Jonathan Ho CS 4375

Image Classification

Import necessary packages

In [1]:
```
import os
import tensorflow as tf
from tensorflow.keras.preprocessing.image import ImageDataGenerator
import matplotlib.pyplot as plt
import seaborn as sns
import warnings
from tensorflow.keras.callbacks import EarlyStopping
import numpy as np
from tensorflow.keras.applications.vgg19 import VGG19
from tensorflow.keras.applications.vgg19 import preprocess_input
from tensorflow.keras.models import Model
from tensorflow.keras import layers
```

In [2]:
```
batch_size = 32
epochs = 20
num_classes = 13
```

Preparing the dataset

In [3]:
```
# Loading the root of the dataset
for dirname, _, filenames in os.walk(r'C:\Users\Jonathan\Desktop\cards'):
    for filename in filenames:
        os.path.join(dirname, filename)
```

In [4]:
```
# Importing datasets
train=tf.keras.utils.image_dataset_from_directory(r'C:\Users\Jonathan\Des
test=tf.keras.utils.image_dataset_from_directory(r'C:\Users\Jonathan\Desk
valid=tf.keras.utils.image_dataset_from_directory(r'C:\Users\Jonathan\Des
class_names=train.class_names
print(class_names)
```

```
Found 2031 files belonging to 13 classes.
Found 65 files belonging to 13 classes.
Found 65 files belonging to 13 classes.
['ace of spades', 'eight of spades', 'five of spades', 'four of spades',
'jack of spades', 'king of spades', 'nine of spades', 'queen of spades',
'seven of spades', 'six of spades', 'ten of spades', 'three of spades',
'two of spades']
```

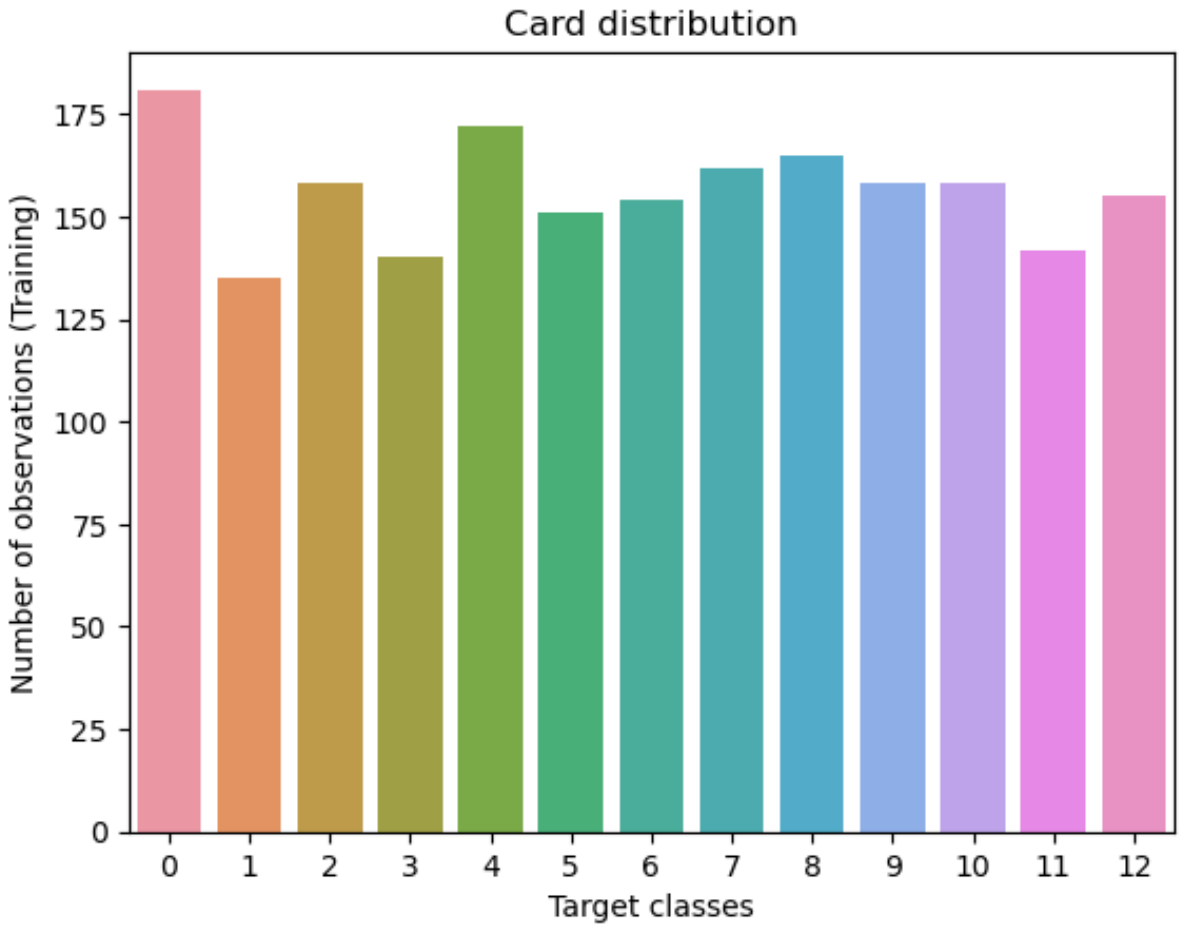
Creating distribution graph

In [5]:
```
# Get labels
graph_labels_datagen = ImageDataGenerator()
graph_labels_path = r'C:\Users\Jonathan\Desktop\cards\train'

graph_labels_set = graph_labels_datagen.flow_from_directory(graph_labels_
                                                    target_size = (224, 224)
                                                    batch_size = batch_size,
                                                    seed = 1234,
                                                    class_mode = 'sparse')

labels=graph_labels_set.classes
```

```
Found 2031 images belonging to 13 classes.
```

In [6]:
```
# Plot categories
warnings.filterwarnings('ignore')

sns.countplot(labels)
plt.title('Card distribution')
plt.xlabel('Target classes')
plt.ylabel('Number of observations (Training)')

print('Category indices:')
graph_labels_set.class_indices
```

Out[6]:
```
Category indices:
{'ace of spades': 0,
 'eight of spades': 1,
 'five of spades': 2,
 'four of spades': 3,
 'jack of spades': 4,
 'king of spades': 5,
 'nine of spades': 6,
 'queen of spades': 7,
 'seven of spades': 8,
 'six of spades': 9,
 'ten of spades': 10,
 'three of spades': 11,
 'two of spades': 12}
```



The original dataset of images are the 53 playing cards. I will be looking at a subset of the data which is specifically all the cards with the suit of spade. The model will be trained with a valid dataset of spade images, and using the test dataset, it should be able to predict if the card is a spade and what rank is the card.

Basic sequential model

In [7]:
```
# Setup the variable for the basic sequential model

model_seq = tf.keras.models.Sequential([
    tf.keras.layers.Flatten(input_shape=(224, 224, 3)),
    tf.keras.layers.Dense(8, activation='relu'),
    tf.keras.layers.Dropout(0.2),
    tf.keras.layers.Dense(num_classes, activation='softmax')
])

model_seq.summary()
```

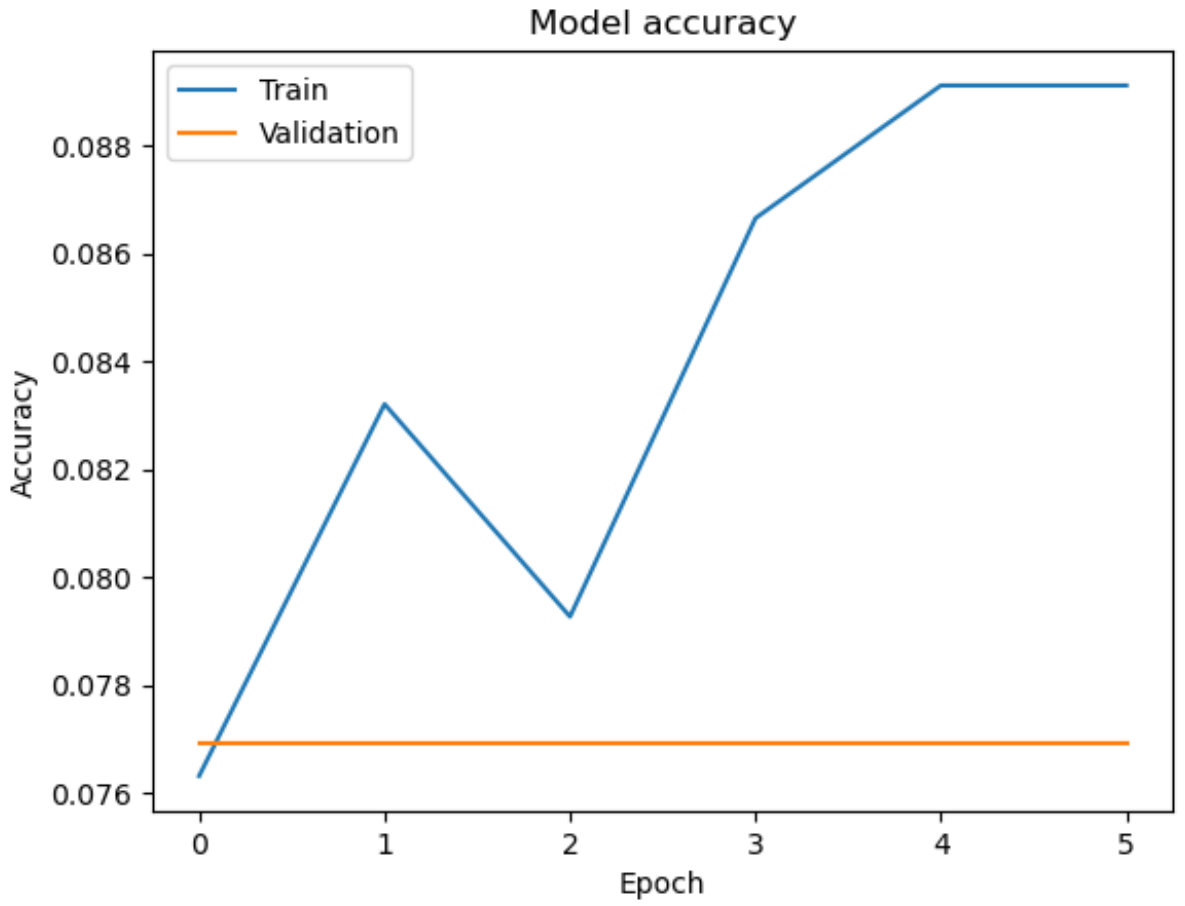
```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 flatten (Flatten)           (None, 150528)            0

 dense (Dense)               (None, 8)                 1204232

 dropout (Dropout)           (None, 8)                 0

 dense_1 (Dense)             (None, 13)                117

=================================================================
Total params: 1,204,349
Trainable params: 1,204,349
Non-trainable params: 0
_________________________________________________________________
```

