Coding Tutorial

November 20, 2020

```
In [1]: import tensorflow as tf
        print(tf.__version__)
```

```
2.0.0
```

1 Saving and loading models

Coding tutorials #### Section **??** #### Section **??** #### Section **??** #### Section **??** #### Section **??**

Saving and loading model weights

Load and inspect CIFAR-10 dataset The CIFAR-10 dataset consists of, in total, 60000 color images, each with one of 10 labels: airplane, automobile, bird, cat, deer, dog, frog, horse, ship, truck. For an introduction and a download, see this link.

```
In [2]: # Import the CIFAR-10 dataset and rescale the pixel values

        (x_train, y_train), (x_test, y_test) = tf.keras.datasets.cifar10.load_data()
        x_train = x_train / 255.0
        x_test = x_test / 255.0

        # Use smaller subset -- speeds things up
        x_train = x_train[:10000]
        y_train = y_train[:10000]
        x_test = x_test[:1000]
        y_test = y_test[:1000]
```

```
Downloading data from https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz
170500096/170498071 [==============================] - 3s 0us/step
```

```
In [3]: # Plot the first 10 CIFAR-10 images

        import matplotlib.pyplot as plt
```

```
fig, ax = plt.subplots(1, 10, figsize=(10, 1))
for i in range(10):
    ax[i].set_axis_off()
    ax[i].imshow(x_train[i])
```

Introduce two useful functions

In [3]:
```
# Introduce function to test model accuracy

def get_test_accuracy(model, x_test, y_test):
    test_loss, test_acc = model.evaluate(x=x_test, y=y_test, verbose=0)
    print('accuracy: {acc:0.3f}'.format(acc=test_acc))
```

In [4]:
```
# Introduce function that creates a new instance of a simple CNN

from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Flatten, Conv2D, MaxPooling2D

def get_new_model():
    model = Sequential([
        Conv2D(filters=16, input_shape=(32, 32, 3), kernel_size=(3, 3),
               activation='relu', name='conv_1'),
        Conv2D(filters=8, kernel_size=(3, 3), activation='relu', name='conv_2'),
        MaxPooling2D(pool_size=(4, 4), name='pool_1'),
        Flatten(name='flatten'),
        Dense(units=32, activation='relu', name='dense_1'),
        Dense(units=10, activation='softmax', name='dense_2')
    ])
    model.compile(optimizer='adam',
                  loss='sparse_categorical_crossentropy',
                  metrics=['accuracy'])
    return model
```

Create simple convolutional neural network classifier

In [6]:
```
# Create an instance of the model and show model summary
model = get_new_model()
model.summary()
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv_1 (Conv2D)              (None, 30, 30, 16)        448
_________________________________________________________________
conv_2 (Conv2D)              (None, 28, 28, 8)         1160
_________________________________________________________________
```

```
pool_1 (MaxPooling2D)        (None, 7, 7, 8)           0
_________________________________________________________________
flatten (Flatten)            (None, 392)               0
_________________________________________________________________
dense_1 (Dense)              (None, 32)                12576
_________________________________________________________________
dense_2 (Dense)              (None, 10)                330
=================================================================
Total params: 14,514
Trainable params: 14,514
Non-trainable params: 0
_________________________________________________________________
```

```
In [7]: # Test accuracy of the untrained model, around 10% (random)
        get_test_accuracy(model, x_test, y_test)
```

```
accuracy: 0.106
```

Train model with checkpoints

```
In [8]: from tensorflow.keras.callbacks import ModelCheckpoint
```

```
In [9]: # Create Tensorflow checkpoint object
        checkpoint_path = 'model_checkpoints/checkpoint'
        checkpoint = ModelCheckpoint(filepath = checkpoint_path, frequency = 'epoch',
                                     save_weights_only = True, verbose = 1)
```

```
In [10]: # Fit model, with simple checkpoint which saves (and overwrites) model weights every
         model.fit(x_train, y_train, epochs = 3, callbacks = [checkpoint])
```

```
Train on 10000 samples
Epoch 1/3
 9984/10000 [============================>.] - ETA: 0s - loss: 1.9295 - accuracy: 0.3009
Epoch 00001: saving model to model_checkpoints/checkpoint
10000/10000 [==============================] - 51s 5ms/sample - loss: 1.9291 - accuracy: 0.3009
Epoch 2/3
 9984/10000 [============================>.] - ETA: 0s - loss: 1.5760 - accuracy: 0.4326
Epoch 00002: saving model to model_checkpoints/checkpoint
10000/10000 [==============================] - 50s 5ms/sample - loss: 1.5757 - accuracy: 0.4326
Epoch 3/3
 9984/10000 [============================>.] - ETA: 0s - loss: 1.4523 - accuracy: 0.4787
Epoch 00003: saving model to model_checkpoints/checkpoint
10000/10000 [==============================] - 48s 5ms/sample - loss: 1.4530 - accuracy: 0.4784
```

```
Out[10]: <tensorflow.python.keras.callbacks.History at 0x7fa3f02e2240>
```

```
In [11]: # Have a look at what the checkpoint creates
         !ls -lh model_checkpoints
```

```
total 184K
-rw-r--r-- 1 jovyan users   77 Nov 18 00:20 checkpoint
-rw-r--r-- 1 jovyan users 174K Nov 18 00:20 checkpoint.data-00000-of-00001
-rw-r--r-- 1 jovyan users 2.0K Nov 18 00:20 checkpoint.index
```

```
In [14]: # Evaluate the performance of the trained model
         get_test_accuracy(model, x_test, y_test)
```

```
accuracy: 0.482
```

Create new model, load weights

```
In [15]: # Create a new instance of the (initialised) model, accuracy around 10% again
         model = get_new_model()
         get_test_accuracy(model, x_test, y_test)
```

```
accuracy: 0.104
```

```
In [16]: # Load weights -- accuracy is the same as the trained model
         model.load_weights(checkpoint_path)
         get_test_accuracy(model, x_test, y_test)
```

```
accuracy: 0.482
```

