Week5: Assignments

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import required packages

In [1]:
```
from tensorflow import keras
from keras import models
from keras import layers
from keras.datasets import imdb
import numpy as np
import matplotlib.pyplot as plt
from tensorflow.keras.utils import to_categorical

from IPython.core.interactiveshell import InteractiveShell
InteractiveShell.ast_node_interactivity = 'all'
```

Assignment 5.1: Classifying movie reviews: A binary classification example

In [2]:
```
# load the data

(train_data, train_labels), (test_data, test_labels) = imdb.load_data(num_words=10000)
```

In [3]:
```
# display train and test data sample

print(train_data[0])
train_labels[0]
```

```
[1, 14, 22, 16, 43, 530, 973, 1622, 1385, 65, 458, 4468, 66, 3941, 4, 173, 36, 256, 5, 25, 100, 43, 838, 112, 5
0, 670, 2, 9, 35, 480, 284, 5, 150, 4, 172, 112, 167, 2, 336, 385, 39, 4, 172, 4536, 1111, 17, 546, 38, 13, 44
7, 4, 192, 50, 16, 6, 147, 2025, 19, 14, 22, 4, 1920, 4613, 469, 4, 22, 71, 87, 12, 16, 43, 530, 38, 76, 15, 1
3, 1247, 4, 22, 17, 515, 17, 12, 16, 626, 18, 2, 5, 62, 386, 12, 8, 316, 8, 106, 5, 4, 2223, 5244, 16, 480, 66,
3785, 33, 4, 130, 12, 16, 38, 619, 5, 25, 124, 51, 36, 135, 48, 25, 1415, 33, 6, 22, 12, 215, 28, 77, 52, 5, 1
4, 407, 16, 82, 2, 8, 4, 107, 117, 5952, 15, 256, 4, 2, 7, 3766, 5, 723, 36, 71, 43, 530, 476, 26, 400, 317, 4
6, 7, 4, 2, 1029, 13, 104, 88, 4, 381, 15, 297, 98, 32, 2071, 56, 26, 141, 6, 194, 7486, 18, 4, 226, 22, 21, 13
4, 476, 26, 480, 5, 144, 30, 5535, 18, 51, 36, 28, 224, 92, 25, 104, 4, 226, 65, 16, 38, 1334, 88, 12, 16, 283,
5, 16, 4472, 113, 103, 32, 15, 16, 5345, 19, 178, 32]
```

Out[3]: 1

Encoding the integer sequences into a binary matrix

In [4]:
```
# create function to encode sequence

def vectorize_sequences(sequences, dimension=10000):
    results = np.zeros((len(sequences), dimension))
    for i, sequence in enumerate(sequences):
        for j in sequence:
            results[i, j] = 1.
    return results
x_train = vectorize_sequences(train_data)
x_test = vectorize_sequences(test_data)
```

In [5]:
```
# display sample of training data after encoding

x_train[0]
```

Out[5]: array([0., 1., 1., ..., 0., 0., 0.])

In [6]:
```
# vectorize the lables

y_train = np.asarray(train_labels).astype("float32")
y_test = np.asarray(test_labels).astype("float32")
```

Build the NN Model

In [7]:
```
model = keras.Sequential([
    layers.Dense(16, activation="relu"),
    layers.Dense(16, activation="relu"),
    layers.Dense(1, activation="sigmoid")
])
```

```
2022-04-17 10:56:30.634364: I tensorflow/core/platform/cpu_feature_guard.cc:151] This TensorFlow binary is opti
mized with oneAPI Deep Neural Network Library (oneDNN) to use the following CPU instructions in performance-cri
tical operations:  AVX2 FMA
To enable them in other operations, rebuild TensorFlow with the appropriate compiler flags.
```

Compile the model

In [8]:
```
model.compile(optimizer="rmsprop",
              loss="binary_crossentropy",
              metrics=["accuracy"])
```

Splitting data into training and validation

In [9]:
```
x_val = x_train[:10000]
partial_x_train = x_train[10000:]
y_val = y_train[:10000]
partial_y_train = y_train[10000:]
```

Train the model

In [10]:
```
history = model.fit(partial_x_train,
                    partial_y_train,
                    epochs=20,
                    batch_size=512,
                    validation_data=(x_val, y_val))
```