In [8]:
```
# Early stopping to avoid overfitting of model
early_stop=EarlyStopping(monitor='val_loss',mode='min',verbose=1,patience
```

In [9]:
```
# Use sparse categorical since the data is not one hot encoded.
# Also can do direct sparse categorical because softmax function was used
model_seq.compile(loss='sparse_categorical_crossentropy',
              optimizer='rmsprop',
              metrics=['accuracy'])


history=model_seq.fit(train,
                      validation_data=valid,
                      callbacks=[early_stop],
                      epochs=epochs)
```

```
Epoch 1/20
64/64 [==============================] - 3s 37ms/step - loss: 1592.2083 -
accuracy: 0.0763 - val_loss: 2.5650 - val_accuracy: 0.0769
Epoch 2/20
64/64 [==============================] - 3s 41ms/step - loss: 2.5946 - ac
curacy: 0.0832 - val_loss: 2.5650 - val_accuracy: 0.0769
Epoch 3/20
64/64 [==============================] - 2s 37ms/step - loss: 2.5641 - ac
curacy: 0.0793 - val_loss: 2.5651 - val_accuracy: 0.0769
Epoch 4/20
64/64 [==============================] - 3s 40ms/step - loss: 2.5637 - ac
curacy: 0.0867 - val_loss: 2.5653 - val_accuracy: 0.0769
Epoch 5/20
64/64 [==============================] - 3s 38ms/step - loss: 2.5634 - ac
curacy: 0.0891 - val_loss: 2.5654 - val_accuracy: 0.0769
Epoch 6/20
64/64 [==============================] - 3s 40ms/step - loss: 2.5632 - ac
curacy: 0.0891 - val_loss: 2.5656 - val_accuracy: 0.0769
Epoch 6: early stopping
```

In [10]:
```
# Plot training & validation accuracy values
plt.plot(history.history['accuracy'])
plt.plot(history.history['val_accuracy'])
plt.title('Model accuracy')
plt.ylabel('Accuracy')
plt.xlabel('Epoch')
plt.legend(['Train', 'Validation'], loc='upper left')
plt.show()
```



In [11]:
```
# Testing the model
score_seq = model_seq.evaluate(test, verbose=0)
print('Test loss:', score_seq[0])
print('Test accuracy:', score_seq[1])

predictions = model_seq.predict(test, verbose=0)
score_seq2 = tf.nn.softmax(predictions[0])

print(
    "This image is probably the {} with a {:.2f} percent confidence."
    .format(class_names[np.argmax(score_seq2)], 100 * np.max(score_seq2))
)
```

```
Test loss: 2.56557035446167
Test accuracy: 0.07692307978868484
This image is probably the ace of spades with a 7.73 percent confidence.
```

Convolutional Neural Networks

In [12]:
```
# Building the CNN model
model_cnn = tf.keras.Sequential([
    tf.keras.layers.Rescaling(1./255, input_shape=(224, 224, 3)),
    tf.keras.layers.Conv2D(16,3,padding='same',activation='relu'),
    tf.keras.layers.MaxPool2D(),
    tf.keras.layers.Conv2D(32,3,padding='same',activation='relu'),
    tf.keras.layers.MaxPool2D(),
    tf.keras.layers.Conv2D(64,3,padding='same',activation='relu'),
    tf.keras.layers.MaxPool2D(),
    tf.keras.layers.Conv2D(128,3,padding='same',activation='relu'),
    tf.keras.layers.MaxPool2D(),
    tf.keras.layers.Conv2D(256,3,padding='same',activation='relu'),
    tf.keras.layers.MaxPool2D(),
    tf.keras.layers.Dropout(.2),
    tf.keras.layers.Flatten(),
    tf.keras.layers.Dense(128,activation='relu'),
    tf.keras.layers.Dense(num_classes, activation='softmax')
])

model_cnn.summary()
```

```
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 rescaling (Rescaling)       (None, 224, 224, 3)       0

 conv2d (Conv2D)             (None, 224, 224, 16)      448

 max_pooling2d (MaxPooling2D  (None, 112, 112, 16)     0
 )

 conv2d_1 (Conv2D)           (None, 112, 112, 32)      4640

 max_pooling2d_1 (MaxPooling  (None, 56, 56, 32)       0
 2D)

 conv2d_2 (Conv2D)           (None, 56, 56, 64)        18496

 max_pooling2d_2 (MaxPooling  (None, 28, 28, 64)       0
 2D)

 conv2d_3 (Conv2D)           (None, 28, 28, 128)       73856

 max_pooling2d_3 (MaxPooling  (None, 14, 14, 128)      0
 2D)

 conv2d_4 (Conv2D)           (None, 14, 14, 256)       295168

 max_pooling2d_4 (MaxPooling  (None, 7, 7, 256)        0
 2D)

 dropout_1 (Dropout)         (None, 7, 7, 256)         0

 flatten_1 (Flatten)         (None, 12544)             0

 dense_2 (Dense)             (None, 128)               1605760

 dense_3 (Dense)             (None, 13)                1677

=================================================================
Total params: 2,000,045
Trainable params: 2,000,045
Non-trainable params: 0
_________________________________________________________________
```

In [13]:

```
model_cnn.compile(loss='sparse_categorical_crossentropy',
              optimizer='rmsprop',
              metrics=['accuracy'])


history=model_cnn.fit(train,
                      validation_data=valid,
```

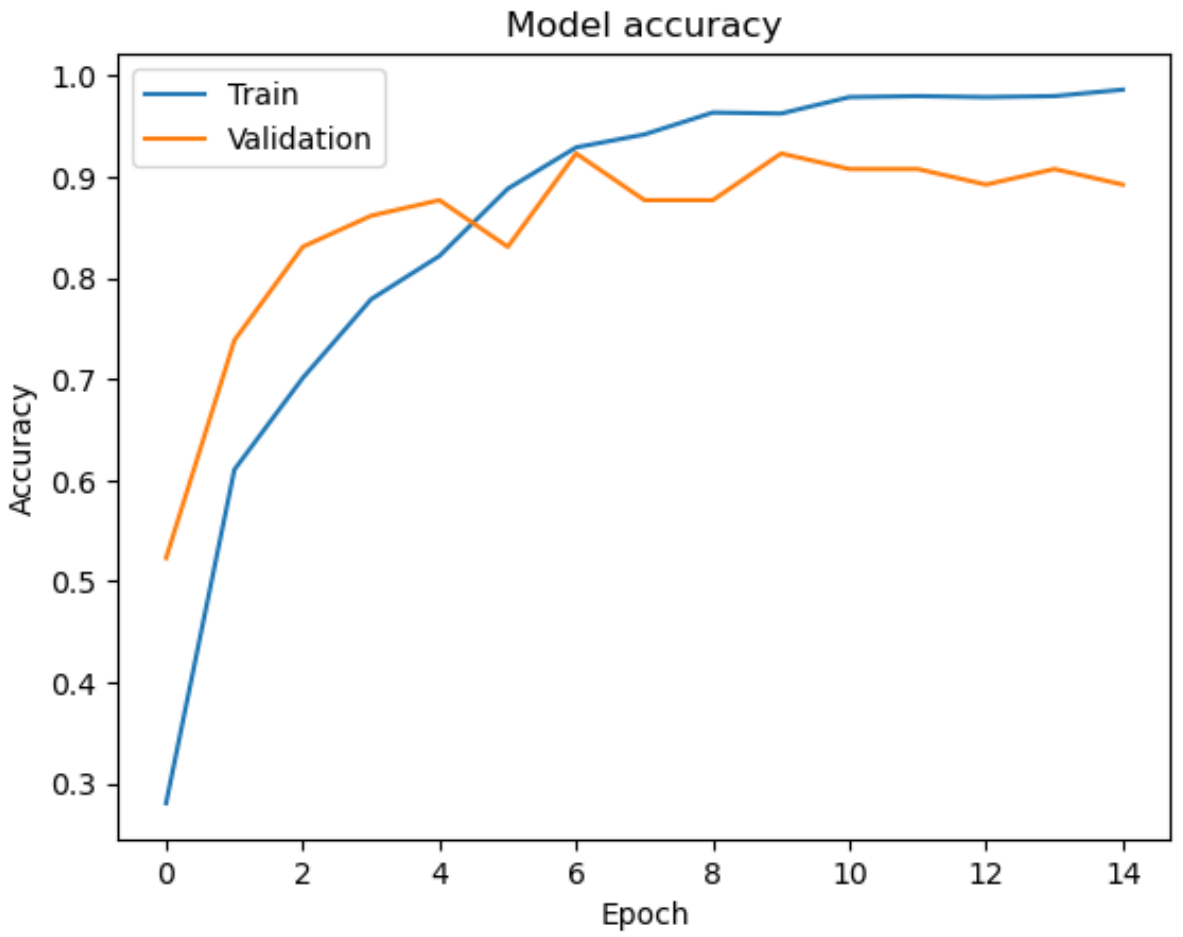
```
                    callbacks=[early_stop],
                    epochs=epochs)
```

```
Epoch 1/20
64/64 [==============================] - 16s 233ms/step - loss: 2.2241 -
accuracy: 0.2806 - val_loss: 1.2217 - val_accuracy: 0.5231
Epoch 2/20
64/64 [==============================] - 15s 234ms/step - loss: 1.2499 -
accuracy: 0.6105 - val_loss: 0.6515 - val_accuracy: 0.7385
Epoch 3/20
64/64 [==============================] - 15s 233ms/step - loss: 0.9310 -
accuracy: 0.7011 - val_loss: 0.5383 - val_accuracy: 0.8308
Epoch 4/20
64/64 [==============================] - 15s 233ms/step - loss: 0.7096 -
accuracy: 0.7789 - val_loss: 0.4008 - val_accuracy: 0.8615
Epoch 5/20
64/64 [==============================] - 15s 233ms/step - loss: 0.5301 -
accuracy: 0.8218 - val_loss: 0.4286 - val_accuracy: 0.8769
Epoch 6/20
64/64 [==============================] - 15s 234ms/step - loss: 0.3504 -
accuracy: 0.8882 - val_loss: 0.4470 - val_accuracy: 0.8308
Epoch 7/20
64/64 [==============================] - 15s 235ms/step - loss: 0.2353 -
accuracy: 0.9291 - val_loss: 0.2653 - val_accuracy: 0.9231
Epoch 8/20
64/64 [==============================] - 15s 231ms/step - loss: 0.1900 -
accuracy: 0.9419 - val_loss: 0.5255 - val_accuracy: 0.8769
Epoch 9/20
64/64 [==============================] - 15s 233ms/step - loss: 0.1254 -
accuracy: 0.9636 - val_loss: 0.5057 - val_accuracy: 0.8769
Epoch 10/20
64/64 [==============================] - 15s 233ms/step - loss: 0.1249 -
accuracy: 0.9626 - val_loss: 0.2303 - val_accuracy: 0.9231
Epoch 11/20
64/64 [==============================] - 15s 236ms/step - loss: 0.0832 -
accuracy: 0.9788 - val_loss: 0.4067 - val_accuracy: 0.9077
Epoch 12/20
64/64 [==============================] - 15s 233ms/step - loss: 0.0629 -
accuracy: 0.9798 - val_loss: 0.4752 - val_accuracy: 0.9077
Epoch 13/20
64/64 [==============================] - 15s 236ms/step - loss: 0.0815 -
accuracy: 0.9788 - val_loss: 0.4247 - val_accuracy: 0.8923
Epoch 14/20
64/64 [==============================] - 15s 232ms/step - loss: 0.0838 -
accuracy: 0.9798 - val_loss: 0.5824 - val_accuracy: 0.9077
Epoch 15/20
64/64 [==============================] - 15s 234ms/step - loss: 0.0473 -
accuracy: 0.9862 - val_loss: 1.1514 - val_accuracy: 0.8923
Epoch 15: early stopping
```