Clear directory

```
In [17]: ! rm -r model_checkpoints
```

Model saving criteria

Create more customised checkpoint

```
In [5]: from tensorflow.keras.callbacks import ModelCheckpoint
```

```
In [6]: # Create Tensorflow checkpoint object with epoch and batch details
        checkpoint_5000_path = 'model_checkpoints_5000/checkpoint_{epoch:02d}_{batch:04d}'
        checkpoint_5000 = ModelCheckpoint(filepath = checkpoint_5000_path,
                                          save_weights_only = True,
                                          save_freq = 5000,
                                          verbose = 1)
```

```
In [7]: # Create and fit model with checkpoint
        model = get_new_model()
        model.fit(x_train, y_train, epochs = 3,
                    validation_data = (x_test, y_test),
                    batch_size = 10, callbacks = [checkpoint_5000])
```

```
Train on 10000 samples, validate on 1000 samples
Epoch 1/3
 4990/10000 [============>...] - ETA: 27s - loss: 2.0540 - accuracy: 0.2303
Epoch 00001: saving model to model_checkpoints_5000/checkpoint_01_0499
 9990/10000 [============================>.] - ETA: 0s - loss: 1.8898 - accuracy: 0.2957
Epoch 00001: saving model to model_checkpoints_5000/checkpoint_01_0999
10000/10000 [==============================] - 57s 6ms/sample - loss: 1.8896 - accuracy: 0.2958
Epoch 2/3
 4990/10000 [============>...] - ETA: 26s - loss: 1.5757 - accuracy: 0.4204
Epoch 00002: saving model to model_checkpoints_5000/checkpoint_02_0499
 9980/10000 [============================>.] - ETA: 0s - loss: 1.5478 - accuracy: 0.4332
Epoch 00002: saving model to model_checkpoints_5000/checkpoint_02_0999
10000/10000 [==============================] - 55s 5ms/sample - loss: 1.5478 - accuracy: 0.4330
Epoch 3/3
 4990/10000 [============>...] - ETA: 26s - loss: 1.4315 - accuracy: 0.4792
Epoch 00003: saving model to model_checkpoints_5000/checkpoint_03_0499
 9990/10000 [============================>.] - ETA: 0s - loss: 1.4282 - accuracy: 0.4854
Epoch 00003: saving model to model_checkpoints_5000/checkpoint_03_0999
10000/10000 [==============================] - 55s 5ms/sample - loss: 1.4281 - accuracy: 0.4854
```

```
Out[7]: <tensorflow.python.keras.callbacks.History at 0x7f5ac3b3b278>
```

```
In [8]: # Have a look at what the checkpoint creates
        !ls -lh model_checkpoints_5000
```

```
total 1.1M
-rw-r--r-- 1 jovyan users   93 Nov 18 13:59 checkpoint
-rw-r--r-- 1 jovyan users 174K Nov 18 13:56 checkpoint_01_0499.data-00000-of-00001
-rw-r--r-- 1 jovyan users 2.0K Nov 18 13:56 checkpoint_01_0499.index
-rw-r--r-- 1 jovyan users 174K Nov 18 13:57 checkpoint_01_0999.data-00000-of-00001
-rw-r--r-- 1 jovyan users 2.0K Nov 18 13:57 checkpoint_01_0999.index
-rw-r--r-- 1 jovyan users 174K Nov 18 13:57 checkpoint_02_0499.data-00000-of-00001
-rw-r--r-- 1 jovyan users 2.0K Nov 18 13:57 checkpoint_02_0499.index
-rw-r--r-- 1 jovyan users 174K Nov 18 13:58 checkpoint_02_0999.data-00000-of-00001
-rw-r--r-- 1 jovyan users 2.0K Nov 18 13:58 checkpoint_02_0999.index
-rw-r--r-- 1 jovyan users 174K Nov 18 13:58 checkpoint_03_0499.data-00000-of-00001
-rw-r--r-- 1 jovyan users 2.0K Nov 18 13:58 checkpoint_03_0499.index
-rw-r--r-- 1 jovyan users 174K Nov 18 13:59 checkpoint_03_0999.data-00000-of-00001
-rw-r--r-- 1 jovyan users 2.0K Nov 18 13:59 checkpoint_03_0999.index
```

Work with model saving criteria

In [9]:
```
# Use tiny training and test set -- will overfit!

x_train = x_train[:100]
y_train = y_train[:100]
x_test = x_test[:100]
y_test = y_test[:100]
```

In [10]:
```
# Create a new instance of untrained model
model = get_new_model()
```

In [12]:
```
# Create Tensorflow checkpoint object which monitors the validation accuracy
checkpoint_best_path = 'model_checkpoints_best/checkpoint'
checkpoint_best = ModelCheckpoint(filepath = checkpoint_best_path,
                                  save_weights_only = True,
                                  save_freq = 'epoch',
                                  monitor = 'val_accuracy',
                                  save_best_only = True,
                                  verbose = 1)
```

In [13]:
```
# Fit the model and save only the weights with the highest validation accuracy
history = model.fit(x_train, y_train, epochs = 50,
                    validation_data = (x_test, y_test),
                    batch_size = 10,
                    callbacks = [checkpoint_best],
                    verbose = 0)
```

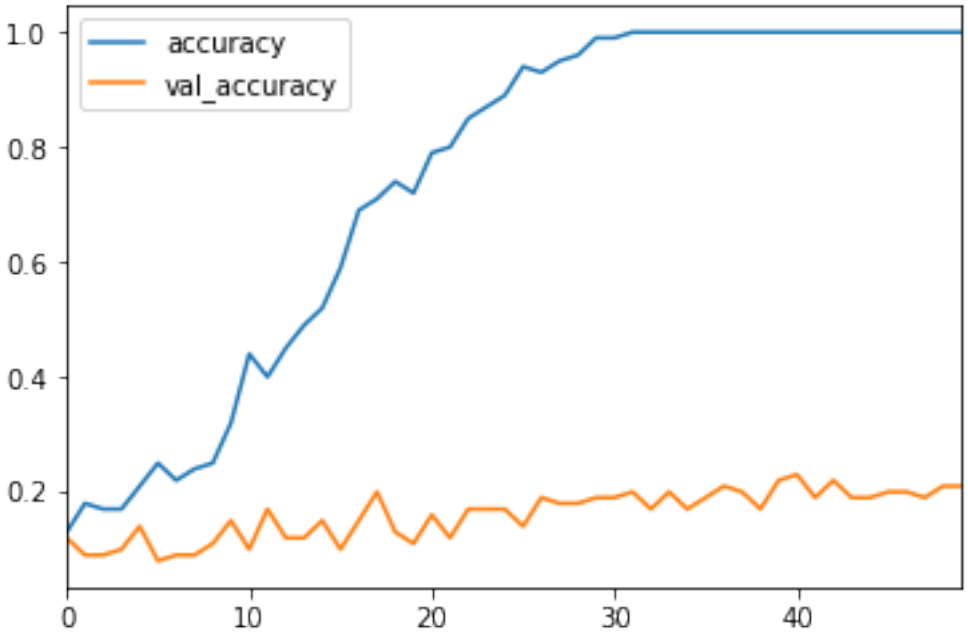
```
Epoch 00001: val_accuracy improved from -inf to 0.12000, saving model to model_checkpoints_best

Epoch 00002: val_accuracy did not improve from 0.12000

Epoch 00003: val_accuracy did not improve from 0.12000

Epoch 00004: val_accuracy did not improve from 0.12000

Epoch 00005: val_accuracy improved from 0.12000 to 0.14000, saving model to model_checkpoints_b

Epoch 00006: val_accuracy did not improve from 0.14000

Epoch 00007: val_accuracy did not improve from 0.14000

Epoch 00008: val_accuracy did not improve from 0.14000

Epoch 00009: val_accuracy did not improve from 0.14000

Epoch 00010: val_accuracy improved from 0.14000 to 0.15000, saving model to model_checkpoints_b
```

```
Epoch 00011: val_accuracy did not improve from 0.15000

Epoch 00012: val_accuracy improved from 0.15000 to 0.17000, saving model to model_checkpoints_l

Epoch 00013: val_accuracy did not improve from 0.17000

Epoch 00014: val_accuracy did not improve from 0.17000

Epoch 00015: val_accuracy did not improve from 0.17000

Epoch 00016: val_accuracy did not improve from 0.17000

Epoch 00017: val_accuracy did not improve from 0.17000

Epoch 00018: val_accuracy improved from 0.17000 to 0.20000, saving model to model_checkpoints_l

Epoch 00019: val_accuracy did not improve from 0.20000

Epoch 00020: val_accuracy did not improve from 0.20000

Epoch 00021: val_accuracy did not improve from 0.20000

Epoch 00022: val_accuracy did not improve from 0.20000

Epoch 00023: val_accuracy did not improve from 0.20000

Epoch 00024: val_accuracy did not improve from 0.20000

Epoch 00025: val_accuracy did not improve from 0.20000

Epoch 00026: val_accuracy did not improve from 0.20000

Epoch 00027: val_accuracy did not improve from 0.20000

Epoch 00028: val_accuracy did not improve from 0.20000

Epoch 00029: val_accuracy did not improve from 0.20000

Epoch 00030: val_accuracy did not improve from 0.20000

Epoch 00031: val_accuracy did not improve from 0.20000

Epoch 00032: val_accuracy did not improve from 0.20000

Epoch 00033: val_accuracy did not improve from 0.20000

Epoch 00034: val_accuracy did not improve from 0.20000
```

```
Epoch 00035: val_accuracy did not improve from 0.20000

Epoch 00036: val_accuracy did not improve from 0.20000

Epoch 00037: val_accuracy improved from 0.20000 to 0.21000, saving model to model_checkpoints_l

Epoch 00038: val_accuracy did not improve from 0.21000

Epoch 00039: val_accuracy did not improve from 0.21000

Epoch 00040: val_accuracy improved from 0.21000 to 0.22000, saving model to model_checkpoints_l

Epoch 00041: val_accuracy improved from 0.22000 to 0.23000, saving model to model_checkpoints_l

Epoch 00042: val_accuracy did not improve from 0.23000

Epoch 00043: val_accuracy did not improve from 0.23000

Epoch 00044: val_accuracy did not improve from 0.23000

Epoch 00045: val_accuracy did not improve from 0.23000

Epoch 00046: val_accuracy did not improve from 0.23000

Epoch 00047: val_accuracy did not improve from 0.23000

Epoch 00048: val_accuracy did not improve from 0.23000

Epoch 00049: val_accuracy did not improve from 0.23000

Epoch 00050: val_accuracy did not improve from 0.23000
```

