
      result = self._run_cell(
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/site-packages/IPytho
n/core/interactiveshell.py", line 2935, in _run_cell
      return runner(coro)
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/site-packages/IPytho
n/core/async_helpers.py", line 129, in _pseudo_sync_runner
      coro.send(None)
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/site-packages/IPytho
n/core/interactiveshell.py", line 3134, in run_cell_async
      has_raised = await self.run_ast_nodes(code_ast.body, cell_name,
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/site-packages/IPytho
n/core/interactiveshell.py", line 3337, in run_ast_nodes
      if await self.run_code(code, result, async_=asy):
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/site-packages/IPytho
n/core/interactiveshell.py", line 3397, in run_code
      exec(code_obj, self.user_global_ns, self.user_ns)
    File "/var/folders/0c/spq36xkd5vz7k9940sd5prhw0000gn/T/ipykernel_2957/1659
230057.py", line 2, in <cell line: 2>
      model.fit(x_train,
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/site-packages/keras/u
tils/traceback_utils.py", line 64, in error_handler
      return fn(*args, **kwargs)
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/site-packages/keras/e
ngine/training.py", line 1409, in fit
      tmp_logs = self.train_function(iterator)
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/site-packages/keras/e
ngine/training.py", line 1051, in train_function
      return step_function(self, iterator)
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/site-packages/keras/e
ngine/training.py", line 1040, in step_function
      outputs = model.distribute_strategy.run(run_step, args=(data,))
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/site-packages/keras/e
ngine/training.py", line 1030, in run_step
      outputs = model.train_step(data)
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/site-packages/keras/e
ngine/training.py", line 893, in train_step
      self.optimizer.minimize(loss, self.trainable_variables, tape=tape)
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/site-packages/keras/o
ptimizers/optimizer_v2/optimizer_v2.py", line 537, in minimize
      grads_and_vars = self._compute_gradients(
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/site-packages/keras/o
ptimizers/optimizer_v2/optimizer_v2.py", line 590, in _compute_gradients
```

```
      grads_and_vars = self._get_gradients(tape, loss, var_list, grad_loss)
    File "/Users/anjanibonda/opt/anaconda3/lib/python3.9/site-packages/keras/optimizers/optimizer_v2/optimizer_v2.py", line 471, in _get_gradients
      grads = tape.gradient(loss, var_list, grad_loss)
Node: 'gradient_tape/categorical_crossentropy/mul/BroadcastGradientArgs'
Incompatible shapes: [512] vs. [512,46]
         [[{{node gradient_tape/categorical_crossentropy/mul/BroadcastGradientArgs}}]] [Op:__inference_train_function_6274]
```

In [35]:
```
# Evaluate model
results = model.evaluate(x_test, y_test)
```

```
71/71 [==============================] - 0s 2ms/step - loss: 1.3359 - accuracy: 0.7876
```

In [37]:
```
# Show results
print(f'Test loss: {results[0]:0.3f}\nTest accuracy: {results[1]:0.3f}')
```

```
Test loss: 1.336
Test accuracy: 0.788
```

In [38]:
```
# Predict test data
predictions = model.predict(x_test)
```

In [39]:
```
predictions[0]
```

Out[39]:
```
array([4.96593930e-06, 8.68394636e-07, 1.36702042e-07, 8.62344682e-01,
       7.67317712e-02, 1.47404214e-10, 3.00806868e-09, 6.34642565e-05,
       6.04539830e-03, 1.01301430e-06, 4.23747331e-08, 2.77778786e-02,
       3.22184064e-06, 5.35935169e-06, 3.60176813e-08, 2.30063506e-07,
       6.53075171e-04, 4.67550336e-08, 1.18455284e-06, 2.89977156e-03,
       2.32233517e-02, 1.07884094e-04, 2.67851181e-08, 6.77256153e-08,
       4.97829822e-09, 4.14858590e-07, 2.04205611e-10, 1.11060615e-07,
       4.64958021e-06, 3.71215856e-06, 1.65704259e-05, 1.66338974e-11,
       9.97571419e-07, 9.28010724e-10, 5.14841759e-06, 1.58880198e-07,
       7.74415894e-05, 4.70382240e-08, 4.13131920e-06, 2.11911884e-05,
       3.13704675e-07, 5.16779664e-07, 7.80447973e-09, 1.84905355e-10,
       2.11908702e-12, 1.00457470e-07], dtype=float32)
```

Assignment 5.3

Implement the housing price regression model found in section 3.6 of Deep Learning with Python

Load Data

In [50]:
```
# Load the Boston Housing dataset
from keras.datasets import boston_housing
# split train / test data
(train_data, train_targets), (test_data, test_targets) = boston_housing.load_da
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/boston_housing.npz
57026/57026 [==============================] - 0s 1us/step
```

In [51]:
```
print("The length of traning dataset: {}".format(len(train_data)))
print("The length of test dataset: {}".format(len(test_data)))
```

```
The length of traning dataset: 404
The length of test dataset: 102
```

Data Preparation

In [52]:
```
## Perform feature-wise normalization
# Normalize train data
mean = train_data.mean(axis=0)
train_data -= mean
std = train_data.std(axis=0)
train_data /=std
# Normalize test data
test_data -= mean
test_data /= std
```

Model Building

In [53]:
```
def build_model():
    # Define the model
    model = models.Sequential()
    model.add(layers.Dense(64, activation='relu',
                           input_shape=(train_data.shape[1],)))
    model.add(layers.Dense(64, activation='relu'))
    model.add(layers.Dense(1))
    # Compile the model
    model.compile(optimizer='rmsprop', loss='mse', metrics=['mae'])
    return model
```

Validate the model

In [54]:
```
# Set up K-fold validation
k = 4
num_val_samples = len(train_data) // k
num_epochs = 500
all_mae_histories = []
for i in range(k):
    print(f"Processing fold #: {i}")
    # prepare the validation data (from partition #k)
    val_data = train_data[i * num_val_samples: (i + 1) * num_val_samples]
    val_targets = train_targets[i * num_val_samples: (i + 1) * num_val_samples]