In [14]:

```
plt.plot(history.history['accuracy'])
plt.plot(history.history['val_accuracy'])
plt.title('Model accuracy')
```

```
plt.ylabel('Accuracy')
plt.xlabel('Epoch')
plt.legend(['Train', 'Validation'], loc='upper left')
plt.show()
```



In [15]:
```
score_cnn = model_cnn.evaluate(test, verbose=0)
print('Test loss:', score_cnn[0])
print('Test accuracy:', score_cnn[1])

predictions = model_cnn.predict(test, verbose=0)
score_cnn2 = tf.nn.softmax(predictions[0])

print(
    "This image is probably the {} with a {:.2f} percent confidence."
    .format(class_names[np.argmax(score_cnn2)], 100 * np.max(score_cnn2))
)
```

```
Test loss: 1.2218966484069824
Test accuracy: 0.8153846263885498
This image is probably the three of spades with a 18.47 percent confidenc
e.
```

Visual Geometry Group 19

In [16]:
```
vgg = VGG19(input_shape=(224, 224, 3), weights='imagenet', include_top=Fa
```

```
# Prevent weights from being updated after training
for layer in vgg.layers:
    layer.trainable = False

x = layers.Flatten()(vgg.output)

#adding output layer.Softmax classifier is used as it is multi-class clas
prediction = tf.keras.layers.Dense(13, activation='softmax')(x)

model_vgg = Model(inputs=vgg.input, outputs=prediction)
```

In [17]:
```
# View the structure of the model
model_vgg.summary()
```

```
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 224, 224, 3)]     0

 block1_conv1 (Conv2D)       (None, 224, 224, 64)      1792

 block1_conv2 (Conv2D)       (None, 224, 224, 64)      36928

 block1_pool (MaxPooling2D)  (None, 112, 112, 64)      0

 block2_conv1 (Conv2D)       (None, 112, 112, 128)     73856

 block2_conv2 (Conv2D)       (None, 112, 112, 128)     147584

 block2_pool (MaxPooling2D)  (None, 56, 56, 128)       0

 block3_conv1 (Conv2D)       (None, 56, 56, 256)       295168

 block3_conv2 (Conv2D)       (None, 56, 56, 256)       590080

 block3_conv3 (Conv2D)       (None, 56, 56, 256)       590080

 block3_conv4 (Conv2D)       (None, 56, 56, 256)       590080

 block3_pool (MaxPooling2D)  (None, 28, 28, 256)       0

 block4_conv1 (Conv2D)       (None, 28, 28, 512)       1180160

 block4_conv2 (Conv2D)       (None, 28, 28, 512)       2359808

 block4_conv3 (Conv2D)       (None, 28, 28, 512)       2359808

 block4_conv4 (Conv2D)       (None, 28, 28, 512)       2359808

 block4_pool (MaxPooling2D)  (None, 14, 14, 512)       0

 block5_conv1 (Conv2D)       (None, 14, 14, 512)       2359808

 block5_conv2 (Conv2D)       (None, 14, 14, 512)       2359808

 block5_conv3 (Conv2D)       (None, 14, 14, 512)       2359808

 block5_conv4 (Conv2D)       (None, 14, 14, 512)       2359808

 block5_pool (MaxPooling2D)  (None, 7, 7, 512)         0

 flatten_2 (Flatten)         (None, 25088)             0

 dense_4 (Dense)             (None, 13)                326157
```

```
=================================================================
Total params: 20,350,541
Trainable params: 326,157
Non-trainable params: 20,024,384
_________________________________________________________________
```

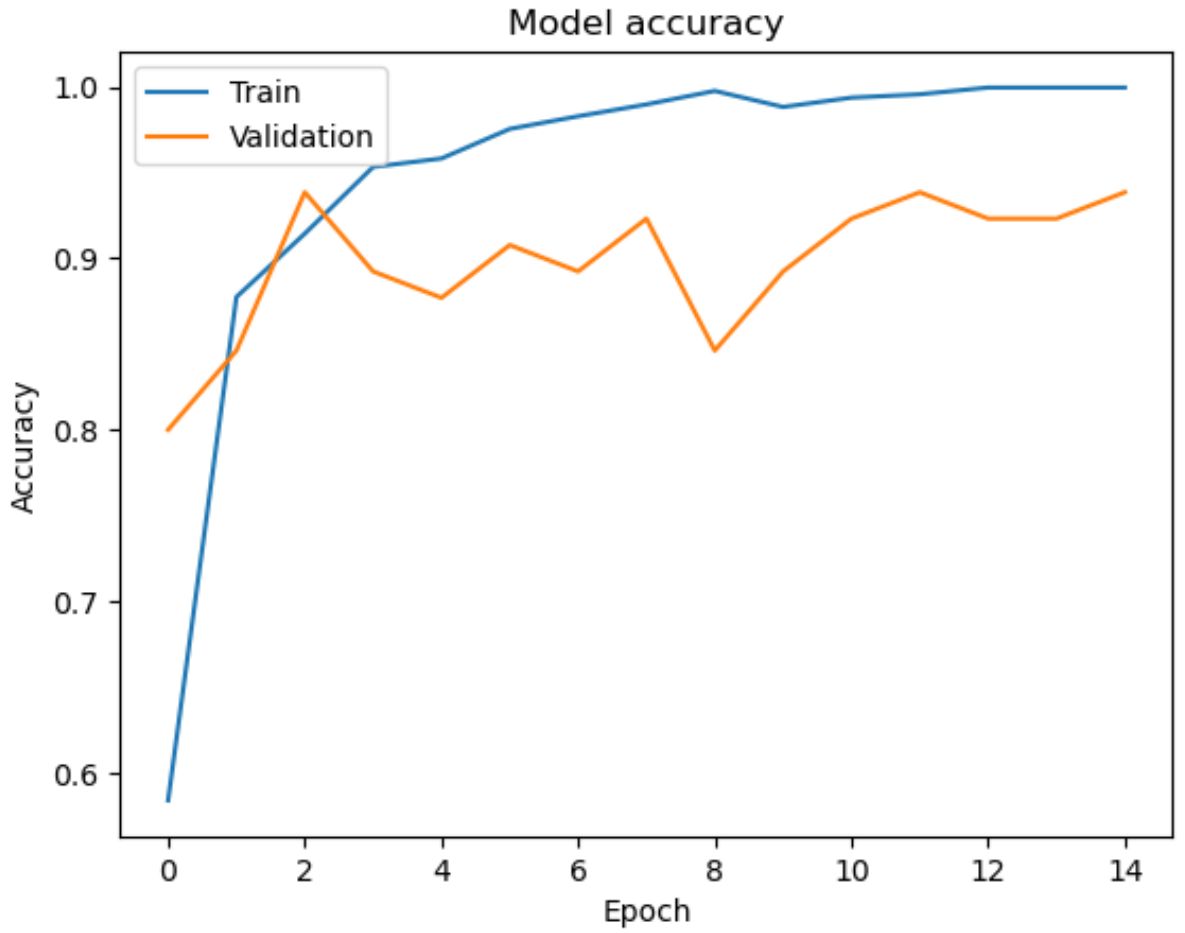
In [18]:
```
model_vgg.compile(
  loss='sparse_categorical_crossentropy',
  optimizer="rmsprop",
  metrics=['accuracy']
)

history=model_vgg.fit(train,
                      validation_data=valid,
                      callbacks=[early_stop],
                      epochs=epochs)
```

```
Epoch 1/20
64/64 [==============================] - 177s 3s/step - loss: 16.1557 - a
ccuracy: 0.5839 - val_loss: 6.2177 - val_accuracy: 0.8000
Epoch 2/20
64/64 [==============================] - 176s 3s/step - loss: 2.7433 - ac
curacy: 0.8774 - val_loss: 4.2978 - val_accuracy: 0.8462
Epoch 3/20
64/64 [==============================] - 176s 3s/step - loss: 1.9825 - ac
curacy: 0.9143 - val_loss: 4.5342 - val_accuracy: 0.9385
Epoch 4/20
64/64 [==============================] - 177s 3s/step - loss: 0.9940 - ac
curacy: 0.9532 - val_loss: 3.5953 - val_accuracy: 0.8923
Epoch 5/20
64/64 [==============================] - 176s 3s/step - loss: 0.9316 - ac
curacy: 0.9581 - val_loss: 3.9242 - val_accuracy: 0.8769
Epoch 6/20
64/64 [==============================] - 177s 3s/step - loss: 0.5833 - ac
curacy: 0.9754 - val_loss: 4.9419 - val_accuracy: 0.9077
Epoch 7/20
64/64 [==============================] - 176s 3s/step - loss: 0.3401 - ac
curacy: 0.9828 - val_loss: 3.6122 - val_accuracy: 0.8923
Epoch 8/20
64/64 [==============================] - 176s 3s/step - loss: 0.1066 - ac
curacy: 0.9897 - val_loss: 3.0115 - val_accuracy: 0.9231
Epoch 9/20
64/64 [==============================] - 176s 3s/step - loss: 0.1064 - ac
curacy: 0.9975 - val_loss: 7.9961 - val_accuracy: 0.8462
Epoch 10/20
64/64 [==============================] - 176s 3s/step - loss: 0.2004 - ac
curacy: 0.9882 - val_loss: 2.9285 - val_accuracy: 0.8923
Epoch 11/20
64/64 [==============================] - 177s 3s/step - loss: 0.0728 - ac
curacy: 0.9936 - val_loss: 3.4358 - val_accuracy: 0.9231
Epoch 12/20
64/64 [==============================] - 175s 3s/step - loss: 0.0862 - ac
curacy: 0.9956 - val_loss: 3.0301 - val_accuracy: 0.9385
Epoch 13/20
64/64 [==============================] - 176s 3s/step - loss: 0.0015 - ac
curacy: 0.9995 - val_loss: 4.3498 - val_accuracy: 0.9231
Epoch 14/20
64/64 [==============================] - 175s 3s/step - loss: 0.0441 - ac
curacy: 0.9995 - val_loss: 5.6168 - val_accuracy: 0.9231
Epoch 15/20
64/64 [==============================] - 175s 3s/step - loss: 0.0023 - ac
curacy: 0.9995 - val_loss: 3.3302 - val_accuracy: 0.9385
Epoch 15: early stopping
```