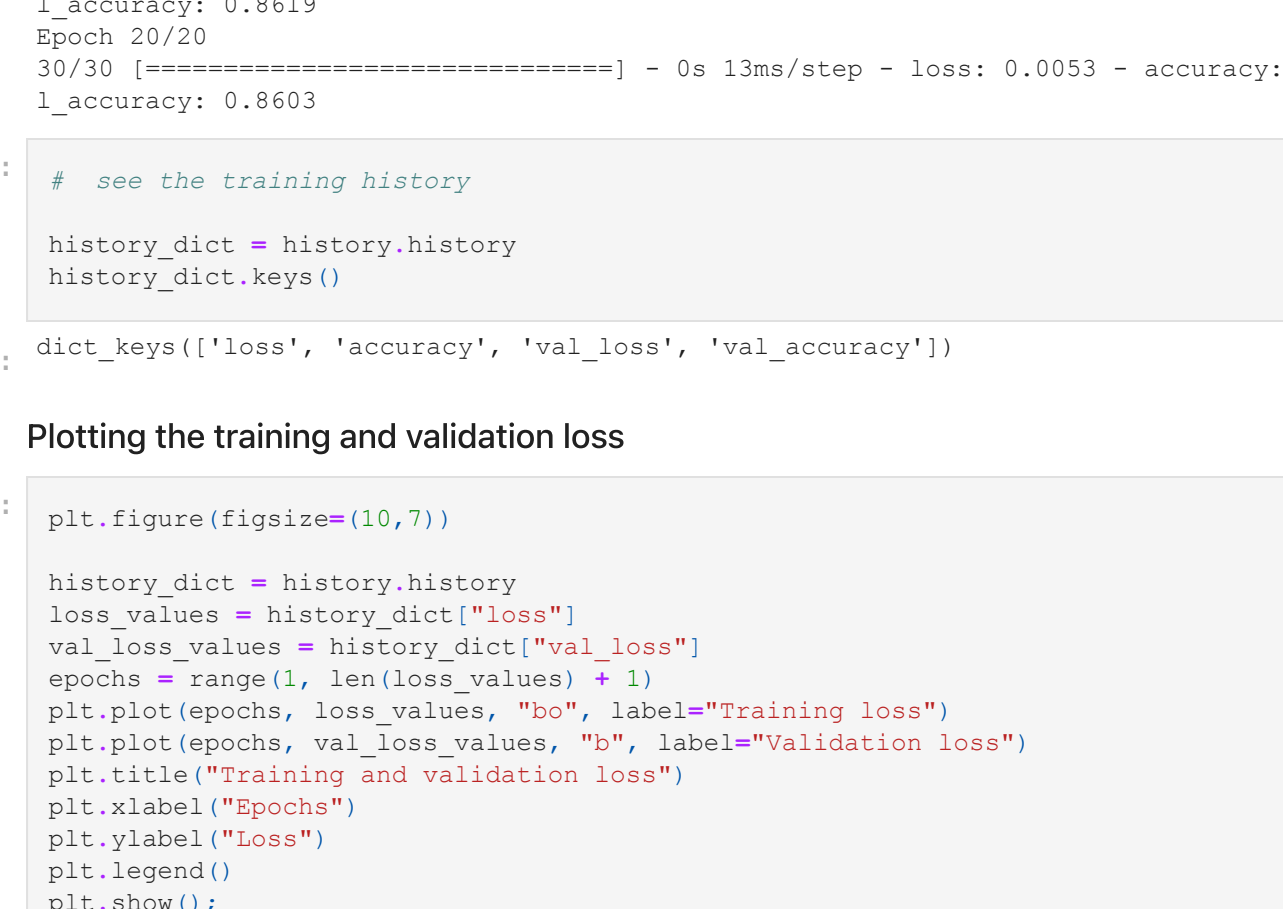
```
Epoch 1/20
30/30 [==============================] - 3s 69ms/step - loss: 0.5071 - accuracy: 0.7899 - val_loss: 0.3863 - va
l_accuracy: 0.8703
Epoch 2/20
30/30 [==============================] - 0s 15ms/step - loss: 0.3069 - accuracy: 0.9043 - val_loss: 0.3096 - va
l_accuracy: 0.8870
Epoch 3/20
30/30 [==============================] - 0s 13ms/step - loss: 0.2246 - accuracy: 0.9288 - val_loss: 0.2816 - va
l_accuracy: 0.8892
Epoch 4/20
30/30 [==============================] - 0s 13ms/step - loss: 0.1792 - accuracy: 0.9407 - val_loss: 0.2817 - va
l_accuracy: 0.8860
Epoch 5/20
30/30 [==============================] - 0s 15ms/step - loss: 0.1454 - accuracy: 0.9545 - val_loss: 0.2880 - va
l_accuracy: 0.8840
Epoch 6/20
30/30 [==============================] - 0s 13ms/step - loss: 0.1201 - accuracy: 0.9633 - val_loss: 0.3103 - va
l_accuracy: 0.8825
Epoch 7/20
30/30 [==============================] - 0s 16ms/step - loss: 0.1005 - accuracy: 0.9703 - val_loss: 0.3057 - va
l_accuracy: 0.8841
Epoch 8/20
30/30 [==============================] - 0s 13ms/step - loss: 0.0827 - accuracy: 0.9767 - val_loss: 0.3256 - va
l_accuracy: 0.8820
Epoch 9/20
30/30 [==============================] - 0s 13ms/step - loss: 0.0713 - accuracy: 0.9799 - val_loss: 0.3523 - va
l_accuracy: 0.8799
Epoch 10/20
30/30 [==============================] - 0s 13ms/step - loss: 0.0580 - accuracy: 0.9856 - val_loss: 0.3721 - va
l_accuracy: 0.8769
Epoch 11/20
30/30 [==============================] - 0s 13ms/step - loss: 0.0453 - accuracy: 0.9895 - val_loss: 0.3984 - va
l_accuracy: 0.8747
Epoch 12/20
30/30 [==============================] - 0s 13ms/step - loss: 0.0381 - accuracy: 0.9917 - val_loss: 0.4344 - va
l_accuracy: 0.8758
Epoch 13/20
30/30 [==============================] - 0s 13ms/step - loss: 0.0313 - accuracy: 0.9931 - val_loss: 0.4585 - va
l_accuracy: 0.8729
Epoch 14/20
30/30 [==============================] - 0s 13ms/step - loss: 0.0263 - accuracy: 0.9954 - val_loss: 0.5093 - va
l_accuracy: 0.8720
Epoch 15/20
30/30 [==============================] - 0s 13ms/step - loss: 0.0213 - accuracy: 0.9961 - val_loss: 0.5226 - va
l_accuracy: 0.8675
Epoch 16/20
30/30 [==============================] - 0s 13ms/step - loss: 0.0174 - accuracy: 0.9973 - val_loss: 0.5685 - va
l_accuracy: 0.8688
Epoch 17/20
30/30 [==============================] - 0s 13ms/step - loss: 0.0116 - accuracy: 0.9991 - val_loss: 0.6928 - va
l_accuracy: 0.8589
Epoch 18/20
30/30 [==============================] - 0s 13ms/step - loss: 0.0102 - accuracy: 0.9993 - val_loss: 0.6292 - va
l_accuracy: 0.8678
Epoch 19/20
30/30 [==============================] - 0s 14ms/step - loss: 0.0062 - accuracy: 0.9991 - val_loss: 0.7379 - va
l_accuracy: 0.8619
Epoch 20/20
30/30 [==============================] - 0s 13ms/step - loss: 0.0053 - accuracy: 0.9997 - val_loss: 0.7032 - va
l_accuracy: 0.8603
```