In [14]:
```
# Plot training and testing curves

import pandas as pd

df = pd.DataFrame(history.history)
df.plot(y=['accuracy', 'val_accuracy'])
```

Out[14]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7f5b69d113c8>
```




```
In [15]: # Inspect the checkpoint directory
         !ls -lh model_checkpoints_best
```

```
total 184K
-rw-r--r-- 1 jovyan users   77 Nov 18 14:22 checkpoint
-rw-r--r-- 1 jovyan users 174K Nov 18 14:22 checkpoint.data-00000-of-00001
-rw-r--r-- 1 jovyan users 2.0K Nov 18 14:22 checkpoint.index
```

```
In [18]: # Create a new model with the saved weights
         new_model = get_new_model()
         new_model.load_weights(checkpoint_best_path)
         get_test_accuracy(new_model, x_test, y_test)
```

```
accuracy: 0.230
```

Clear directory

```
In [19]: ! rm -r model_checkpoints_5000 model_checkpoints_best
```

Saving the entire model

Create checkpoint that saves whole model, not just weights

```
In [5]: from tensorflow.keras.callbacks import ModelCheckpoint

In [6]: # Create Tensorflow checkpoint object
        checkpoint_path = 'model_checkpoints'
        checkpoint = ModelCheckpoint(filepath = checkpoint_path,
                                     save_weights_only = False,
                                     frequency = 'epoch',
                                     verbose = 1)

In [7]: # Create and fit model with checkpoint
        model = get_new_model()
        model.fit(x_train, y_train, epochs = 3, callbacks = [checkpoint])

Train on 10000 samples
Epoch 1/3
 9984/10000 [============================>.] - ETA: 0s - loss: 2.0021 - accuracy: 0.2648
Epoch 00001: saving model to model_checkpoints
WARNING:tensorflow:From /opt/conda/lib/python3.7/site-packages/tensorflow_core/python/ops/resou
Instructions for updating:
If using Keras pass *_constraint arguments to layers.
INFO:tensorflow:Assets written to: model_checkpoints/assets
10000/10000 [==============================] - 47s 5ms/sample - loss: 2.0015 - accuracy: 0.265
Epoch 2/3
 9984/10000 [============================>.] - ETA: 0s - loss: 1.6207 - accuracy: 0.4116
Epoch 00002: saving model to model_checkpoints
INFO:tensorflow:Assets written to: model_checkpoints/assets
10000/10000 [==============================] - 45s 5ms/sample - loss: 1.6206 - accuracy: 0.411
Epoch 3/3
 9984/10000 [============================>.] - ETA: 0s - loss: 1.4863 - accuracy: 0.4649
Epoch 00003: saving model to model_checkpoints
INFO:tensorflow:Assets written to: model_checkpoints/assets
10000/10000 [==============================] - 44s 4ms/sample - loss: 1.4865 - accuracy: 0.4648


Out[7]: <tensorflow.python.keras.callbacks.History at 0x7f3ebc403f98>
```

Inspect what the checkpoint has created

```
In [8]: # Have a look at what the checkpoint creates
        !ls -lh model_checkpoints

total 128K
drwxr-xr-x 2 jovyan users 6.0K Nov 19 03:40 assets
-rw-r--r-- 1 jovyan users 118K Nov 19 03:42 saved_model.pb
drwxr-xr-x 2 jovyan users 6.0K Nov 19 03:42 variables
```

```
In [9]: # Enter variables directory
        !ls -lh model_checkpoints/variables
```

```
total 184K
-rw-r--r-- 1 jovyan users 177K Nov 19 03:42 variables.data-00000-of-00001
-rw-r--r-- 1 jovyan users 2.1K Nov 19 03:42 variables.index
```

```
In [10]: # Get the model's test accuracy
         get_test_accuracy(model, x_test, y_test)
```

```
accuracy: 0.470
```

Create new model from scratch

```
In [11]: # Delete model
         del model
```

```
In [13]: from tensorflow.keras.models import load_model
```

```
In [15]: # Reload model from scratch
         model = load_model(checkpoint_path)
         get_test_accuracy(model, x_test, y_test)
```

```
accuracy: 0.470
```

Use the .h5 format to save model

```
In [16]: # Save the model in .h5 format
         model.save('my_model.h5')
```

```
In [17]: # Inspect .h5 file
         !ls -lh my_model.h5
```

```
-rw-r--r-- 1 jovyan users 77K Nov 19 03:47 my_model.h5
```

```
In [18]: # Delete model
         del model
```

```
In [20]: # Reload model from scratch
         model = load_model('my_model.h5')
         get_test_accuracy(model, x_test, y_test)
```

```
accuracy: 0.470
```

Clear directory

```
In [21]: ! rm -r model_checkpoints
         ! rm my_model.h5
```

Loading pre-trained Keras models

Import and build Keras ResNet50 model Today we'll be using the ResNet50 model designed by a team at Microsoft Research, available through Keras applications. Please see the description on the Keras applications page for details. If you continue using it, please cite it properly! The paper it comes from is:

Kaiming He, Xiangyu Zhang, Shaoqing Ren, Jian Sun. "Deep Residual Learning for Image Recognition", 2015.

This model takes a long time to download on the Coursera platform, so it is pre-downloaded in your workspace and saved in Keras HDF5 format. If you want to import it on your personal machine, use the following code:

```
from tensorflow.keras.applications import ResNet50
model = ResNet50(weights='imagenet')
```

In this coding tutorial, you will instead load the model directly from disk.