In [19]:

```
# Plot training & validation accuracy values
plt.plot(history.history['accuracy'])
plt.plot(history.history['val_accuracy'])
plt.title('Model accuracy')
plt.ylabel('Accuracy')
```

```
plt.xlabel('Epoch')
plt.legend(['Train', 'Validation'], loc='upper left')
plt.show()
```



In [20]:
```
score_vgg = model_vgg.evaluate(test, verbose=0)
print('Test loss:', score_vgg[0])
print('Test accuracy:', score_vgg[1])

predictions = model_vgg.predict(test, verbose=0)
score_vgg2 = tf.nn.softmax(predictions[0])

print(
    "This image is probably the {} with a {:.2f} percent confidence."
    .format(class_names[np.argmax(score_vgg2)], 100 * np.max(score_vgg2))
)
```

```
Test loss: 12.564727783203125
Test accuracy: 0.7846153974533081
This image is probably the six of spades with a 18.47 percent confidence.
```

Pre-trained model (EfficientNet B3)

In [21]:
```
# Must resize images to 200x200
train2=tf.keras.utils.image_dataset_from_directory(r'C:\Users\Jonathan\De
test2=tf.keras.utils.image_dataset_from_directory(r'C:\Users\Jonathan\Des
```

```
valid2=tf.keras.utils.image_dataset_from_directory(r'C:\Users\Jonathan\De

model_pre_trained = tf.keras.models.load_model(r'C:\Users\Jonathan\Deskto
```

```
Found 2031 files belonging to 13 classes.
Found 65 files belonging to 13 classes.
Found 65 files belonging to 13 classes.
```