In [11]:
```
# see the training history

history_dict = history.history
history_dict.keys()
```

Out[11]: dict_keys(['loss', 'accuracy', 'val_loss', 'val_accuracy'])

Plotting the training and validation loss

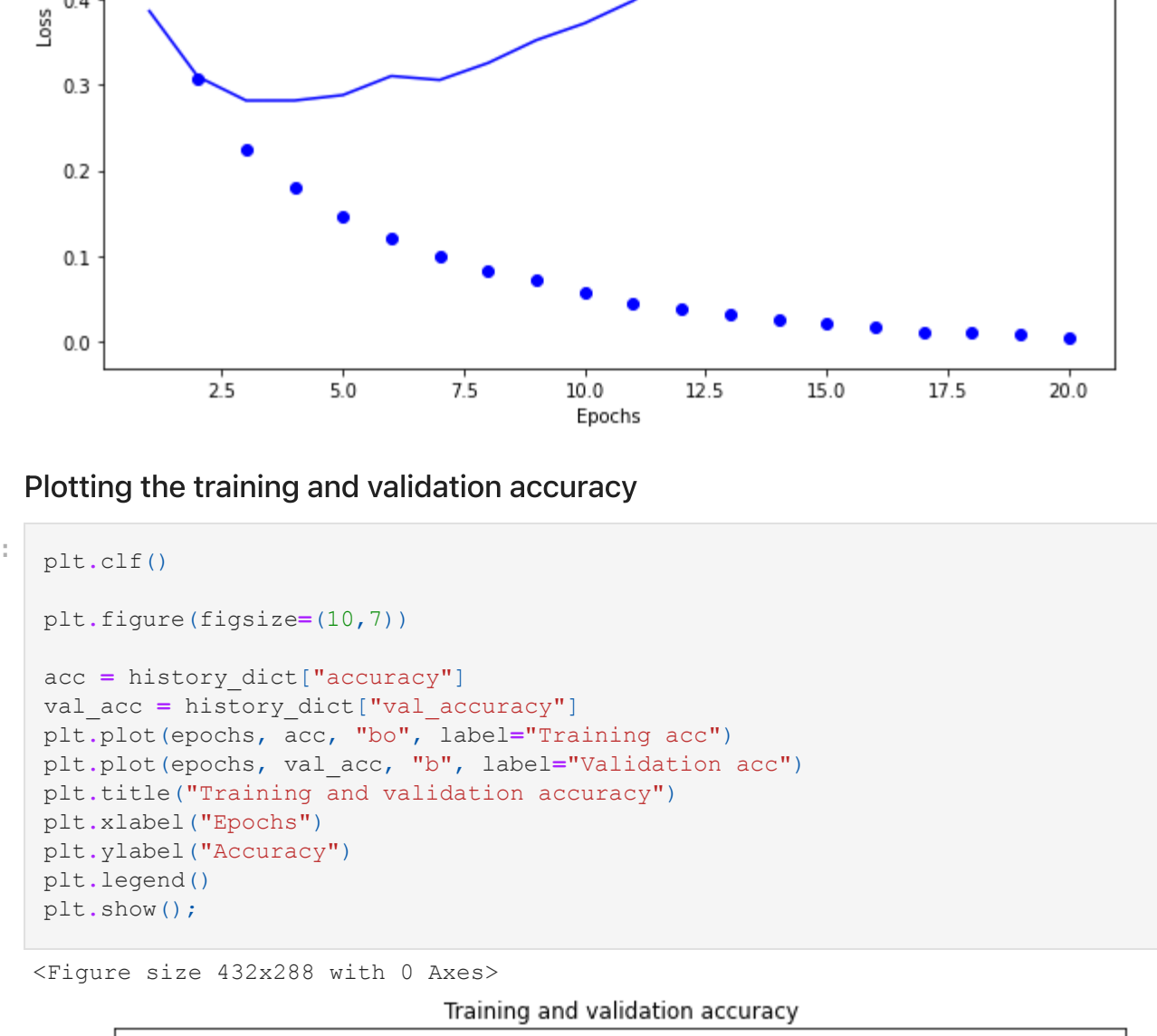
In [12]:
```
plt.figure(figsize=(10,7))

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")
plt.plot(epochs, val_loss_values, "b", label="Validation loss")
plt.title("Training and validation loss")
plt.xlabel("Epochs")
plt.ylabel("Loss")
plt.legend()
plt.show();
```