```
In [2]: from tensorflow.keras.models import load_model

In [3]: # Build Keras ResNet50 model
        model = load_model('models/Keras_ResNet50.h5')
        model.summary()
```

```
WARNING:tensorflow:No training configuration found in save file: the model was *not* compiled.
Model: "resnet50"
__________________________________________________________________________________________________
Layer (type)                    Output Shape         Param #     Connected to
==================================================================================================
input_1 (InputLayer)            [(None, 224, 224, 3) 0
__________________________________________________________________________________________________
conv1_pad (ZeroPadding2D)       (None, 230, 230, 3)  0           input_1[0][0]
__________________________________________________________________________________________________
conv1_conv (Conv2D)             (None, 112, 112, 64) 9472        conv1_pad[0][0]
__________________________________________________________________________________________________
conv1_bn (BatchNormalization)   (None, 112, 112, 64) 256         conv1_conv[0][0]
__________________________________________________________________________________________________
conv1_relu (Activation)         (None, 112, 112, 64) 0           conv1_bn[0][0]
__________________________________________________________________________________________________
pool1_pad (ZeroPadding2D)       (None, 114, 114, 64) 0           conv1_relu[0][0]
__________________________________________________________________________________________________
pool1_pool (MaxPooling2D)       (None, 56, 56, 64)   0           pool1_pad[0][0]
__________________________________________________________________________________________________
```

```
conv2_block1_1_conv (Conv2D)    (None, 56, 56, 64)   4160        pool1_pool[0][0]
__________________________________________________________________________________________________
conv2_block1_1_bn (BatchNormali (None, 56, 56, 64)   256         conv2_block1_1_conv[0][0]
__________________________________________________________________________________________________
conv2_block1_1_relu (Activation (None, 56, 56, 64)   0           conv2_block1_1_bn[0][0]
__________________________________________________________________________________________________
conv2_block1_2_conv (Conv2D)    (None, 56, 56, 64)   36928       conv2_block1_1_relu[0][0]
__________________________________________________________________________________________________
conv2_block1_2_bn (BatchNormali (None, 56, 56, 64)   256         conv2_block1_2_conv[0][0]
__________________________________________________________________________________________________
conv2_block1_2_relu (Activation (None, 56, 56, 64)   0           conv2_block1_2_bn[0][0]
__________________________________________________________________________________________________
conv2_block1_0_conv (Conv2D)    (None, 56, 56, 256)  16640       pool1_pool[0][0]
__________________________________________________________________________________________________
conv2_block1_3_conv (Conv2D)    (None, 56, 56, 256)  16640       conv2_block1_2_relu[0][0]
__________________________________________________________________________________________________
conv2_block1_0_bn (BatchNormali (None, 56, 56, 256)  1024        conv2_block1_0_conv[0][0]
__________________________________________________________________________________________________
conv2_block1_3_bn (BatchNormali (None, 56, 56, 256)  1024        conv2_block1_3_conv[0][0]
__________________________________________________________________________________________________
conv2_block1_add (Add)          (None, 56, 56, 256)  0           conv2_block1_0_bn[0][0]
                                                                 conv2_block1_3_bn[0][0]
__________________________________________________________________________________________________
conv2_block1_out (Activation)   (None, 56, 56, 256)  0           conv2_block1_add[0][0]
__________________________________________________________________________________________________
conv2_block2_1_conv (Conv2D)    (None, 56, 56, 64)   16448       conv2_block1_out[0][0]
__________________________________________________________________________________________________
conv2_block2_1_bn (BatchNormali (None, 56, 56, 64)   256         conv2_block2_1_conv[0][0]
__________________________________________________________________________________________________
conv2_block2_1_relu (Activation (None, 56, 56, 64)   0           conv2_block2_1_bn[0][0]
__________________________________________________________________________________________________
conv2_block2_2_conv (Conv2D)    (None, 56, 56, 64)   36928       conv2_block2_1_relu[0][0]
__________________________________________________________________________________________________
conv2_block2_2_bn (BatchNormali (None, 56, 56, 64)   256         conv2_block2_2_conv[0][0]
__________________________________________________________________________________________________
conv2_block2_2_relu (Activation (None, 56, 56, 64)   0           conv2_block2_2_bn[0][0]
__________________________________________________________________________________________________
conv2_block2_3_conv (Conv2D)    (None, 56, 56, 256)  16640       conv2_block2_2_relu[0][0]
__________________________________________________________________________________________________
conv2_block2_3_bn (BatchNormali (None, 56, 56, 256)  1024        conv2_block2_3_conv[0][0]
__________________________________________________________________________________________________
conv2_block2_add (Add)          (None, 56, 56, 256)  0           conv2_block1_out[0][0]
                                                                 conv2_block2_3_bn[0][0]
__________________________________________________________________________________________________
conv2_block2_out (Activation)   (None, 56, 56, 256)  0           conv2_block2_add[0][0]
__________________________________________________________________________________________________
conv2_block3_1_conv (Conv2D)    (None, 56, 56, 64)   16448       conv2_block2_out[0][0]
__________________________________________________________________________________________________
```