In [22]:
```
model_pre_trained.summary()
```

```
Model: "model_3"
_________________________________________________________________
 Layer (type)                Output Shape              Param #   Connected to
=================================================================
 input_4 (InputLayer)        [(None, 200, 200, 3)]     0         []

 rescaling_3 (Rescaling)     (None, 200, 200, 3)       0         ['input_4[0][0]']

 normalization_3 (Normalization  (None, 200, 200, 3)   7         ['rescaling_3[0][0]']
 )

 stem_conv_pad (ZeroPadding2D)  (None, 201, 201, 3)    0         ['normalization_3[0][0]']

 stem_conv (Conv2D)          (None, 100, 100, 40)      1080      ['stem_conv_pad[0][0]']

 stem_bn (BatchNormalization)   (None, 100, 100, 40)   160       ['stem_conv[0][0]']

 stem_activation (Activation)   (None, 100, 100, 40)   0         ['stem_bn[0][0]']

 block1a_dwconv (DepthwiseConv2  (None, 100, 100, 40)  360       ['stem_activation[0][0]']
 D)                          )

 block1a_bn (BatchNormalization  (None, 100, 100, 40)  160       ['block1a_dwconv[0][0]']
 )                           )

 block1a_activation (Activation  (None, 100, 100, 40)  0         ['block1a_bn[0][0]']
 )                           )

 block1a_se_squeeze (GlobalAver  (None, 40)            0         ['block1a_activation[0][0]']
 agePooling2D)

 block1a_se_reshape (Reshape)   (None, 1, 1, 40)       0         ['block1a_se_squeeze[0][0]']

 block1a_se_reduce (Conv2D)     (None, 1, 1, 10)       410       ['block1
```

```
a_se_reshape[0][0']

 block1a_se_expand (Conv2D)     (None, 1, 1, 40)     440         ['block1
a_se_reduce[0][0']

 block1a_se_excite (Multiply)   (None, 100, 100, 40  0           ['block1
a_activation[0][0]',
                                )                                 'block1
a_se_expand[0][0']

 block1a_project_conv (Conv2D)  (None, 100, 100, 24  960         ['block1
a_se_excite[0][0']
                                )

 block1a_project_bn (BatchNorma  (None, 100, 100, 24  96         ['block1
a_project_conv[0][0']
 lization)                      )

 block1b_dwconv (DepthwiseConv2  (None, 100, 100, 24  216        ['block1
a_project_bn[0][0']
 D)                             )

 block1b_bn (BatchNormalization  (None, 100, 100, 24  96         ['block1
b_dwconv[0][0']
 )                              )

 block1b_activation (Activation  (None, 100, 100, 24  0          ['block1
b_bn[0][0']
 )                              )

 block1b_se_squeeze (GlobalAver  (None, 24)          0           ['block1
b_activation[0][0']
 agePooling2D)

 block1b_se_reshape (Reshape)   (None, 1, 1, 24)     0           ['block1
b_se_squeeze[0][0']

 block1b_se_reduce (Conv2D)     (None, 1, 1, 6)      150         ['block1
b_se_reshape[0][0']

 block1b_se_expand (Conv2D)     (None, 1, 1, 24)     168         ['block1
b_se_reduce[0][0']

 block1b_se_excite (Multiply)   (None, 100, 100, 24  0           ['block1
b_activation[0][0]',
                                )                                 'block1
b_se_expand[0][0']

 block1b_project_conv (Conv2D)  (None, 100, 100, 24  576         ['block1
b_se_excite[0][0']
                                )
```

```
 block1b_project_bn (BatchNorma  (None, 100, 100, 24  96         ['block1
b_project_conv[0][0]']
 lization)                      )

 block1b_drop (Dropout)         (None, 100, 100, 24  0           ['block1
b_project_bn[0][0]']
                                )

 block1b_add (Add)              (None, 100, 100, 24  0           ['block1
b_drop[0][0]',
                                )                                 'block1
a_project_bn[0][0]']

 block2a_expand_conv (Conv2D)   (None, 100, 100, 14  3456        ['block1
b_add[0][0]']
                                4)

 block2a_expand_bn (BatchNormal  (None, 100, 100, 14  576        ['block2
a_expand_conv[0][0]']
 ization)                       4)

 block2a_expand_activation (Act  (None, 100, 100, 14  0          ['block2
a_expand_bn[0][0]']
 ivation)                       4)

 block2a_dwconv_pad (ZeroPaddin  (None, 101, 101, 14  0          ['block2
a_expand_activation[0][0]
 g2D)                           4)                                ']

 block2a_dwconv (DepthwiseConv2  (None, 50, 50, 144)  1296       ['block2
a_dwconv_pad[0][0]']
 D)

 block2a_bn (BatchNormalization  (None, 50, 50, 144)  576        ['block2
a_dwconv[0][0]']
 )

 block2a_activation (Activation  (None, 50, 50, 144)  0          ['block2
a_bn[0][0]']
 )

 block2a_se_squeeze (GlobalAver  (None, 144)         0           ['block2
a_activation[0][0]']
 agePooling2D)

 block2a_se_reshape (Reshape)   (None, 1, 1, 144)    0           ['block2
a_se_squeeze[0][0]']

 block2a_se_reduce (Conv2D)     (None, 1, 1, 6)      870         ['block2
a_se_reshape[0][0]']

 block2a_se_expand (Conv2D)     (None, 1, 1, 144)    1008        ['block2
```

```
a_se_reduce[0][0]']

 block2a_se_excite (Multiply)   (None, 50, 50, 144)  0           ['block2
a_activation[0][0]',
                                                                  'block2
a_se_expand[0][0]']

 block2a_project_conv (Conv2D)  (None, 50, 50, 32)   4608        ['block2
a_se_excite[0][0]']

 block2a_project_bn (BatchNorma  (None, 50, 50, 32)  128         ['block2
a_project_conv[0][0]']
 lization)

 block2b_expand_conv (Conv2D)   (None, 50, 50, 192)  6144        ['block2
a_project_bn[0][0]']

 block2b_expand_bn (BatchNormal  (None, 50, 50, 192)  768        ['block2
b_expand_conv[0][0]']
 ization)

 block2b_expand_activation (Act  (None, 50, 50, 192)  0          ['block2
b_expand_bn[0][0]']
 ivation)

 block2b_dwconv (DepthwiseConv2  (None, 50, 50, 192)  1728       ['block2
b_expand_activation[0][0]
 D)                                                              ']

 block2b_bn (BatchNormalization  (None, 50, 50, 192)  768        ['block2
b_dwconv[0][0]']
 )

 block2b_activation (Activation  (None, 50, 50, 192)  0          ['block2
b_bn[0][0]']
 )

 block2b_se_squeeze (GlobalAver  (None, 192)         0          ['block2
b_activation[0][0]']
 agePooling2D)

 block2b_se_reshape (Reshape)   (None, 1, 1, 192)    0          ['block2
b_se_squeeze[0][0]']

 block2b_se_reduce (Conv2D)     (None, 1, 1, 8)      1544       ['block2
b_se_reshape[0][0]']

 block2b_se_expand (Conv2D)     (None, 1, 1, 192)    1728       ['block2
b_se_reduce[0][0]']

 block2b_se_excite (Multiply)   (None, 50, 50, 192)  0          ['block2
b_activation[0][0]',
```

```
                                                                 'block2
b_se_expand[0][0]']

 block2b_project_conv (Conv2D)  (None, 50, 50, 32)   6144        ['block2
b_se_excite[0][0]']

 block2b_project_bn (BatchNorma  (None, 50, 50, 32)  128         ['block2
b_project_conv[0][0]']
 lization)

 block2b_drop (Dropout)         (None, 50, 50, 32)   0           ['block2
b_project_bn[0][0]']

 block2b_add (Add)              (None, 50, 50, 32)   0           ['block2
b_drop[0][0]',
                                                                 'block2
a_project_bn[0][0]']

 block2c_expand_conv (Conv2D)   (None, 50, 50, 192)  6144        ['block2
b_add[0][0]']

 block2c_expand_bn (BatchNormal  (None, 50, 50, 192)  768        ['block2
c_expand_conv[0][0]']
 ization)

 block2c_expand_activation (Act  (None, 50, 50, 192)  0          ['block2
c_expand_bn[0][0]']
 ivation)

 block2c_dwconv (DepthwiseConv2  (None, 50, 50, 192)  1728       ['block2
c_expand_activation[0][0]
 D)                                                              ']

 block2c_bn (BatchNormalization  (None, 50, 50, 192)  768        ['block2
c_dwconv[0][0]']
 )

 block2c_activation (Activation  (None, 50, 50, 192)  0          ['block2
c_bn[0][0]']
 )

 block2c_se_squeeze (GlobalAver  (None, 192)         0           ['block2
c_activation[0][0]']
 agePooling2D)

 block2c_se_reshape (Reshape)   (None, 1, 1, 192)    0           ['block2
c_se_squeeze[0][0]']

 block2c_se_reduce (Conv2D)     (None, 1, 1, 8)      1544        ['block2
c_se_reshape[0][0]']

 block2c_se_expand (Conv2D)     (None, 1, 1, 192)    1728        ['block2
```

```
c_se_reduce[0][0]']

 block2c_se_excite (Multiply)   (None, 50, 50, 192)  0           ['block2
c_activation[0][0]',
                                                                  'block2
c_se_expand[0][0]']

 block2c_project_conv (Conv2D)  (None, 50, 50, 32)   6144        ['block2
c_se_excite[0][0]']

 block2c_project_bn (BatchNorma  (None, 50, 50, 32)  128         ['block2
c_project_conv[0][0]']
 lization)

 block2c_drop (Dropout)         (None, 50, 50, 32)   0           ['block2
c_project_bn[0][0]']

 block2c_add (Add)              (None, 50, 50, 32)   0           ['block2
c_drop[0][0]',
                                                                  'block2
b_add[0][0]']

 block3a_expand_conv (Conv2D)   (None, 50, 50, 192)  6144        ['block2
c_add[0][0]']

 block3a_expand_bn (BatchNormal  (None, 50, 50, 192)  768        ['block3
a_expand_conv[0][0]']
 ization)

 block3a_expand_activation (Act  (None, 50, 50, 192)  0          ['block3
a_expand_bn[0][0]']
 ivation)

 block3a_dwconv_pad (ZeroPaddin  (None, 53, 53, 192)  0          ['block3
a_expand_activation[0][0]
 g2D)                                                            ']

 block3a_dwconv (DepthwiseConv2  (None, 25, 25, 192)  4800       ['block3
a_dwconv_pad[0][0]']
 D)

 block3a_bn (BatchNormalization  (None, 25, 25, 192)  768        ['block3
a_dwconv[0][0]']
 )

 block3a_activation (Activation  (None, 25, 25, 192)  0          ['block3
a_bn[0][0]']
 )

 block3a_se_squeeze (GlobalAver  (None, 192)         0           ['block3
a_activation[0][0]']
 agePooling2D)
```

```
 block3a_se_reshape (Reshape)   (None, 1, 1, 192)    0           ['block3
a_se_squeeze[0][0]']

 block3a_se_reduce (Conv2D)     (None, 1, 1, 8)      1544        ['block3
a_se_reshape[0][0]']

 block3a_se_expand (Conv2D)     (None, 1, 1, 192)    1728        ['block3
a_se_reduce[0][0]']

 block3a_se_excite (Multiply)   (None, 25, 25, 192)  0           ['block3
a_activation[0][0]',
                                                                  'block3
a_se_expand[0][0]']

 block3a_project_conv (Conv2D)  (None, 25, 25, 48)   9216        ['block3
a_se_excite[0][0]']

 block3a_project_bn (BatchNorma  (None, 25, 25, 48)  192         ['block3
a_project_conv[0][0]']
 lization)

 block3b_expand_conv (Conv2D)   (None, 25, 25, 288)  13824       ['block3
a_project_bn[0][0]']

 block3b_expand_bn (BatchNormal  (None, 25, 25, 288)  1152       ['block3
b_expand_conv[0][0]']
 ization)

 block3b_expand_activation (Act  (None, 25, 25, 288)  0          ['block3
b_expand_bn[0][0]']
 ivation)

 block3b_dwconv (DepthwiseConv2  (None, 25, 25, 288)  7200       ['block3
b_expand_activation[0][0]
 D)                                                              ']

 block3b_bn (BatchNormalization  (None, 25, 25, 288)  1152       ['block3
b_dwconv[0][0]']
 )

 block3b_activation (Activation  (None, 25, 25, 288)  0          ['block3
b_bn[0][0]']
 )

 block3b_se_squeeze (GlobalAver  (None, 288)         0           ['block3
b_activation[0][0]']
 agePooling2D)

 block3b_se_reshape (Reshape)   (None, 1, 1, 288)    0           ['block3
b_se_squeeze[0][0]']
```

```