Plotting the training and validation accuracy

In [13]:
```
plt.clf()

plt.figure(figsize=(10,7))

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();
```

<Figure size 432x288 with 0 Axes>



Retraining a model from scratch - for 4 epochs

In [14]:
```
model = keras.Sequential([
    layers.Dense(16, activation="relu"),
    layers.Dense(16, activation="relu"),
    layers.Dense(1, activation="sigmoid")
])
model.compile(optimizer="rmsprop",
              loss="binary_crossentropy",
              metrics=["accuracy"])
model.fit(x_train, y_train, epochs=4, batch_size=512)
results = model.evaluate(x_test, y_test)
```

```
Epoch 1/4
49/49 [==============================] - 1s 15ms/step - loss: 0.4464 - accuracy: 0.8209
Epoch 2/4
49/49 [==============================] - 0s 8ms/step - loss: 0.2545 - accuracy: 0.9110
Epoch 3/4
49/49 [==============================] - 0s 8ms/step - loss: 0.1990 - accuracy: 0.9305
Epoch 4/4
49/49 [==============================] - 0s 8ms/step - loss: 0.1652 - accuracy: 0.9422
```

Out[14]: <keras.callbacks.History at 0x1630c5c40>

```
782/782 [==============================] - 1s 1ms/step - loss: 0.2949 - accuracy: 0.8832
```

In [15]:
```
# display the result

results
```

Out[15]: [0.29487749353964233, 0.8831599950790405]

In [16]:
```
print(f"The accuracy of the model is {round(results[1],2)*100}%")
```

The accuracy of the model is 88.0%

generate predictions on new data

In [18]:
```
model.predict(x_test)[:5]
```

Out[18]:
```
array([[0.16713482],
       [0.9998865 ],
       [0.88808084],
       [0.82244337],
       [0.957493  ]], dtype=float32)
```

Further experiments

Retraining a model from scratch - for 4 epochs with 3 hidden layers

In [19]:
```
model = keras.Sequential([
    layers.Dense(16, activation="relu"),
    layers.Dense(16, activation="relu"),
    layers.Dense(16, activation="relu"),
    layers.Dense(1, activation="sigmoid")
])
model.compile(optimizer="rmsprop",
              loss="binary_crossentropy",
              metrics=["accuracy"])
model.fit(x_train, y_train, epochs=4, batch_size=512)
results = model.evaluate(x_test, y_test)
```

```
Epoch 1/4
49/49 [==============================] - 1s 14ms/step - loss: 0.4451 - accuracy: 0.8171
Epoch 2/4
49/49 [==============================] - 0s 8ms/step - loss: 0.2477 - accuracy: 0.9078
Epoch 3/4
49/49 [==============================] - 0s 8ms/step - loss: 0.1917 - accuracy: 0.9286
Epoch 4/4
49/49 [==============================] - 0s 8ms/step - loss: 0.1568 - accuracy: 0.9444
```

Out[19]: <keras.callbacks.History at 0x162497eb0>

```
782/782 [==============================] - 1s 2ms/step - loss: 0.3205 - accuracy: 0.8773
```

In [20]:
```
print(f"The accuracy of the model is {round(results[1],2)*100}%")

# generate predictions on new data

model.predict(x_test)[:5]

# it seems accuracy did not change by adding 1 extra hidden layer but the predictions got changed (less confid
```

The accuracy of the model is 88.0%

Out[20]:
```
array([[0.12783876],
       [0.9995216 ],
       [0.39128823],
       [0.8492501 ],
       [0.95924145]], dtype=float32)
```

Retraining a model from scratch - for 4 epochs with multiple hidden layer with 32 and 64 units

In [21]:
```
model = keras.Sequential([
    layers.Dense(32, activation="relu"),
    layers.Dense(64, activation="relu"),
    layers.Dense(32, activation="relu"),
    layers.Dense(1, activation="sigmoid")
])
model.compile(optimizer="rmsprop",
              loss="binary_crossentropy",
              metrics=["accuracy"])
model.fit(x_train, y_train, epochs=4, batch_size=512)
results = model.evaluate(x_test, y_test)
```

```
Epoch 1/4
49/49 [==============================] - 2s 15ms/step - loss: 0.4705 - accuracy: 0.7957
Epoch 2/4
49/49 [==============================] - 0s 9ms/step - loss: 0.2523 - accuracy: 0.9062
Epoch 3/4
49/49 [==============================] - 0s 9ms/step - loss: 0.1964 - accuracy: 0.9266
Epoch 4/4
49/49 [==============================] - 0s 10ms/step - loss: 0.1653 - accuracy: 0.9374
```

Out[21]: <keras.callbacks.History at 0x1659bc6c0>

```
782/782 [==============================] - 1s 2ms/step - loss: 0.3295 - accuracy: 0.8766
```