```
conv2_block3_1_bn (BatchNormali (None, 56, 56, 64)   256         conv2_block3_1_conv[0][0]
__________________________________________________________________________________________
conv2_block3_1_relu (Activation (None, 56, 56, 64)   0           conv2_block3_1_bn[0][0]
__________________________________________________________________________________________
conv2_block3_2_conv (Conv2D)    (None, 56, 56, 64)   36928       conv2_block3_1_relu[0][0]
__________________________________________________________________________________________
conv2_block3_2_bn (BatchNormali (None, 56, 56, 64)   256         conv2_block3_2_conv[0][0]
__________________________________________________________________________________________
conv2_block3_2_relu (Activation (None, 56, 56, 64)   0           conv2_block3_2_bn[0][0]
__________________________________________________________________________________________
conv2_block3_3_conv (Conv2D)    (None, 56, 56, 256)  16640       conv2_block3_2_relu[0][0]
__________________________________________________________________________________________
conv2_block3_3_bn (BatchNormali (None, 56, 56, 256)  1024        conv2_block3_3_conv[0][0]
__________________________________________________________________________________________
conv2_block3_add (Add)          (None, 56, 56, 256)  0           conv2_block2_out[0][0]
                                                                 conv2_block3_3_bn[0][0]
__________________________________________________________________________________________
conv2_block3_out (Activation)   (None, 56, 56, 256)  0           conv2_block3_add[0][0]
__________________________________________________________________________________________
conv3_block1_1_conv (Conv2D)    (None, 28, 28, 128)  32896       conv2_block3_out[0][0]
__________________________________________________________________________________________
conv3_block1_1_bn (BatchNormali (None, 28, 28, 128)  512         conv3_block1_1_conv[0][0]
__________________________________________________________________________________________
conv3_block1_1_relu (Activation (None, 28, 28, 128)  0           conv3_block1_1_bn[0][0]
__________________________________________________________________________________________
conv3_block1_2_conv (Conv2D)    (None, 28, 28, 128)  147584      conv3_block1_1_relu[0][0]
__________________________________________________________________________________________
conv3_block1_2_bn (BatchNormali (None, 28, 28, 128)  512         conv3_block1_2_conv[0][0]
__________________________________________________________________________________________
conv3_block1_2_relu (Activation (None, 28, 28, 128)  0           conv3_block1_2_bn[0][0]
__________________________________________________________________________________________
conv3_block1_0_conv (Conv2D)    (None, 28, 28, 512)  131584      conv2_block3_out[0][0]
__________________________________________________________________________________________
conv3_block1_3_conv (Conv2D)    (None, 28, 28, 512)  66048       conv3_block1_2_relu[0][0]
__________________________________________________________________________________________
conv3_block1_0_bn (BatchNormali (None, 28, 28, 512)  2048        conv3_block1_0_conv[0][0]
__________________________________________________________________________________________
conv3_block1_3_bn (BatchNormali (None, 28, 28, 512)  2048        conv3_block1_3_conv[0][0]
__________________________________________________________________________________________
conv3_block1_add (Add)          (None, 28, 28, 512)  0           conv3_block1_0_bn[0][0]
                                                                 conv3_block1_3_bn[0][0]
__________________________________________________________________________________________
conv3_block1_out (Activation)   (None, 28, 28, 512)  0           conv3_block1_add[0][0]
__________________________________________________________________________________________
conv3_block2_1_conv (Conv2D)    (None, 28, 28, 128)  65664       conv3_block1_out[0][0]
__________________________________________________________________________________________
conv3_block2_1_bn (BatchNormali (None, 28, 28, 128)  512         conv3_block2_1_conv[0][0]
__________________________________________________________________________________________
```

```
conv3_block2_1_relu (Activation (None, 28, 28, 128)  0           conv3_block2_1_bn[0][0]
__________________________________________________________________________________________
conv3_block2_2_conv (Conv2D)    (None, 28, 28, 128)  147584      conv3_block2_1_relu[0][0]
__________________________________________________________________________________________
conv3_block2_2_bn (BatchNormali (None, 28, 28, 128)  512         conv3_block2_2_conv[0][0]
__________________________________________________________________________________________
conv3_block2_2_relu (Activation (None, 28, 28, 128)  0           conv3_block2_2_bn[0][0]
__________________________________________________________________________________________
conv3_block2_3_conv (Conv2D)    (None, 28, 28, 512)  66048       conv3_block2_2_relu[0][0]
__________________________________________________________________________________________
conv3_block2_3_bn (BatchNormali (None, 28, 28, 512)  2048        conv3_block2_3_conv[0][0]
__________________________________________________________________________________________
conv3_block2_add (Add)          (None, 28, 28, 512)  0           conv3_block1_out[0][0]
                                                                 conv3_block2_3_bn[0][0]
__________________________________________________________________________________________
conv3_block2_out (Activation)   (None, 28, 28, 512)  0           conv3_block2_add[0][0]
__________________________________________________________________________________________
conv3_block3_1_conv (Conv2D)    (None, 28, 28, 128)  65664       conv3_block2_out[0][0]
__________________________________________________________________________________________
conv3_block3_1_bn (BatchNormali (None, 28, 28, 128)  512         conv3_block3_1_conv[0][0]
__________________________________________________________________________________________
conv3_block3_1_relu (Activation (None, 28, 28, 128)  0           conv3_block3_1_bn[0][0]
__________________________________________________________________________________________
conv3_block3_2_conv (Conv2D)    (None, 28, 28, 128)  147584      conv3_block3_1_relu[0][0]
__________________________________________________________________________________________
conv3_block3_2_bn (BatchNormali (None, 28, 28, 128)  512         conv3_block3_2_conv[0][0]
__________________________________________________________________________________________
conv3_block3_2_relu (Activation (None, 28, 28, 128)  0           conv3_block3_2_bn[0][0]
__________________________________________________________________________________________
conv3_block3_3_conv (Conv2D)    (None, 28, 28, 512)  66048       conv3_block3_2_relu[0][0]
__________________________________________________________________________________________
conv3_block3_3_bn (BatchNormali (None, 28, 28, 512)  2048        conv3_block3_3_conv[0][0]
__________________________________________________________________________________________
conv3_block3_add (Add)          (None, 28, 28, 512)  0           conv3_block2_out[0][0]
                                                                 conv3_block3_3_bn[0][0]
__________________________________________________________________________________________
conv3_block3_out (Activation)   (None, 28, 28, 512)  0           conv3_block3_add[0][0]
__________________________________________________________________________________________
conv3_block4_1_conv (Conv2D)    (None, 28, 28, 128)  65664       conv3_block3_out[0][0]
__________________________________________________________________________________________
conv3_block4_1_bn (BatchNormali (None, 28, 28, 128)  512         conv3_block4_1_conv[0][0]
__________________________________________________________________________________________
conv3_block4_1_relu (Activation (None, 28, 28, 128)  0           conv3_block4_1_bn[0][0]
__________________________________________________________________________________________
conv3_block4_2_conv (Conv2D)    (None, 28, 28, 128)  147584      conv3_block4_1_relu[0][0]
__________________________________________________________________________________________
conv3_block4_2_bn (BatchNormali (None, 28, 28, 128)  512         conv3_block4_2_conv[0][0]
__________________________________________________________________________________________
```