 block3b_se_reduce (Conv2D)     (None, 1, 1, 12)     3468        ['block3
b_se_reshape[0][0]']

 block3b_se_expand (Conv2D)     (None, 1, 1, 288)    3744        ['block3
b_se_reduce[0][0]']

 block3b_se_excite (Multiply)   (None, 25, 25, 288)  0           ['block3
b_activation[0][0]',
                                                                  'block3
b_se_expand[0][0]']

 block3b_project_conv (Conv2D)  (None, 25, 25, 48)   13824       ['block3
b_se_excite[0][0]']

 block3b_project_bn (BatchNorma  (None, 25, 25, 48)  192         ['block3
b_project_conv[0][0]']
 lization)

 block3b_drop (Dropout)         (None, 25, 25, 48)   0           ['block3
b_project_bn[0][0]']

 block3b_add (Add)              (None, 25, 25, 48)   0           ['block3
b_drop[0][0]',
                                                                  'block3
a_project_bn[0][0]']

 block3c_expand_conv (Conv2D)   (None, 25, 25, 288)  13824       ['block3
b_add[0][0]']

 block3c_expand_bn (BatchNormal  (None, 25, 25, 288)  1152       ['block3
c_expand_conv[0][0]']
 ization)

 block3c_expand_activation (Act  (None, 25, 25, 288)  0          ['block3
c_expand_bn[0][0]']
 ivation)

 block3c_dwconv (DepthwiseConv2  (None, 25, 25, 288)  7200       ['block3
c_expand_activation[0][0]
 D)                                                              ']

 block3c_bn (BatchNormalization  (None, 25, 25, 288)  1152       ['block3
c_dwconv[0][0]']
 )

 block3c_activation (Activation  (None, 25, 25, 288)  0          ['block3
c_bn[0][0]']
 )

 block3c_se_squeeze (GlobalAver  (None, 288)         0           ['block3
c_activation[0][0]']
 agePooling2D)
```

```
 block3c_se_reshape (Reshape)   (None, 1, 1, 288)    0           ['block3
c_se_squeeze[0][0]']

 block3c_se_reduce (Conv2D)     (None, 1, 1, 12)     3468        ['block3
c_se_reshape[0][0]']

 block3c_se_expand (Conv2D)     (None, 1, 1, 288)    3744        ['block3
c_se_reduce[0][0]']

 block3c_se_excite (Multiply)   (None, 25, 25, 288)  0           ['block3
c_activation[0][0]',
                                                                  'block3
c_se_expand[0][0]']

 block3c_project_conv (Conv2D)  (None, 25, 25, 48)   13824       ['block3
c_se_excite[0][0]']

 block3c_project_bn (BatchNorma  (None, 25, 25, 48)  192         ['block3
c_project_conv[0][0]']
 lization)

 block3c_drop (Dropout)         (None, 25, 25, 48)   0           ['block3
c_project_bn[0][0]']

 block3c_add (Add)              (None, 25, 25, 48)   0           ['block3
c_drop[0][0]',
                                                                  'block3
b_add[0][0]']

 block4a_expand_conv (Conv2D)   (None, 25, 25, 288)  13824       ['block3
c_add[0][0]']

 block4a_expand_bn (BatchNormal  (None, 25, 25, 288)  1152       ['block4
a_expand_conv[0][0]']
 ization)

 block4a_expand_activation (Act  (None, 25, 25, 288)  0          ['block4
a_expand_bn[0][0]']
 ivation)

 block4a_dwconv_pad (ZeroPaddin  (None, 27, 27, 288)  0          ['block4
a_expand_activation[0][0]
 g2D)                                                            ']

 block4a_dwconv (DepthwiseConv2  (None, 13, 13, 288)  2592       ['block4
a_dwconv_pad[0][0]']
 D)

 block4a_bn (BatchNormalization  (None, 13, 13, 288)  1152       ['block4
a_dwconv[0][0]']
 )
```

```
 block4a_activation (Activation  (None, 13, 13, 288)  0          ['block4
a_bn[0][0]']
 )

 block4a_se_squeeze (GlobalAver  (None, 288)         0           ['block4
a_activation[0][0]']
 agePooling2D)

 block4a_se_reshape (Reshape)   (None, 1, 1, 288)    0          ['block4
a_se_squeeze[0][0]']

 block4a_se_reduce (Conv2D)     (None, 1, 1, 12)     3468       ['block4
a_se_reshape[0][0]']

 block4a_se_expand (Conv2D)     (None, 1, 1, 288)    3744       ['block4
a_se_reduce[0][0]']

 block4a_se_excite (Multiply)   (None, 13, 13, 288)  0          ['block4
a_activation[0][0]',
                                                                 'block4
a_se_expand[0][0]']

 block4a_project_conv (Conv2D)  (None, 13, 13, 96)   27648      ['block4
a_se_excite[0][0]']

 block4a_project_bn (BatchNorma  (None, 13, 13, 96)  384        ['block4
a_project_conv[0][0]']
 lization)

 block4b_expand_conv (Conv2D)   (None, 13, 13, 576)  55296      ['block4
a_project_bn[0][0]']

 block4b_expand_bn (BatchNormal  (None, 13, 13, 576)  2304      ['block4
b_expand_conv[0][0]']
 ization)

 block4b_expand_activation (Act  (None, 13, 13, 576)  0         ['block4
b_expand_bn[0][0]']
 ivation)

 block4b_dwconv (DepthwiseConv2  (None, 13, 13, 576)  5184      ['block4
b_expand_activation[0][0]
 D)                                                             ']

 block4b_bn (BatchNormalization  (None, 13, 13, 576)  2304      ['block4
b_dwconv[0][0]']
 )

 block4b_activation (Activation  (None, 13, 13, 576)  0         ['block4
b_bn[0][0]']
 )
```

```
 block4b_se_squeeze (GlobalAver  (None, 576)         0           ['block4
b_activation[0][0]']
 agePooling2D)

 block4b_se_reshape (Reshape)   (None, 1, 1, 576)    0           ['block4
b_se_squeeze[0][0]']

 block4b_se_reduce (Conv2D)     (None, 1, 1, 24)     13848       ['block4
b_se_reshape[0][0]']

 block4b_se_expand (Conv2D)     (None, 1, 1, 576)    14400       ['block4
b_se_reduce[0][0]']

 block4b_se_excite (Multiply)   (None, 13, 13, 576)  0           ['block4
b_activation[0][0]',
                                                                  'block4
b_se_expand[0][0]']

 block4b_project_conv (Conv2D)  (None, 13, 13, 96)   55296       ['block4
b_se_excite[0][0]']

 block4b_project_bn (BatchNorma  (None, 13, 13, 96)  384         ['block4
b_project_conv[0][0]']
 lization)

 block4b_drop (Dropout)         (None, 13, 13, 96)   0           ['block4
b_project_bn[0][0]']

 block4b_add (Add)              (None, 13, 13, 96)   0           ['block4
b_drop[0][0]',
                                                                  'block4
a_project_bn[0][0]']

 block4c_expand_conv (Conv2D)   (None, 13, 13, 576)  55296       ['block4
b_add[0][0]']

 block4c_expand_bn (BatchNormal  (None, 13, 13, 576)  2304       ['block4
c_expand_conv[0][0]']
 ization)

 block4c_expand_activation (Act  (None, 13, 13, 576)  0          ['block4
c_expand_bn[0][0]']
 ivation)

 block4c_dwconv (DepthwiseConv2  (None, 13, 13, 576)  5184       ['block4
c_expand_activation[0][0]
 D)                                                              ']

 block4c_bn (BatchNormalization  (None, 13, 13, 576)  2304       ['block4
c_dwconv[0][0]']
 )
```

```
 block4c_activation (Activation  (None, 13, 13, 576)  0          ['block4
c_bn[0][0]']
 )

 block4c_se_squeeze (GlobalAver  (None, 576)         0           ['block4
c_activation[0][0]']
 agePooling2D)

 block4c_se_reshape (Reshape)   (None, 1, 1, 576)    0           ['block4
c_se_squeeze[0][0]']

 block4c_se_reduce (Conv2D)     (None, 1, 1, 24)     13848       ['block4
c_se_reshape[0][0]']

 block4c_se_expand (Conv2D)     (None, 1, 1, 576)    14400       ['block4
c_se_reduce[0][0]']

 block4c_se_excite (Multiply)   (None, 13, 13, 576)  0           ['block4
c_activation[0][0]',
                                                                  'block4
c_se_expand[0][0]']

 block4c_project_conv (Conv2D)  (None, 13, 13, 96)   55296       ['block4
c_se_excite[0][0]']

 block4c_project_bn (BatchNorma  (None, 13, 13, 96)  384         ['block4
c_project_conv[0][0]']
 lization)

 block4c_drop (Dropout)         (None, 13, 13, 96)   0           ['block4
c_project_bn[0][0]']

 block4c_add (Add)              (None, 13, 13, 96)   0           ['block4
c_drop[0][0]',
                                                                  'block4
b_add[0][0]']

 block4d_expand_conv (Conv2D)   (None, 13, 13, 576)  55296       ['block4
c_add[0][0]']

 block4d_expand_bn (BatchNormal  (None, 13, 13, 576)  2304       ['block4
d_expand_conv[0][0]']
 ization)

 block4d_expand_activation (Act  (None, 13, 13, 576)  0          ['block4
d_expand_bn[0][0]']
 ivation)

 block4d_dwconv (DepthwiseConv2  (None, 13, 13, 576)  5184       ['block4
d_expand_activation[0][0]
 D)                                                              ']
```

```
 block4d_bn (BatchNormalization  (None, 13, 13, 576)  2304       ['block4
d_dwconv[0][0]']
 )

 block4d_activation (Activation  (None, 13, 13, 576)  0          ['block4
d_bn[0][0]']
 )

 block4d_se_squeeze (GlobalAver  (None, 576)         0          ['block4
d_activation[0][0]']
 agePooling2D)

 block4d_se_reshape (Reshape)   (None, 1, 1, 576)    0          ['block4
d_se_squeeze[0][0]']

 block4d_se_reduce (Conv2D)     (None, 1, 1, 24)     13848      ['block4
d_se_reshape[0][0]']

 block4d_se_expand (Conv2D)     (None, 1, 1, 576)    14400      ['block4
d_se_reduce[0][0]']

 block4d_se_excite (Multiply)   (None, 13, 13, 576)  0          ['block4
d_activation[0][0]',
                                                                 'block4
d_se_expand[0][0]']

 block4d_project_conv (Conv2D)  (None, 13, 13, 96)   55296      ['block4
d_se_excite[0][0]']

 block4d_project_bn (BatchNorma  (None, 13, 13, 96)  384        ['block4
d_project_conv[0][0]']
 lization)

 block4d_drop (Dropout)         (None, 13, 13, 96)   0          ['block4
d_project_bn[0][0]']

 block4d_add (Add)              (None, 13, 13, 96)   0          ['block4
d_drop[0][0]',
                                                                 'block4
c_add[0][0]']

 block4e_expand_conv (Conv2D)   (None, 13, 13, 576)  55296      ['block4
d_add[0][0]']

 block4e_expand_bn (BatchNormal  (None, 13, 13, 576)  2304       ['block4
e_expand_conv[0][0]']
 ization)

 block4e_expand_activation (Act  (None, 13, 13, 576)  0          ['block4
e_expand_bn[0][0]']
 ivation)
```

```
 block4e_dwconv (DepthwiseConv2  (None, 13, 13, 576)  5184       ['block4
e_expand_activation[0][0]
 D)                                                              ']

 block4e_bn (BatchNormalization  (None, 13, 13, 576)  2304       ['block4
e_dwconv[0][0]']
 )

 block4e_activation (Activation  (None, 13, 13, 576)  0          ['block4
e_bn[0][0]']
 )

 block4e_se_squeeze (GlobalAver  (None, 576)          0          ['block4
e_activation[0][0]']
 agePooling2D)

 block4e_se_reshape (Reshape)   (None, 1, 1, 576)    0          ['block4
e_se_squeeze[0][0]']

 block4e_se_reduce (Conv2D)     (None, 1, 1, 24)     13848      ['block4
e_se_reshape[0][0]']

 block4e_se_expand (Conv2D)     (None, 1, 1, 576)    14400      ['block4
e_se_reduce[0][0]']

 block4e_se_excite (Multiply)   (None, 13, 13, 576)  0          ['block4
e_activation[0][0]',
                                                                 'block4
e_se_expand[0][0]']

 block4e_project_conv (Conv2D)  (None, 13, 13, 96)   55296      ['block4
e_se_excite[0][0]']

 block4e_project_bn (BatchNorma  (None, 13, 13, 96)  384        ['block4
e_project_conv[0][0]']
 lization)

 block4e_drop (Dropout)         (None, 13, 13, 96)   0          ['block4
e_project_bn[0][0]']

 block4e_add (Add)              (None, 13, 13, 96)   0          ['block4
e_drop[0][0]',
                                                                 'block4
d_add[0][0]']

 block5a_expand_conv (Conv2D)   (None, 13, 13, 576)  55296      ['block4
e_add[0][0]']

 block5a_expand_bn (BatchNormal  (None, 13, 13, 576)  2304       ['block5
a_expand_conv[0][0]']