In [24]:
```
print(f"The accuracy of the model is {round(results[1],2)*100}%")

# generate predictions on new data

model.predict(x_test)[:5]

# the accuracy unchanged but predictions improved
```

The accuracy of the model is 88.0%

Out[24]:
```
array([[0.15023993],
       [0.9982275 ],
       [0.7006961 ],
       [0.62140115],
       [0.9586922 ]], dtype=float32)
```

using the mse loss function instead of binary_crossentropy

In [25]:
```
model = keras.Sequential([
    layers.Dense(16, activation="relu"),
    layers.Dense(16, activation="relu"),
    # layers.Dense(32, activation="relu"),
    layers.Dense(1, activation="sigmoid")
])
model.compile(optimizer="rmsprop",
              loss="mse",
              metrics=["accuracy"])
model.fit(x_train, y_train, epochs=4, batch_size=512)
results = model.evaluate(x_test, y_test)
```

```
Epoch 1/4
49/49 [==============================] - 1s 20ms/step - loss: 0.1397 - accuracy: 0.8233
Epoch 2/4
49/49 [==============================] - 0s 8ms/step - loss: 0.0741 - accuracy: 0.9120
Epoch 3/4
49/49 [==============================] - 0s 8ms/step - loss: 0.0564 - accuracy: 0.9327
Epoch 4/4
49/49 [==============================] - 0s 8ms/step - loss: 0.0460 - accuracy: 0.9463
```

Out[25]: <keras.callbacks.History at 0x16487eb0>

```
782/782 [==============================] - 1s 1ms/step - loss: 0.0868 - accuracy: 0.8819
```

In [26]:
```
print(f"The accuracy of the model is {round(results[1],2)*100}%")

# generate predictions on new data

model.predict(x_test)[:5]

# the accuracy unchanged but predictions improved
```

The accuracy of the model is 88.0%

Out[26]:
```
array([[0.16193843],
       [0.9994571 ],
       [0.7189584 ],
       [0.8269198 ],
       [0.8366305 ]], dtype=float32)
```

using the tanh activation

In [28]:
```
model = keras.Sequential([
    layers.Dense(16, activation="tanh"),
    layers.Dense(16, activation="tanh"),
    # layers.Dense(32, activation="relu"),
    layers.Dense(1, activation="sigmoid")
])
model.compile(optimizer="rmsprop",
              loss="binary_crossentropy",
              metrics=["accuracy"])
model.fit(x_train, y_train, epochs=4, batch_size=512)
results = model.evaluate(x_test, y_test)
```

```
Epoch 1/4
49/49 [==============================] - 1s 14ms/step - loss: 0.4295 - accuracy: 0.8295
Epoch 2/4
49/49 [==============================] - 0s 8ms/step - loss: 0.2442 - accuracy: 0.9133
Epoch 3/4
49/49 [==============================] - 0s 8ms/step - loss: 0.1829 - accuracy: 0.9337
Epoch 4/4
49/49 [==============================] - 0s 8ms/step - loss: 0.1516 - accuracy: 0.9462
```

Out[28]: <keras.callbacks.History at 0x161e07df0>

```
782/782 [==============================] - 1s 1ms/step - loss: 0.3526 - accuracy: 0.8676
```

In [29]:
```
print(f"The accuracy of the model is {round(results[1],2)*100}%")

# generate predictions on new data

model.predict(x_test)[:5]

# the accuracy changed to 87% (lowered) and predictions too
```

The accuracy of the model is 87.0%

Out[29]:
```
array([[0.04673791],
       [0.9957482 ],
       [0.66159715],
       [0.7986678 ],
       [0.95125973]], dtype=float32)
```

END

Assignment 5.2: Classifying newswires: A multiclass classification example

In [30]:
```
# Loading the Reuters dataset

from tensorflow.keras.datasets import reuters
(train_data, train_labels), (test_data, test_labels) = reuters.load_data(
    num_words=10000)
```

In [31]:
```
# display  records in each data set train and test

len(train_data)
len(test_data)
```

Out[31]: 8982

Out[31]: 2246

In [32]:
```
# display train data sample

print(train_data[0])
```

```
[1, 245, 273, 207, 156, 53, 74, 160, 26, 14, 46, 296, 26, 39, 74, 2979, 3554, 14, 46, 4689, 4329, 86, 61, 3499,
4795, 14, 61, 451, 4329, 17, 12]
```

In [33]:
```
# Decoding newswires back to text

word_index = reuters.get_word_index()
reverse_word_index = dict([(value, key) for (key, value) in word_index.items()])
decoded_newswire = " ".join([reverse_word_index.get(i - 3, "?") for i in train_data[0]])

decoded_newswire
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/reuters_word_index.json
557056/550378 [==============================] - 0s 1us/step
565248/550378 [==============================] - 0s 1us/step
```

Out[33]: '? ? ? said as a result of its december acquisition of space co it expects earnings per share in 1987 of 1 15 to 1 30 dlrs per share up from 70 cts in 1986 the company said pretax net should rise to nine to 10 mln dlrs from six mln dlrs in 1986 and rental operation revenues to 19 to 22 mln dlrs from 12 5 mln dlrs it said cash flow per share this year should be 2 50 to three dlrs reuter 3'

In [34]:
```
# label associated with an example is an integer between 0 and 45

train_labels[10]
```