```
conv3_block4_2_relu (Activation (None, 28, 28, 128)  0           conv3_block4_2_bn[0][0]
__________________________________________________________________________________________
conv3_block4_3_conv (Conv2D)    (None, 28, 28, 512)  66048       conv3_block4_2_relu[0][0]
__________________________________________________________________________________________
conv3_block4_3_bn (BatchNormali (None, 28, 28, 512)  2048        conv3_block4_3_conv[0][0]
__________________________________________________________________________________________
conv3_block4_add (Add)          (None, 28, 28, 512)  0           conv3_block3_out[0][0]
                                                                 conv3_block4_3_bn[0][0]
__________________________________________________________________________________________
conv3_block4_out (Activation)   (None, 28, 28, 512)  0           conv3_block4_add[0][0]
__________________________________________________________________________________________
conv4_block1_1_conv (Conv2D)    (None, 14, 14, 256)  131328      conv3_block4_out[0][0]
__________________________________________________________________________________________
conv4_block1_1_bn (BatchNormali (None, 14, 14, 256)  1024        conv4_block1_1_conv[0][0]
__________________________________________________________________________________________
conv4_block1_1_relu (Activation (None, 14, 14, 256)  0           conv4_block1_1_bn[0][0]
__________________________________________________________________________________________
conv4_block1_2_conv (Conv2D)    (None, 14, 14, 256)  590080      conv4_block1_1_relu[0][0]
__________________________________________________________________________________________
conv4_block1_2_bn (BatchNormali (None, 14, 14, 256)  1024        conv4_block1_2_conv[0][0]
__________________________________________________________________________________________
conv4_block1_2_relu (Activation (None, 14, 14, 256)  0           conv4_block1_2_bn[0][0]
__________________________________________________________________________________________
conv4_block1_0_conv (Conv2D)    (None, 14, 14, 1024) 525312      conv3_block4_out[0][0]
__________________________________________________________________________________________
conv4_block1_3_conv (Conv2D)    (None, 14, 14, 1024) 263168      conv4_block1_2_relu[0][0]
__________________________________________________________________________________________
conv4_block1_0_bn (BatchNormali (None, 14, 14, 1024) 4096        conv4_block1_0_conv[0][0]
__________________________________________________________________________________________
conv4_block1_3_bn (BatchNormali (None, 14, 14, 1024) 4096        conv4_block1_3_conv[0][0]
__________________________________________________________________________________________
conv4_block1_add (Add)          (None, 14, 14, 1024) 0           conv4_block1_0_bn[0][0]
                                                                 conv4_block1_3_bn[0][0]
__________________________________________________________________________________________
conv4_block1_out (Activation)   (None, 14, 14, 1024) 0           conv4_block1_add[0][0]
__________________________________________________________________________________________
conv4_block2_1_conv (Conv2D)    (None, 14, 14, 256)  262400      conv4_block1_out[0][0]
__________________________________________________________________________________________
conv4_block2_1_bn (BatchNormali (None, 14, 14, 256)  1024        conv4_block2_1_conv[0][0]
__________________________________________________________________________________________
conv4_block2_1_relu (Activation (None, 14, 14, 256)  0           conv4_block2_1_bn[0][0]
__________________________________________________________________________________________
conv4_block2_2_conv (Conv2D)    (None, 14, 14, 256)  590080      conv4_block2_1_relu[0][0]
__________________________________________________________________________________________
conv4_block2_2_bn (BatchNormali (None, 14, 14, 256)  1024        conv4_block2_2_conv[0][0]
__________________________________________________________________________________________
conv4_block2_2_relu (Activation (None, 14, 14, 256)  0           conv4_block2_2_bn[0][0]
__________________________________________________________________________________________
```

```
conv4_block2_3_conv (Conv2D)    (None, 14, 14, 1024) 263168      conv4_block2_2_relu[0][0]
__________________________________________________________________________________________________
conv4_block2_3_bn (BatchNormali (None, 14, 14, 1024) 4096        conv4_block2_3_conv[0][0]
__________________________________________________________________________________________________
conv4_block2_add (Add)          (None, 14, 14, 1024) 0           conv4_block1_out[0][0]
                                                                 conv4_block2_3_bn[0][0]
__________________________________________________________________________________________________
conv4_block2_out (Activation)   (None, 14, 14, 1024) 0           conv4_block2_add[0][0]
__________________________________________________________________________________________________
conv4_block3_1_conv (Conv2D)    (None, 14, 14, 256)  262400      conv4_block2_out[0][0]
__________________________________________________________________________________________________
conv4_block3_1_bn (BatchNormali (None, 14, 14, 256)  1024        conv4_block3_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block3_1_relu (Activation (None, 14, 14, 256)  0           conv4_block3_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block3_2_conv (Conv2D)    (None, 14, 14, 256)  590080      conv4_block3_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block3_2_bn (BatchNormali (None, 14, 14, 256)  1024        conv4_block3_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block3_2_relu (Activation (None, 14, 14, 256)  0           conv4_block3_2_bn[0][0]
__________________________________________________________________________________________________
conv4_block3_3_conv (Conv2D)    (None, 14, 14, 1024) 263168      conv4_block3_2_relu[0][0]
__________________________________________________________________________________________________
conv4_block3_3_bn (BatchNormali (None, 14, 14, 1024) 4096        conv4_block3_3_conv[0][0]
__________________________________________________________________________________________________
conv4_block3_add (Add)          (None, 14, 14, 1024) 0           conv4_block2_out[0][0]
                                                                 conv4_block3_3_bn[0][0]
__________________________________________________________________________________________________
conv4_block3_out (Activation)   (None, 14, 14, 1024) 0           conv4_block3_add[0][0]
__________________________________________________________________________________________________
conv4_block4_1_conv (Conv2D)    (None, 14, 14, 256)  262400      conv4_block3_out[0][0]
__________________________________________________________________________________________________
conv4_block4_1_bn (BatchNormali (None, 14, 14, 256)  1024        conv4_block4_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block4_1_relu (Activation (None, 14, 14, 256)  0           conv4_block4_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block4_2_conv (Conv2D)    (None, 14, 14, 256)  590080      conv4_block4_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block4_2_bn (BatchNormali (None, 14, 14, 256)  1024        conv4_block4_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block4_2_relu (Activation (None, 14, 14, 256)  0           conv4_block4_2_bn[0][0]
__________________________________________________________________________________________________
conv4_block4_3_conv (Conv2D)    (None, 14, 14, 1024) 263168      conv4_block4_2_relu[0][0]
__________________________________________________________________________________________________
conv4_block4_3_bn (BatchNormali (None, 14, 14, 1024) 4096        conv4_block4_3_conv[0][0]
__________________________________________________________________________________________________
conv4_block4_add (Add)          (None, 14, 14, 1024) 0           conv4_block3_out[0][0]
                                                                 conv4_block4_3_bn[0][0]
```

```
conv4_block4_out (Activation)   (None, 14, 14, 1024) 0           conv4_block4_add[0][0]
conv4_block5_1_conv (Conv2D)    (None, 14, 14, 256)  262400      conv4_block4_out[0][0]
conv4_block5_1_bn (BatchNormali (None, 14, 14, 256)  1024        conv4_block5_1_conv[0][0]
conv4_block5_1_relu (Activation (None, 14, 14, 256)  0           conv4_block5_1_bn[0][0]
conv4_block5_2_conv (Conv2D)    (None, 14, 14, 256)  590080      conv4_block5_1_relu[0][0]
conv4_block5_2_bn (BatchNormali (None, 14, 14, 256)  1024        conv4_block5_2_conv[0][0]
conv4_block5_2_relu (Activation (None, 14, 14, 256)  0           conv4_block5_2_bn[0][0]
conv4_block5_3_conv (Conv2D)    (None, 14, 14, 1024) 263168      conv4_block5_2_relu[0][0]
conv4_block5_3_bn (BatchNormali (None, 14, 14, 1024) 4096        conv4_block5_3_conv[0][0]
conv4_block5_add (Add)          (None, 14, 14, 1024) 0           conv4_block4_out[0][0]
                                                                 conv4_block5_3_bn[0][0]
conv4_block5_out (Activation)   (None, 14, 14, 1024) 0           conv4_block5_add[0][0]
conv4_block6_1_conv (Conv2D)    (None, 14, 14, 256)  262400      conv4_block5_out[0][0]
conv4_block6_1_bn (BatchNormali (None, 14, 14, 256)  1024        conv4_block6_1_conv[0][0]
conv4_block6_1_relu (Activation (None, 14, 14, 256)  0           conv4_block6_1_bn[0][0]
conv4_block6_2_conv (Conv2D)    (None, 14, 14, 256)  590080      conv4_block6_1_relu[0][0]
conv4_block6_2_bn (BatchNormali (None, 14, 14, 256)  1024        conv4_block6_2_conv[0][0]
conv4_block6_2_relu (Activation (None, 14, 14, 256)  0           conv4_block6_2_bn[0][0]
conv4_block6_3_conv (Conv2D)    (None, 14, 14, 1024) 263168      conv4_block6_2_relu[0][0]
conv4_block6_3_bn (BatchNormali (None, 14, 14, 1024) 4096        conv4_block6_3_conv[0][0]
conv4_block6_add (Add)          (None, 14, 14, 1024) 0           conv4_block5_out[0][0]
                                                                 conv4_block6_3_bn[0][0]
conv4_block6_out (Activation)   (None, 14, 14, 1024) 0           conv4_block6_add[0][0]
conv5_block1_1_conv (Conv2D)    (None, 7, 7, 512)    524800      conv4_block6_out[0][0]
conv5_block1_1_bn (BatchNormali (None, 7, 7, 512)    2048        conv5_block1_1_conv[0][0]
```