 ization)
```

```
 block5a_expand_activation (Act  (None, 13, 13, 576)  0          ['block5
a_expand_bn[0][0]']
 ivation)

 block5a_dwconv (DepthwiseConv2  (None, 13, 13, 576)  14400      ['block5
a_expand_activation[0][0]
 D)                                                              ']

 block5a_bn (BatchNormalization  (None, 13, 13, 576)  2304       ['block5
a_dwconv[0][0]']
 )

 block5a_activation (Activation  (None, 13, 13, 576)  0          ['block5
a_bn[0][0]']
 )

 block5a_se_squeeze (GlobalAver  (None, 576)         0          ['block5
a_activation[0][0]']
 agePooling2D)

 block5a_se_reshape (Reshape)   (None, 1, 1, 576)    0          ['block5
a_se_squeeze[0][0]']

 block5a_se_reduce (Conv2D)     (None, 1, 1, 24)     13848      ['block5
a_se_reshape[0][0]']

 block5a_se_expand (Conv2D)     (None, 1, 1, 576)    14400      ['block5
a_se_reduce[0][0]']

 block5a_se_excite (Multiply)   (None, 13, 13, 576)  0          ['block5
a_activation[0][0]',
                                                                 'block5
a_se_expand[0][0]']

 block5a_project_conv (Conv2D)  (None, 13, 13, 136)  78336      ['block5
a_se_excite[0][0]']

 block5a_project_bn (BatchNorma  (None, 13, 13, 136)  544        ['block5
a_project_conv[0][0]']
 lization)

 block5b_expand_conv (Conv2D)   (None, 13, 13, 816)  110976     ['block5
a_project_bn[0][0]']

 block5b_expand_bn (BatchNormal  (None, 13, 13, 816)  3264       ['block5
b_expand_conv[0][0]']
 ization)

 block5b_expand_activation (Act  (None, 13, 13, 816)  0          ['block5
b_expand_bn[0][0]']
 ivation)
```

```
 block5b_dwconv (DepthwiseConv2  (None, 13, 13, 816)  20400      ['block5
b_expand_activation[0][0]
 D)                                                              ']

 block5b_bn (BatchNormalization  (None, 13, 13, 816)  3264       ['block5
b_dwconv[0][0]']
 )

 block5b_activation (Activation  (None, 13, 13, 816)  0          ['block5
b_bn[0][0]']
 )

 block5b_se_squeeze (GlobalAver  (None, 816)         0           ['block5
b_activation[0][0]']
 agePooling2D)

 block5b_se_reshape (Reshape)   (None, 1, 1, 816)    0          ['block5
b_se_squeeze[0][0]']

 block5b_se_reduce (Conv2D)     (None, 1, 1, 34)     27778      ['block5
b_se_reshape[0][0]']

 block5b_se_expand (Conv2D)     (None, 1, 1, 816)    28560      ['block5
b_se_reduce[0][0]']

 block5b_se_excite (Multiply)   (None, 13, 13, 816)  0          ['block5
b_activation[0][0]',
                                                                 'block5
b_se_expand[0][0]']

 block5b_project_conv (Conv2D)  (None, 13, 13, 136)  110976     ['block5
b_se_excite[0][0]']

 block5b_project_bn (BatchNorma  (None, 13, 13, 136)  544       ['block5
b_project_conv[0][0]']
 lization)

 block5b_drop (Dropout)         (None, 13, 13, 136)  0          ['block5
b_project_bn[0][0]']

 block5b_add (Add)              (None, 13, 13, 136)  0          ['block5
b_drop[0][0]',
                                                                 'block5
a_project_bn[0][0]']

 block5c_expand_conv (Conv2D)   (None, 13, 13, 816)  110976     ['block5
b_add[0][0]']

 block5c_expand_bn (BatchNormal  (None, 13, 13, 816)  3264      ['block5
c_expand_conv[0][0]']
 ization)
```

```
 block5c_expand_activation (Act  (None, 13, 13, 816)  0          ['block5
c_expand_bn[0][0]']
 ivation)

 block5c_dwconv (DepthwiseConv2  (None, 13, 13, 816)  20400      ['block5
c_expand_activation[0][0]
 D)                                                              ']

 block5c_bn (BatchNormalization  (None, 13, 13, 816)  3264       ['block5
c_dwconv[0][0]']
 )

 block5c_activation (Activation  (None, 13, 13, 816)  0          ['block5
c_bn[0][0]']
 )

 block5c_se_squeeze (GlobalAver  (None, 816)         0          ['block5
c_activation[0][0]']
 agePooling2D)

 block5c_se_reshape (Reshape)   (None, 1, 1, 816)    0          ['block5
c_se_squeeze[0][0]']

 block5c_se_reduce (Conv2D)     (None, 1, 1, 34)     27778      ['block5
c_se_reshape[0][0]']

 block5c_se_expand (Conv2D)     (None, 1, 1, 816)    28560      ['block5
c_se_reduce[0][0]']

 block5c_se_excite (Multiply)   (None, 13, 13, 816)  0          ['block5
c_activation[0][0]',
                                                                 'block5
c_se_expand[0][0]']

 block5c_project_conv (Conv2D)  (None, 13, 13, 136)  110976     ['block5
c_se_excite[0][0]']

 block5c_project_bn (BatchNorma  (None, 13, 13, 136)  544        ['block5
c_project_conv[0][0]']
 lization)

 block5c_drop (Dropout)         (None, 13, 13, 136)  0          ['block5
c_project_bn[0][0]']

 block5c_add (Add)              (None, 13, 13, 136)  0          ['block5
c_drop[0][0]',
                                                                 'block5
b_add[0][0]']

 block5d_expand_conv (Conv2D)   (None, 13, 13, 816)  110976     ['block5
c_add[0][0]']
```

```
 block5d_expand_bn (BatchNormal  (None, 13, 13, 816)  3264       ['block5
d_expand_conv[0][0]']
 ization)

 block5d_expand_activation (Act  (None, 13, 13, 816)  0          ['block5
d_expand_bn[0][0]']
 ivation)

 block5d_dwconv (DepthwiseConv2  (None, 13, 13, 816)  20400      ['block5
d_expand_activation[0][0]
 D)                                                              ']

 block5d_bn (BatchNormalization  (None, 13, 13, 816)  3264       ['block5
d_dwconv[0][0]']
 )

 block5d_activation (Activation  (None, 13, 13, 816)  0          ['block5
d_bn[0][0]']
 )

 block5d_se_squeeze (GlobalAver  (None, 816)         0          ['block5
d_activation[0][0]']
 agePooling2D)

 block5d_se_reshape (Reshape)   (None, 1, 1, 816)    0          ['block5
d_se_squeeze[0][0]']

 block5d_se_reduce (Conv2D)     (None, 1, 1, 34)     27778      ['block5
d_se_reshape[0][0]']

 block5d_se_expand (Conv2D)     (None, 1, 1, 816)    28560      ['block5
d_se_reduce[0][0]']

 block5d_se_excite (Multiply)   (None, 13, 13, 816)  0          ['block5
d_activation[0][0]',
                                                                 'block5
d_se_expand[0][0]']

 block5d_project_conv (Conv2D)  (None, 13, 13, 136)  110976     ['block5
d_se_excite[0][0]']

 block5d_project_bn (BatchNorma  (None, 13, 13, 136)  544        ['block5
d_project_conv[0][0]']
 lization)

 block5d_drop (Dropout)         (None, 13, 13, 136)  0          ['block5
d_project_bn[0][0]']

 block5d_add (Add)              (None, 13, 13, 136)  0          ['block5
d_drop[0][0]',
                                                                 'block5
```

```
c_add[0][0]']

 block5e_expand_conv (Conv2D)   (None, 13, 13, 816)  110976      ['block5
d_add[0][0]']

 block5e_expand_bn (BatchNormal  (None, 13, 13, 816)  3264       ['block5
e_expand_conv[0][0]']
 ization)

 block5e_expand_activation (Act  (None, 13, 13, 816)  0          ['block5
e_expand_bn[0][0]']
 ivation)

 block5e_dwconv (DepthwiseConv2  (None, 13, 13, 816)  20400      ['block5
e_expand_activation[0][0]
 D)                                                              ']

 block5e_bn (BatchNormalization  (None, 13, 13, 816)  3264       ['block5
e_dwconv[0][0]']
 )

 block5e_activation (Activation  (None, 13, 13, 816)  0          ['block5
e_bn[0][0]']
 )

 block5e_se_squeeze (GlobalAver  (None, 816)         0          ['block5
e_activation[0][0]']
 agePooling2D)

 block5e_se_reshape (Reshape)   (None, 1, 1, 816)    0          ['block5
e_se_squeeze[0][0]']

 block5e_se_reduce (Conv2D)     (None, 1, 1, 34)     27778      ['block5
e_se_reshape[0][0]']

 block5e_se_expand (Conv2D)     (None, 1, 1, 816)    28560      ['block5
e_se_reduce[0][0]']

 block5e_se_excite (Multiply)   (None, 13, 13, 816)  0          ['block5
e_activation[0][0]',
                                                                 'block5
e_se_expand[0][0]']

 block5e_project_conv (Conv2D)  (None, 13, 13, 136)  110976     ['block5
e_se_excite[0][0]']

 block5e_project_bn (BatchNorma  (None, 13, 13, 136)  544        ['block5
e_project_conv[0][0]']
 lization)

 block5e_drop (Dropout)         (None, 13, 13, 136)  0          ['block5
e_project_bn[0][0]']
```

```
 block5e_add (Add)              (None, 13, 13, 136)  0           ['block5
e_drop[0][0]',
                                                                  'block5
d_add[0][0]']

 block6a_expand_conv (Conv2D)   (None, 13, 13, 816)  110976      ['block5
e_add[0][0]']

 block6a_expand_bn (BatchNormal  (None, 13, 13, 816)  3264       ['block6
a_expand_conv[0][0]']
 ization)

 block6a_expand_activation (Act  (None, 13, 13, 816)  0          ['block6
a_expand_bn[0][0]']
 ivation)

 block6a_dwconv_pad (ZeroPaddin  (None, 17, 17, 816)  0          ['block6
a_expand_activation[0][0]
 g2D)                                                            ']

 block6a_dwconv (DepthwiseConv2  (None, 7, 7, 816)   20400       ['block6
a_dwconv_pad[0][0]']
 D)

 block6a_bn (BatchNormalization  (None, 7, 7, 816)   3264        ['block6
a_dwconv[0][0]']
 )

 block6a_activation (Activation  (None, 7, 7, 816)   0           ['block6
a_bn[0][0]']
 )

 block6a_se_squeeze (GlobalAver  (None, 816)         0           ['block6
a_activation[0][0]']
 agePooling2D)

 block6a_se_reshape (Reshape)   (None, 1, 1, 816)    0           ['block6
a_se_squeeze[0][0]']

 block6a_se_reduce (Conv2D)     (None, 1, 1, 34)     27778       ['block6
a_se_reshape[0][0]']

 block6a_se_expand (Conv2D)     (None, 1, 1, 816)    28560       ['block6
a_se_reduce[0][0]']

 block6a_se_excite (Multiply)   (None, 7, 7, 816)    0           ['block6
a_activation[0][0]',
                                                                  'block6
a_se_expand[0][0]']

 block6a_project_conv (Conv2D)  (None, 7, 7, 232)    189312      ['block6
```

```
a_se_excite[0][0]']

 block6a_project_bn (BatchNorma  (None, 7, 7, 232)   928         ['block6
a_project_conv[0][0]']
 lization)

 block6b_expand_conv (Conv2D)   (None, 7, 7, 1392)   322944      ['block6
a_project_bn[0][0]']

 block6b_expand_bn (BatchNormal  (None, 7, 7, 1392)  5568        ['block6
b_expand_conv[0][0]']
 ization)

 block6b_expand_activation (Act  (None, 7, 7, 1392)  0           ['block6
b_expand_bn[0][0]']
 ivation)

 block6b_dwconv (DepthwiseConv2  (None, 7, 7, 1392)  34800       ['block6
b_expand_activation[0][0]
 D)                                                             ']

 block6b_bn (BatchNormalization  (None, 7, 7, 1392)  5568        ['block6
b_dwconv[0][0]']
 )

 block6b_activation (Activation  (None, 7, 7, 1392)  0           ['block6
b_bn[0][0]']
 )

 block6b_se_squeeze (GlobalAver  (None, 1392)        0           ['block6
b_activation[0][0]']
 agePooling2D)

 block6b_se_reshape (Reshape)   (None, 1, 1, 1392)   0           ['block6
b_se_squeeze[0][0]']

 block6b_se_reduce (Conv2D)     (None, 1, 1, 58)     80794       ['block6
b_se_reshape[0][0]']

 block6b_se_expand (Conv2D)     (None, 1, 1, 1392)   82128       ['block6
b_se_reduce[0][0]']

 block6b_se_excite (Multiply)   (None, 7, 7, 1392)   0           ['block6
b_activation[0][0]',
                                                                 'block6
b_se_expand[0][0]']

 block6b_project_conv (Conv2D)  (None, 7, 7, 232)    322944      ['block6
b_se_excite[0][0]']

 block6b_project_bn (BatchNorma  (None, 7, 7, 232)   928         ['block6
b_project_conv[0][0]']
```

```
 lization)