Out[34]: 3

Encoding the input data

In [35]:
```
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 [36]:
```
x_train = vectorize_sequences(train_data)
x_test = vectorize_sequences(test_data)
```

Encoding the labels

In [37]:
```
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
y_train = to_one_hot(train_labels)
y_test = to_one_hot(test_labels)
```

In [38]:
```
y_train = to_categorical(train_labels)
y_test = to_categorical(test_labels)
```

Building your model

In [39]:
```
model = keras.Sequential([
    layers.Dense(64, activation="relu"),
    layers.Dense(64, activation="relu"),
    layers.Dense(46, activation="softmax")
])
```

Compiling the model

In [40]:
```
model.compile(optimizer="rmsprop",
              loss="categorical_crossentropy",
              metrics=["accuracy"])
```

Setting aside a validation set

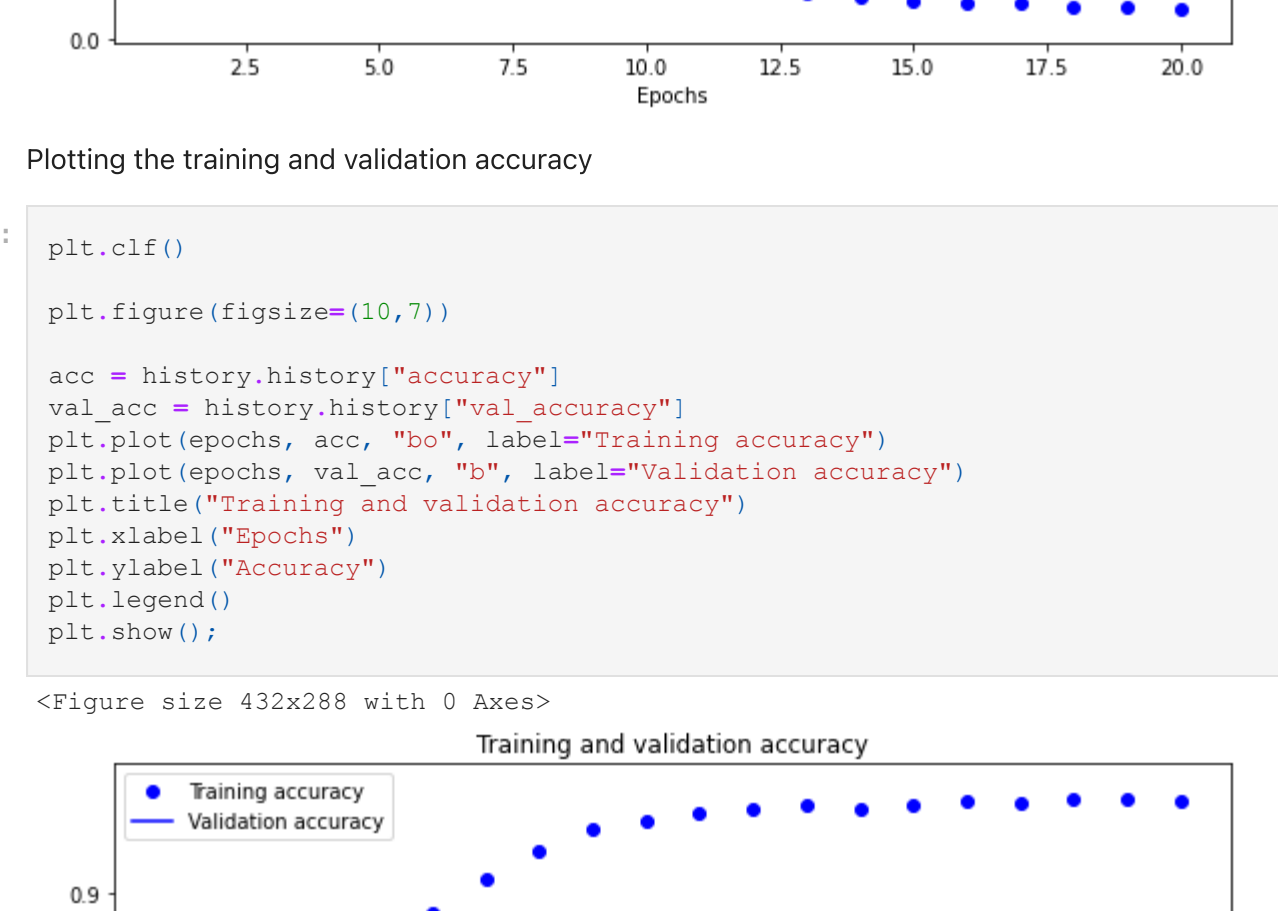
In [41]:
```
x_val = x_train[:1000]
partial_x_train = x_train[1000:]
y_val = y_train[:1000]
partial_y_train = y_train[1000:]
```

In [42]:
```
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 [==============================] - 1s 27ms/step - loss: 2.5408 - accuracy: 0.5276 - val_loss: 1.6787 - va
l_accuracy: 0.6410
Epoch 2/20
16/16 [==============================] - 0s 17ms/step - loss: 1.4003 - accuracy: 0.6993 - val_loss: 1.3064 - va
l_accuracy: 0.7050
Epoch 3/20
16/16 [==============================] - 0s 17ms/step - loss: 1.0647 - accuracy: 0.7719 - val_loss: 1.1450 - va
l_accuracy: 0.7500
Epoch 4/20
16/16 [==============================] - 0s 17ms/step - loss: 0.8489 - accuracy: 0.8148 - val_loss: 1.0541 - va
l_accuracy: 0.7730
Epoch 5/20
16/16 [==============================] - 0s 18ms/step - loss: 0.6837 - accuracy: 0.8519 - val_loss: 0.9991 - va
l_accuracy: 0.7990
Epoch 6/20
16/16 [==============================] - 0s 18ms/step - loss: 0.5532 - accuracy: 0.8870 - val_loss: 0.9521 - va
l_accuracy: 0.8050
Epoch 7/20
16/16 [==============================] - 0s 18ms/step - loss: 0.4438 - accuracy: 0.9083 - val_loss: 0.9330 - va