    # prepare training data (from non-k partitions)
    partial_train_data = np.concatenate(
        [train_data[:i * num_val_samples],
         train_data[(i + 1) * num_val_samples:]],
        axis=0)
    partial_train_targets = np.concatenate(
        [train_targets[:i * num_val_samples],
         train_targets[(i + 1) * num_val_samples:]],
        axis=0)

    # build the already compiled keras model
    model = build_model()

    # train the model, saving validation logs at each fold
    history = model.fit(partial_train_data, partial_train_targets,
                        validation_data=(val_data, val_targets),
```

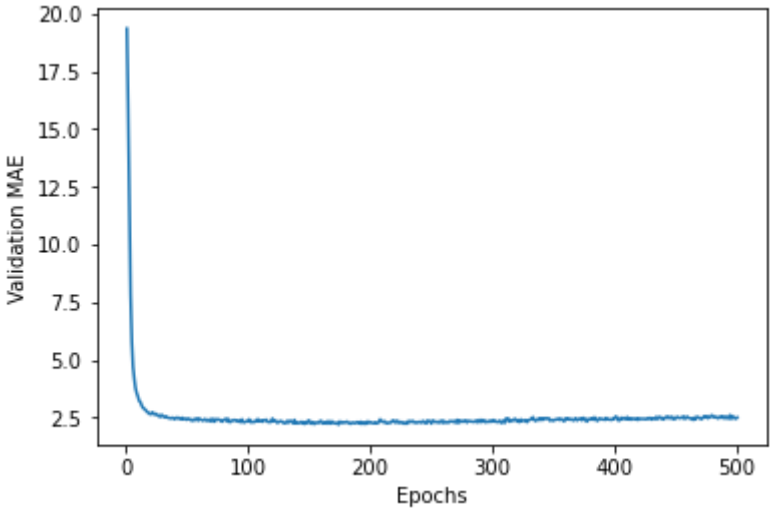
```
                          epochs=num_epochs, batch_size=16, verbose=0) # verbose=
    mae_history = history.history["val_mae"]
    all_mae_histories.append(mae_history)
```

```
Processing fold #: 0
Processing fold #: 1
Processing fold #: 2
Processing fold #: 3
```

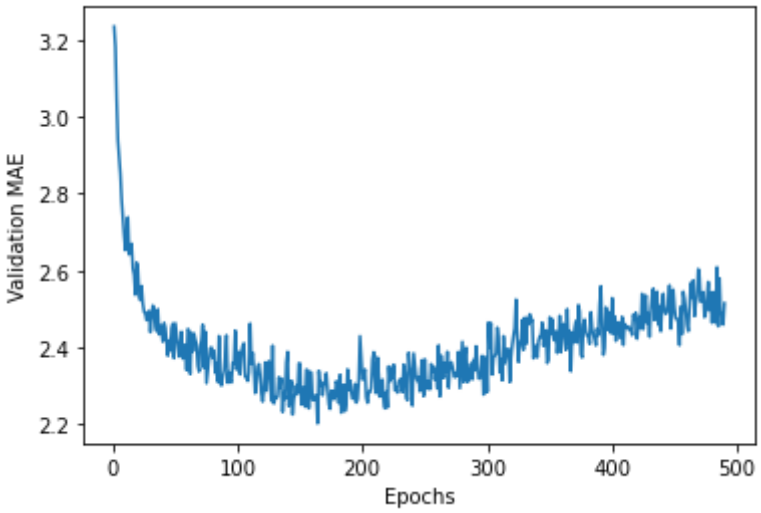
In [55]:
```
# Compute the average of per-epoch MAE scores for all folds
average_mae_history = [
    np.mean([x[i] for x in all_mae_histories]) for i in range(num_epochs)
]
```

Plot the results

In [56]:
```
# Plot the validation MAE by epoch
plt.plot(range(1, len(average_mae_history) + 1), average_mae_history)
plt.xlabel("Epochs")
plt.ylabel("Validation MAE")
plt.show()
```



In [57]:
```
# Plot again, omitting the first 10 data points
truncated_mae_history = average_mae_history[10:]
plt.plot(range(1, len(truncated_mae_history) + 1), truncated_mae_history)
plt.xlabel("Epochs")
plt.ylabel("Validation MAE")
plt.show()
```



Model Training

In [58]:
```
model = build_model() # get a fresh compiled model
# Train on the entirety of the training data
model.fit(train_data, train_targets,
          epochs=130, batch_size=16, verbose=0)
test_mse_score, test_mae_score = model.evaluate(test_data, test_targets)
```

```
4/4 [==============================] - 0s 3ms/step - loss: 18.8116 - mae: 2.56
01
```

In [59]:
```
# Evaluate model
test_mae_score
```

Out[59]:
```
2.5600898265838623
```

Generate Predictions

In [60]:
```
# Predict test data
predictions = model.predict(test_data)
predictions[0]
```

```
4/4 [==============================] - 0s 3ms/step
```

Out[60]:
```
array([8.194735], dtype=float32)
```

In [ ]:
```

```