```
conv5_block1_1_relu (Activation (None, 7, 7, 512)    0           conv5_block1_1_bn[0][0]
__________________________________________________________________________________________
conv5_block1_2_conv (Conv2D)    (None, 7, 7, 512)    2359808     conv5_block1_1_relu[0][0]
__________________________________________________________________________________________
conv5_block1_2_bn (BatchNormali (None, 7, 7, 512)    2048        conv5_block1_2_conv[0][0]
__________________________________________________________________________________________
conv5_block1_2_relu (Activation (None, 7, 7, 512)    0           conv5_block1_2_bn[0][0]
__________________________________________________________________________________________
conv5_block1_0_conv (Conv2D)    (None, 7, 7, 2048)   2099200     conv4_block6_out[0][0]
__________________________________________________________________________________________
conv5_block1_3_conv (Conv2D)    (None, 7, 7, 2048)   1050624     conv5_block1_2_relu[0][0]
__________________________________________________________________________________________
conv5_block1_0_bn (BatchNormali (None, 7, 7, 2048)   8192        conv5_block1_0_conv[0][0]
__________________________________________________________________________________________
conv5_block1_3_bn (BatchNormali (None, 7, 7, 2048)   8192        conv5_block1_3_conv[0][0]
__________________________________________________________________________________________
conv5_block1_add (Add)          (None, 7, 7, 2048)   0           conv5_block1_0_bn[0][0]
                                                                 conv5_block1_3_bn[0][0]
__________________________________________________________________________________________
conv5_block1_out (Activation)   (None, 7, 7, 2048)   0           conv5_block1_add[0][0]
__________________________________________________________________________________________
conv5_block2_1_conv (Conv2D)    (None, 7, 7, 512)    1049088     conv5_block1_out[0][0]
__________________________________________________________________________________________
conv5_block2_1_bn (BatchNormali (None, 7, 7, 512)    2048        conv5_block2_1_conv[0][0]
__________________________________________________________________________________________
conv5_block2_1_relu (Activation (None, 7, 7, 512)    0           conv5_block2_1_bn[0][0]
__________________________________________________________________________________________
conv5_block2_2_conv (Conv2D)    (None, 7, 7, 512)    2359808     conv5_block2_1_relu[0][0]
__________________________________________________________________________________________
conv5_block2_2_bn (BatchNormali (None, 7, 7, 512)    2048        conv5_block2_2_conv[0][0]
__________________________________________________________________________________________
conv5_block2_2_relu (Activation (None, 7, 7, 512)    0           conv5_block2_2_bn[0][0]
__________________________________________________________________________________________
conv5_block2_3_conv (Conv2D)    (None, 7, 7, 2048)   1050624     conv5_block2_2_relu[0][0]
__________________________________________________________________________________________
conv5_block2_3_bn (BatchNormali (None, 7, 7, 2048)   8192        conv5_block2_3_conv[0][0]
__________________________________________________________________________________________
conv5_block2_add (Add)          (None, 7, 7, 2048)   0           conv5_block1_out[0][0]
                                                                 conv5_block2_3_bn[0][0]
__________________________________________________________________________________________
conv5_block2_out (Activation)   (None, 7, 7, 2048)   0           conv5_block2_add[0][0]
__________________________________________________________________________________________
conv5_block3_1_conv (Conv2D)    (None, 7, 7, 512)    1049088     conv5_block2_out[0][0]
__________________________________________________________________________________________
conv5_block3_1_bn (BatchNormali (None, 7, 7, 512)    2048        conv5_block3_1_conv[0][0]
__________________________________________________________________________________________
conv5_block3_1_relu (Activation (None, 7, 7, 512)    0           conv5_block3_1_bn[0][0]
```

```
conv5_block3_2_conv (Conv2D)    (None, 7, 7, 512)    2359808     conv5_block3_1_relu[0][0]
__________________________________________________________________________________________________
conv5_block3_2_bn (BatchNormali (None, 7, 7, 512)    2048        conv5_block3_2_conv[0][0]
__________________________________________________________________________________________________
conv5_block3_2_relu (Activation (None, 7, 7, 512)    0           conv5_block3_2_bn[0][0]
__________________________________________________________________________________________________
conv5_block3_3_conv (Conv2D)    (None, 7, 7, 2048)   1050624     conv5_block3_2_relu[0][0]
__________________________________________________________________________________________________
conv5_block3_3_bn (BatchNormali (None, 7, 7, 2048)   8192        conv5_block3_3_conv[0][0]
__________________________________________________________________________________________________
conv5_block3_add (Add)          (None, 7, 7, 2048)   0           conv5_block2_out[0][0]
                                                                 conv5_block3_3_bn[0][0]
__________________________________________________________________________________________________
conv5_block3_out (Activation)   (None, 7, 7, 2048)   0           conv5_block3_add[0][0]
__________________________________________________________________________________________________
avg_pool (GlobalAveragePooling2 (None, 2048)         0           conv5_block3_out[0][0]
__________________________________________________________________________________________________
probs (Dense)                   (None, 1000)         2049000     avg_pool[0][0]
==================================================================================================
Total params: 25,636,712
Trainable params: 25,583,592
Non-trainable params: 53,120
__________________________________________________________________________________________________
```

Import and preprocess 3 sample images