l_accuracy: 0.8120
Epoch 8/20
16/16 [==============================] - 0s 18ms/step - loss: 0.3569 - accuracy: 0.9257 - val_loss: 0.9278 - va
l_accuracy: 0.8070
Epoch 9/20
16/16 [==============================] - 0s 18ms/step - loss: 0.2963 - accuracy: 0.9335 - val_loss: 0.9244 - va
l_accuracy: 0.8060
Epoch 10/20
16/16 [==============================] - 0s 18ms/step - loss: 0.2489 - accuracy: 0.9448 - val_loss: 0.9322 - va
l_accuracy: 0.8060
Epoch 11/20
16/16 [==============================] - 0s 17ms/step - loss: 0.2122 - accuracy: 0.9500 - val_loss: 0.9792 - va
l_accuracy: 0.8040
Epoch 12/20
16/16 [==============================] - 0s 17ms/step - loss: 0.1845 - accuracy: 0.9518 - val_loss: 0.9971 - va
l_accuracy: 0.7980
Epoch 13/20
16/16 [==============================] - 0s 17ms/step - loss: 0.1671 - accuracy: 0.9541 - val_loss: 0.9661 - va
l_accuracy: 0.8210
Epoch 14/20
16/16 [==============================] - 0s 16ms/step - loss: 0.1527 - accuracy: 0.9519 - val_loss: 1.0236 - va
l_accuracy: 0.8030
Epoch 15/20
16/16 [==============================] - 0s 18ms/step - loss: 0.1400 - accuracy: 0.9550 - val_loss: 1.0989 - va
l_accuracy: 0.7830
Epoch 16/20
16/16 [==============================] - 0s 16ms/step - loss: 0.1316 - accuracy: 0.9575 - val_loss: 1.0472 - va
l_accuracy: 0.8040
Epoch 17/20
16/16 [==============================] - 0s 18ms/step - loss: 0.1270 - accuracy: 0.9562 - val_loss: 1.0989 - va
l_accuracy: 0.8010
Epoch 18/20
16/16 [==============================] - 0s 17ms/step - loss: 0.1174 - accuracy: 0.9588 - val_loss: 1.1031 - va
l_accuracy: 0.8010
Epoch 19/20
16/16 [==============================] - 0s 18ms/step - loss: 0.1164 - accuracy: 0.9577 - val_loss: 1.0728 - va
l_accuracy: 0.8080
Epoch 20/20
16/16 [==============================] - 0s 18ms/step - loss: 0.1122 - accuracy: 0.9573 - val_loss: 1.1327 - va
l_accuracy: 0.7960
```

Plotting the training and validation loss

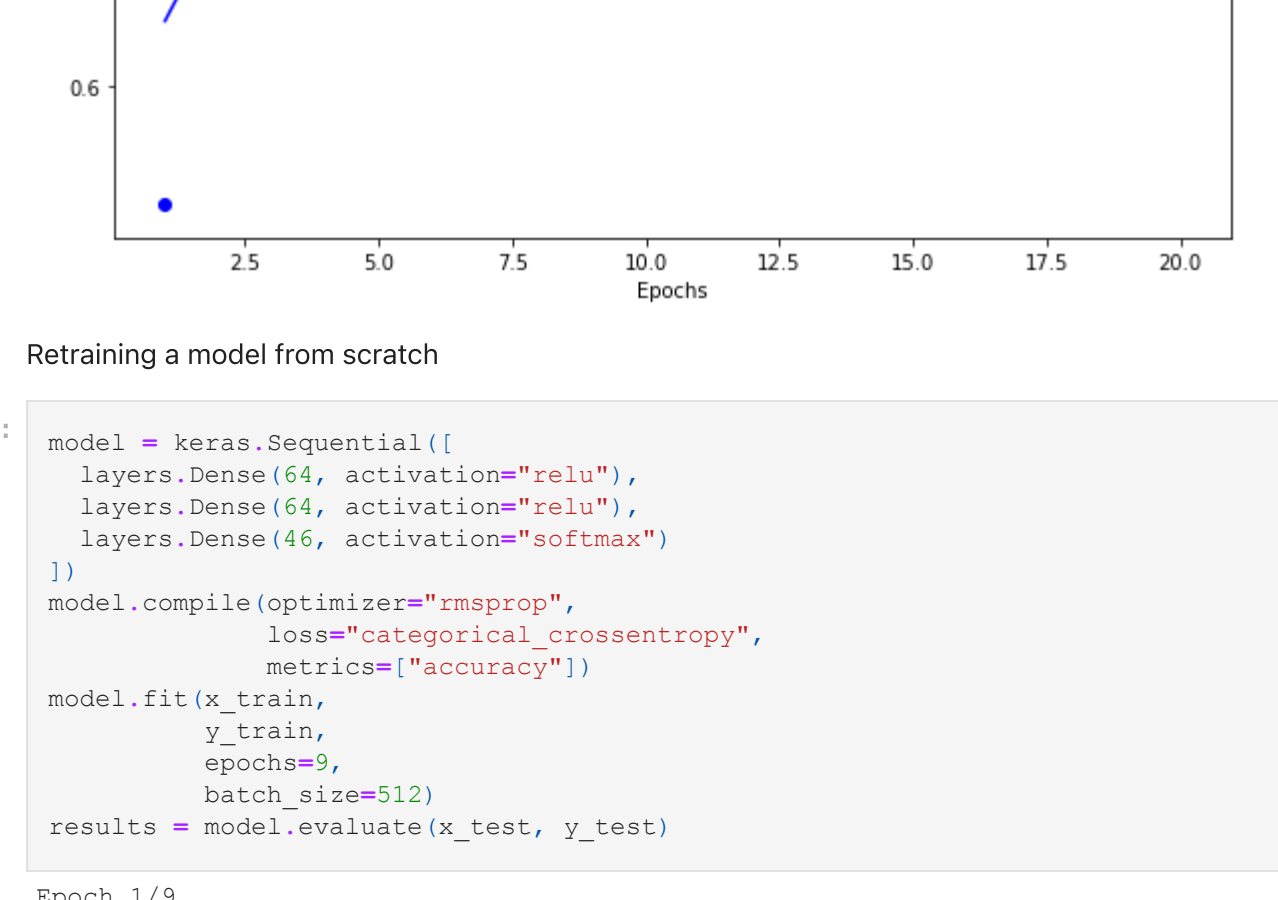
In [43]:
```
plt.figure(figsize=(10,7))

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();
```



Plotting the training and validation accuracy

In [44]:
```
plt.clf()

plt.figure(figsize=(10,7))

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();
```

<Figure size 432x288 with 0 Axes>



Retraining a model from scratch

In [45]:
```
model = keras.Sequential([
    layers.Dense(64, activation="relu"),
    layers.Dense(64, activation="relu"),
    layers.Dense(46, activation="softmax")
])
model.compile(optimizer="rmsprop",
              loss="categorical_crossentropy",
              metrics=["accuracy"])
model.fit(x_train,
          y_train,
          epochs=9,
          batch_size=512)
results = model.evaluate(x_test, y_test)
```

```
Epoch 1/9
18/18 [==============================] - 1s 14ms/step - loss: 2.5927 - accuracy: 0.5016
Epoch 2/9
18/18 [==============================] - 0s 14ms/step - loss: 1.3850 - accuracy: 0.7091
Epoch 3/9
18/18 [==============================] - 0s 13ms/step - loss: 1.0141 - accuracy: 0.7831
Epoch 4/9
18/18 [==============================] - 0s 14ms/step - loss: 0.7921 - accuracy: 0.8359
Epoch 5/9
18/18 [==============================] - 0s 15ms/step - loss: 0.6271 - accuracy: 0.8736
Epoch 6/9
18/18 [==============================] - 0s 15ms/step - loss: 0.4943 - accuracy: 0.9004
Epoch 7/9
18/18 [==============================] - 0s 14ms/step - loss: 0.4006 - accuracy: 0.9176
Epoch 8/9
18/18 [==============================] - 0s 14ms/step - loss: 0.3233 - accuracy: 0.9323
Epoch 9/9
18/18 [==============================] - 0s 14ms/step - loss: 0.2739 - accuracy: 0.9363
```

Out[45]: <keras.callbacks.History at 0x163e49b80>

```
71/71 [==============================] - 0s 1ms/step - loss: 0.9757 - accuracy: 0.7930
```

In [46]:
```
# display the result

results
```

Out[46]: [0.9757130146026611, 0.792965292930603]

In [47]:
```
print(f"The accuracy of the model is {round(results[1],2)*100}%")
```

The accuracy of the model is 79.0%

predictions on new data

In [48]:
```
# predictions is a vector of length 46

predictions = model.predict(x_test)
predictions[0].shape
```

Out[48]: (46,)

In [49]:
```
# The coefficients in this vector sum to 1

np.sum(predictions[0])
```

Out[49]: 1.0

In [50]:
```
# the class with the highest probability

np.argmax(predictions[0])
```

Out[50]: 3

different way to handle the labels and the loss

In [51]:
```
y_train = np.array(train_labels)
y_test = np.array(test_labels)
```

In [52]:
```
model.compile(optimizer="rmsprop",
              loss="sparse_categorical_crossentropy",
              metrics=["accuracy"])
```

importance of having sufficiently large intermediate layers

In [53]:
```
model = keras.Sequential([
    layers.Dense(64, activation="relu"),
    layers.Dense(4, activation="relu"),
    layers.Dense(46, activation="softmax")
])
model.compile(optimizer="rmsprop",
              loss="categorical_crossentropy",
              metrics=["accuracy"])
model.fit(partial_x_train,
          partial_y_train,
          epochs=20,
          batch_size=128,
          validation_data=(x_val, y_val))
```