```
In [4]: # Import 3 sample ImageNet images

        from tensorflow.keras.preprocessing.image import load_img

        lemon_img = load_img('data/lemon.jpg', target_size=(224, 224))
        viaduct_img = load_img('data/viaduct.jpg', target_size=(224, 224))
        water_tower_img = load_img('data/water_tower.jpg', target_size=(224, 224))
```

Use ResNet50 model to classify images

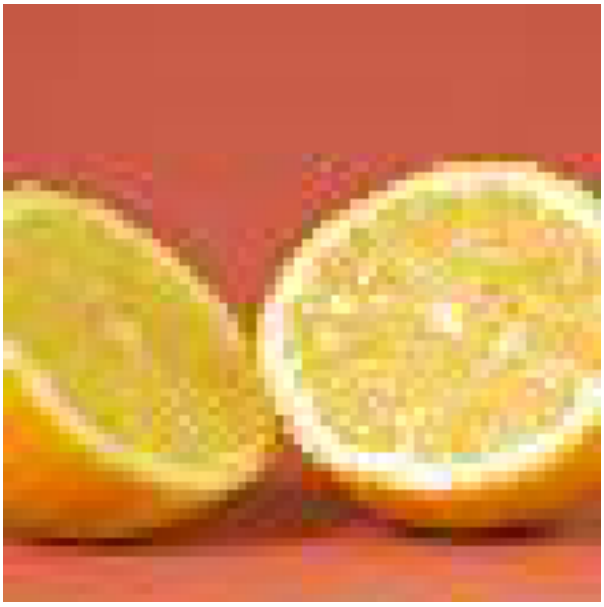
```
In [5]: # Useful function: presents top 5 predictions and probabilities

        from tensorflow.keras.preprocessing.image import img_to_array
        from tensorflow.keras.applications.resnet50 import preprocess_input, decode_predictions
        import numpy as np
        import pandas as pd

        def get_top_5_predictions(img):
            x = img_to_array(img)[np.newaxis, ...]
            x = preprocess_input(x)
```

```
    preds = decode_predictions(model.predict(x), top=5)
    top_preds = pd.DataFrame(columns=['prediction', 'probability'],
                             index=np.arange(5)+1)
    for i in range(5):
        top_preds.loc[i+1, 'prediction'] = preds[0][i][1]
        top_preds.loc[i+1, 'probability'] = preds[0][i][2]
    return top_preds
```

Image 1: lemon

In [6]:
```
# Display image
lemon_img
```

Out[6]:



In [8]:
```
# Display top 5 predictions
get_top_5_predictions(lemon_img)
```

```
Downloading data from https://storage.googleapis.com/download.tensorflow.org/data/imagenet_clas
40960/35363 [==================================] - 0s 0us/step
```

Out[8]:

	prediction	probability
1	consomme	0.227801
2	lemon	0.221758
3	eggnog	0.151335
4	ladle	0.0400883
5	spotlight	0.0291972

Image 2: viaduct

```
In [9]: # Display image
        viaduct_img
```

Out[9]:

```
In [10]: # Display top 5 predictions
         get_top_5_predictions(viaduct_img)
```

Out[10]:

	prediction	probability
1	vault	0.367951
2	prison	0.111742
3	viaduct	0.110738
4	window_screen	0.0882307
5	fire_screen	0.0206752

Image 3: water tower

```
In [11]: # Display image
         water_tower_img
```

Out[11]:

```
In [12]: # Display top 5 predictions
         get_top_5_predictions(water_tower_img)
```

```
Out[12]:       prediction probability
         1     solar_dish    0.384681
         2          ladle    0.196179
         3    planetarium    0.116682
         4       strainer     0.04999
         5  jigsaw_puzzle   0.0219473
```

Tensorflow Hub modules

Import and build Tensorflow Hub MobileNet v1 model Today we'll be using Google's MobileNet v1 model, available on Tensorflow Hub. Please see the description on the Tensorflow Hub page for details on it's architecture, how it's trained, and the reference. If you continue using it, please cite it properly! The paper it comes from is:

Andrew G. Howard, Menglong Zhu, Bo Chen, Dmitry Kalenichenko, Weijun Wang, Tobias Weyand, Marco Andreetto, Hartwig Adam: "MobileNets: Efficient Convolutional Neural Networks for Mobile Vision Applications", 2017.

This model takes a long time to download on the Coursera platform, so it is pre-downloaded in your workspace and saved in Tensorflow SavedModel format. If you want to import it on your personal machine, use the following code:

```
module_url = "https://tfhub.dev/google/imagenet/mobilenet_v1_050_160/classification/4"
model = Sequential([hub.KerasLayer(module_url)])
model.build(input_shape=[None, 160, 160, 3])
```

In this coding tutorial, you will instead load the model directly from disk.

```
In [4]: import tensorflow_hub as hub
        from tensorflow.keras.models import load_model, Sequential

In [17]: import numpy as np
         import pandas as pd

In [5]: # Build Google's Mobilenet v1 model
        module = load_model('models/Tensorflow_MobileNet_v1')
        model = Sequential(hub.KerasLayer(module))
        model.build(input_shape = [None, 160, 160, 3])
        model.summary()
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
keras_layer (KerasLayer)     multiple                  1343049
=================================================================
Total params: 1,343,049
Trainable params: 0
Non-trainable params: 1,343,049
_________________________________________________________________
```

Use MobileNet model to classify images

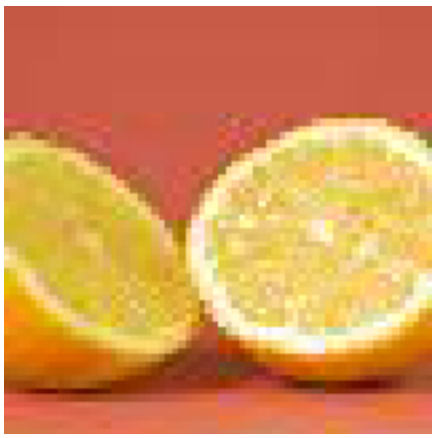
```
In [11]: # Import and preprocess 3 sample ImageNet images

         from tensorflow.keras.preprocessing.image import load_img, img_to_array

         lemon_img = load_img("data/lemon.jpg", target_size=(160, 160))
         viaduct_img = load_img("data/viaduct.jpg", target_size=(160, 160))
         water_tower_img = load_img("data/water_tower.jpg", target_size=(160, 160))

In [13]: # Read in categories text file

         with open('data/imagenet_categories.txt') as txt_file:
             categories = txt_file.read().splitlines()

In [14]: # Useful function: presents top 5 predictions

         import pandas as pd

         def get_top_5_predictions(img):
             x = img_to_array(img)[np.newaxis, ...] / 255.0
             preds = model.predict(x)
             top_preds = pd.DataFrame(columns=['prediction'],
```

```
                                    index=np.arange(5)+1)
    sorted_index = np.argsort(-preds[0])
    for i in range(5):
        ith_pred = categories[sorted_index[i]]
        top_preds.loc[i+1, 'prediction'] = ith_pred

    return top_preds
```

Image 1: lemon

```
In [15]: lemon_img
```

Out[15]:



```
In [18]: get_top_5_predictions(lemon_img)
```

Out[18]:

	prediction
1	shower cap
2	tray
3	candle
4	brassiere
5	African chameleon

Image 2: viaduct

```
In [19]: viaduct_img
```

Out[19]:

```
In [20]: get_top_5_predictions(viaduct_img)
```

```
Out[20]:    prediction
         1     viaduct
         2        pier
         3         dam
         4      prison
         5  solar dish
```

Image 3: water tower

```
In [21]: water_tower_img
```

```
Out[21]:
```

```
In [22]: get_top_5_predictions(water_tower_img)
```

```
Out[22]:          prediction
          1        solar dish
          2       water tower
          3  aircraft carrier
          4     jigsaw puzzle
          5       oxygen mask
```