 block6b_drop (Dropout)         (None, 7, 7, 232)    0           ['block6
b_project_bn[0][0]']

 block6b_add (Add)              (None, 7, 7, 232)    0           ['block6
b_drop[0][0]',
                                                                  'block6
a_project_bn[0][0]']

 block6c_expand_conv (Conv2D)   (None, 7, 7, 1392)   322944      ['block6
b_add[0][0]']

 block6c_expand_bn (BatchNormal  (None, 7, 7, 1392)  5568        ['block6
c_expand_conv[0][0]']
 ization)

 block6c_expand_activation (Act  (None, 7, 7, 1392)  0           ['block6
c_expand_bn[0][0]']
 ivation)

 block6c_dwconv (DepthwiseConv2  (None, 7, 7, 1392)  34800       ['block6
c_expand_activation[0][0]
 D)                                                              ']

 block6c_bn (BatchNormalization  (None, 7, 7, 1392)  5568        ['block6
c_dwconv[0][0]']
 )

 block6c_activation (Activation  (None, 7, 7, 1392)  0           ['block6
c_bn[0][0]']
 )

 block6c_se_squeeze (GlobalAver  (None, 1392)        0           ['block6
c_activation[0][0]']
 agePooling2D)

 block6c_se_reshape (Reshape)   (None, 1, 1, 1392)   0           ['block6
c_se_squeeze[0][0]']

 block6c_se_reduce (Conv2D)     (None, 1, 1, 58)     80794       ['block6
c_se_reshape[0][0]']

 block6c_se_expand (Conv2D)     (None, 1, 1, 1392)   82128       ['block6
c_se_reduce[0][0]']

 block6c_se_excite (Multiply)   (None, 7, 7, 1392)   0           ['block6
c_activation[0][0]',
                                                                  'block6
c_se_expand[0][0]']

 block6c_project_conv (Conv2D)  (None, 7, 7, 232)    322944      ['block6
```

```
c_se_excite[0][0]']

 block6c_project_bn (BatchNorma  (None, 7, 7, 232)   928         ['block6
c_project_conv[0][0]']
 lization)

 block6c_drop (Dropout)         (None, 7, 7, 232)    0           ['block6
c_project_bn[0][0]']

 block6c_add (Add)              (None, 7, 7, 232)    0           ['block6
c_drop[0][0]',
                                                                 'block6
b_add[0][0]']

 block6d_expand_conv (Conv2D)   (None, 7, 7, 1392)   322944      ['block6
c_add[0][0]']

 block6d_expand_bn (BatchNormal  (None, 7, 7, 1392)  5568        ['block6
d_expand_conv[0][0]']
 ization)

 block6d_expand_activation (Act  (None, 7, 7, 1392)  0           ['block6
d_expand_bn[0][0]']
 ivation)

 block6d_dwconv (DepthwiseConv2  (None, 7, 7, 1392)  34800       ['block6
d_expand_activation[0][0]
 D)                                                              ']

 block6d_bn (BatchNormalization  (None, 7, 7, 1392)  5568        ['block6
d_dwconv[0][0]']
 )

 block6d_activation (Activation  (None, 7, 7, 1392)  0           ['block6
d_bn[0][0]']
 )

 block6d_se_squeeze (GlobalAver  (None, 1392)        0           ['block6
d_activation[0][0]']
 agePooling2D)

 block6d_se_reshape (Reshape)   (None, 1, 1, 1392)   0           ['block6
d_se_squeeze[0][0]']

 block6d_se_reduce (Conv2D)     (None, 1, 1, 58)     80794       ['block6
d_se_reshape[0][0]']

 block6d_se_expand (Conv2D)     (None, 1, 1, 1392)   82128       ['block6
d_se_reduce[0][0]']

 block6d_se_excite (Multiply)   (None, 7, 7, 1392)   0           ['block6
d_activation[0][0]',
```

```
                                                                 'block6
d_se_expand[0][0]']

 block6d_project_conv (Conv2D)  (None, 7, 7, 232)    322944      ['block6
d_se_excite[0][0]']

 block6d_project_bn (BatchNorma  (None, 7, 7, 232)   928         ['block6
d_project_conv[0][0]']
 lization)

 block6d_drop (Dropout)         (None, 7, 7, 232)    0           ['block6
d_project_bn[0][0]']

 block6d_add (Add)              (None, 7, 7, 232)    0           ['block6
d_drop[0][0]',
                                                                 'block6
c_add[0][0]']

 block6e_expand_conv (Conv2D)   (None, 7, 7, 1392)   322944      ['block6
d_add[0][0]']

 block6e_expand_bn (BatchNormal  (None, 7, 7, 1392)  5568        ['block6
e_expand_conv[0][0]']
 ization)

 block6e_expand_activation (Act  (None, 7, 7, 1392)  0           ['block6
e_expand_bn[0][0]']
 ivation)

 block6e_dwconv (DepthwiseConv2  (None, 7, 7, 1392)  34800       ['block6
e_expand_activation[0][0]
 D)                                                              ']

 block6e_bn (BatchNormalization  (None, 7, 7, 1392)  5568        ['block6
e_dwconv[0][0]']
 )

 block6e_activation (Activation  (None, 7, 7, 1392)  0           ['block6
e_bn[0][0]']
 )

 block6e_se_squeeze (GlobalAver  (None, 1392)        0           ['block6
e_activation[0][0]']
 agePooling2D)

 block6e_se_reshape (Reshape)   (None, 1, 1, 1392)   0           ['block6
e_se_squeeze[0][0]']

 block6e_se_reduce (Conv2D)     (None, 1, 1, 58)     80794       ['block6
e_se_reshape[0][0]']

 block6e_se_expand (Conv2D)     (None, 1, 1, 1392)   82128       ['block6
```

```
e_se_reduce[0][0]']

 block6e_se_excite (Multiply)   (None, 7, 7, 1392)   0           ['block6
e_activation[0][0]',
                                                                  'block6
e_se_expand[0][0]']

 block6e_project_conv (Conv2D)  (None, 7, 7, 232)    322944      ['block6
e_se_excite[0][0]']

 block6e_project_bn (BatchNorma  (None, 7, 7, 232)   928         ['block6
e_project_conv[0][0]']
 lization)

 block6e_drop (Dropout)         (None, 7, 7, 232)    0           ['block6
e_project_bn[0][0]']

 block6e_add (Add)              (None, 7, 7, 232)    0           ['block6
e_drop[0][0]',
                                                                  'block6
d_add[0][0]']

 block6f_expand_conv (Conv2D)   (None, 7, 7, 1392)   322944      ['block6
e_add[0][0]']

 block6f_expand_bn (BatchNormal  (None, 7, 7, 1392)  5568        ['block6
f_expand_conv[0][0]']
 ization)

 block6f_expand_activation (Act  (None, 7, 7, 1392)  0           ['block6
f_expand_bn[0][0]']
 ivation)

 block6f_dwconv (DepthwiseConv2  (None, 7, 7, 1392)  34800       ['block6
f_expand_activation[0][0]
 D)                                                              ']

 block6f_bn (BatchNormalization  (None, 7, 7, 1392)  5568        ['block6
f_dwconv[0][0]']
 )

 block6f_activation (Activation  (None, 7, 7, 1392)  0           ['block6
f_bn[0][0]']
 )

 block6f_se_squeeze (GlobalAver  (None, 1392)        0           ['block6
f_activation[0][0]']
 agePooling2D)

 block6f_se_reshape (Reshape)   (None, 1, 1, 1392)   0           ['block6
f_se_squeeze[0][0]']
```

```
 block6f_se_reduce (Conv2D)     (None, 1, 1, 58)     80794       ['block6
f_se_reshape[0][0]']

 block6f_se_expand (Conv2D)     (None, 1, 1, 1392)   82128       ['block6
f_se_reduce[0][0]']

 block6f_se_excite (Multiply)   (None, 7, 7, 1392)   0           ['block6
f_activation[0][0]',
                                                                  'block6
f_se_expand[0][0]']

 block6f_project_conv (Conv2D)  (None, 7, 7, 232)    322944      ['block6
f_se_excite[0][0]']

 block6f_project_bn (BatchNorma  (None, 7, 7, 232)   928         ['block6
f_project_conv[0][0]']
 lization)

 block6f_drop (Dropout)         (None, 7, 7, 232)    0           ['block6
f_project_bn[0][0]']

 block6f_add (Add)              (None, 7, 7, 232)    0           ['block6
f_drop[0][0]',
                                                                  'block6
e_add[0][0]']

 block7a_expand_conv (Conv2D)   (None, 7, 7, 1392)   322944      ['block6
f_add[0][0]']

 block7a_expand_bn (BatchNormal  (None, 7, 7, 1392)  5568        ['block7
a_expand_conv[0][0]']
 ization)

 block7a_expand_activation (Act  (None, 7, 7, 1392)  0           ['block7
a_expand_bn[0][0]']
 ivation)

 block7a_dwconv (DepthwiseConv2  (None, 7, 7, 1392)  12528       ['block7
a_expand_activation[0][0]
 D)                                                              ']

 block7a_bn (BatchNormalization  (None, 7, 7, 1392)  5568        ['block7
a_dwconv[0][0]']
 )

 block7a_activation (Activation  (None, 7, 7, 1392)  0           ['block7
a_bn[0][0]']
 )

 block7a_se_squeeze (GlobalAver  (None, 1392)        0           ['block7
a_activation[0][0]']
 agePooling2D)
```

```
 block7a_se_reshape (Reshape)   (None, 1, 1, 1392)   0           ['block7
a_se_squeeze[0][0]']

 block7a_se_reduce (Conv2D)     (None, 1, 1, 58)     80794       ['block7
a_se_reshape[0][0]']

 block7a_se_expand (Conv2D)     (None, 1, 1, 1392)   82128       ['block7
a_se_reduce[0][0]']

 block7a_se_excite (Multiply)   (None, 7, 7, 1392)   0           ['block7
a_activation[0][0]',
                                                                 'block7
a_se_expand[0][0]']

 block7a_project_conv (Conv2D)  (None, 7, 7, 384)    534528      ['block7
a_se_excite[0][0]']

 block7a_project_bn (BatchNorma  (None, 7, 7, 384)   1536        ['block7
a_project_conv[0][0]']
 lization)

 block7b_expand_conv (Conv2D)   (None, 7, 7, 2304)   884736      ['block7
a_project_bn[0][0]']

 block7b_expand_bn (BatchNormal  (None, 7, 7, 2304)  9216        ['block7
b_expand_conv[0][0]']
 ization)

 block7b_expand_activation (Act  (None, 7, 7, 2304)  0           ['block7
b_expand_bn[0][0]']
 ivation)

 block7b_dwconv (DepthwiseConv2  (None, 7, 7, 2304)  20736       ['block7
b_expand_activation[0][0]
 D)                                                              ']

 block7b_bn (BatchNormalization  (None, 7, 7, 2304)  9216        ['block7
b_dwconv[0][0]']
 )

 block7b_activation (Activation  (None, 7, 7, 2304)  0           ['block7
b_bn[0][0]']
 )

 block7b_se_squeeze (GlobalAver  (None, 2304)        0           ['block7
b_activation[0][0]']
 agePooling2D)

 block7b_se_reshape (Reshape)   (None, 1, 1, 2304)   0           ['block7
b_se_squeeze[0][0]']
```

```
 block7b_se_reduce (Conv2D)     (None, 1, 1, 96)     221280      ['block7
b_se_reshape[0][0]']

 block7b_se_expand (Conv2D)     (None, 1, 1, 2304)   223488      ['block7
b_se_reduce[0][0]']

 block7b_se_excite (Multiply)   (None, 7, 7, 2304)   0           ['block7
b_activation[0][0]',
                                                                  'block7
b_se_expand[0][0]']

 block7b_project_conv (Conv2D)  (None, 7, 7, 384)    884736      ['block7
b_se_excite[0][0]']

 block7b_project_bn (BatchNorma  (None, 7, 7, 384)   1536        ['block7
b_project_conv[0][0]']
 lization)

 block7b_drop (Dropout)         (None, 7, 7, 384)    0           ['block7
b_project_bn[0][0]']

 block7b_add (Add)              (None, 7, 7, 384)    0           ['block7
b_drop[0][0]',
                                                                  'block7
a_project_bn[0][0]']

 top_conv (Conv2D)              (None, 7, 7, 1536)   589824      ['block7
b_add[0][0]']

 top_bn (BatchNormalization)    (None, 7, 7, 1536)   6144        ['top_co
nv[0][0]']

 top_activation (Activation)    (None, 7, 7, 1536)   0           ['top_bn
[0][0]']

 max_pool (GlobalMaxPooling2D)  (None, 1536)         0           ['top_ac
tivation[0][0]']

 batch_normalization_3 (BatchNo  (None, 1536)        6144        ['max_po
ol[0][0]']
 rmalization)

 dense_6 (Dense)                (None, 256)          393472      ['batch_
normalization_3[0][0]']

 dropout_3 (Dropout)            (None, 256)          0           ['dense_
6[0][0]']

 dense_7 (Dense)                (None, 14)           3598        ['dropou
t_3[0][0]']

==================================================================================
```

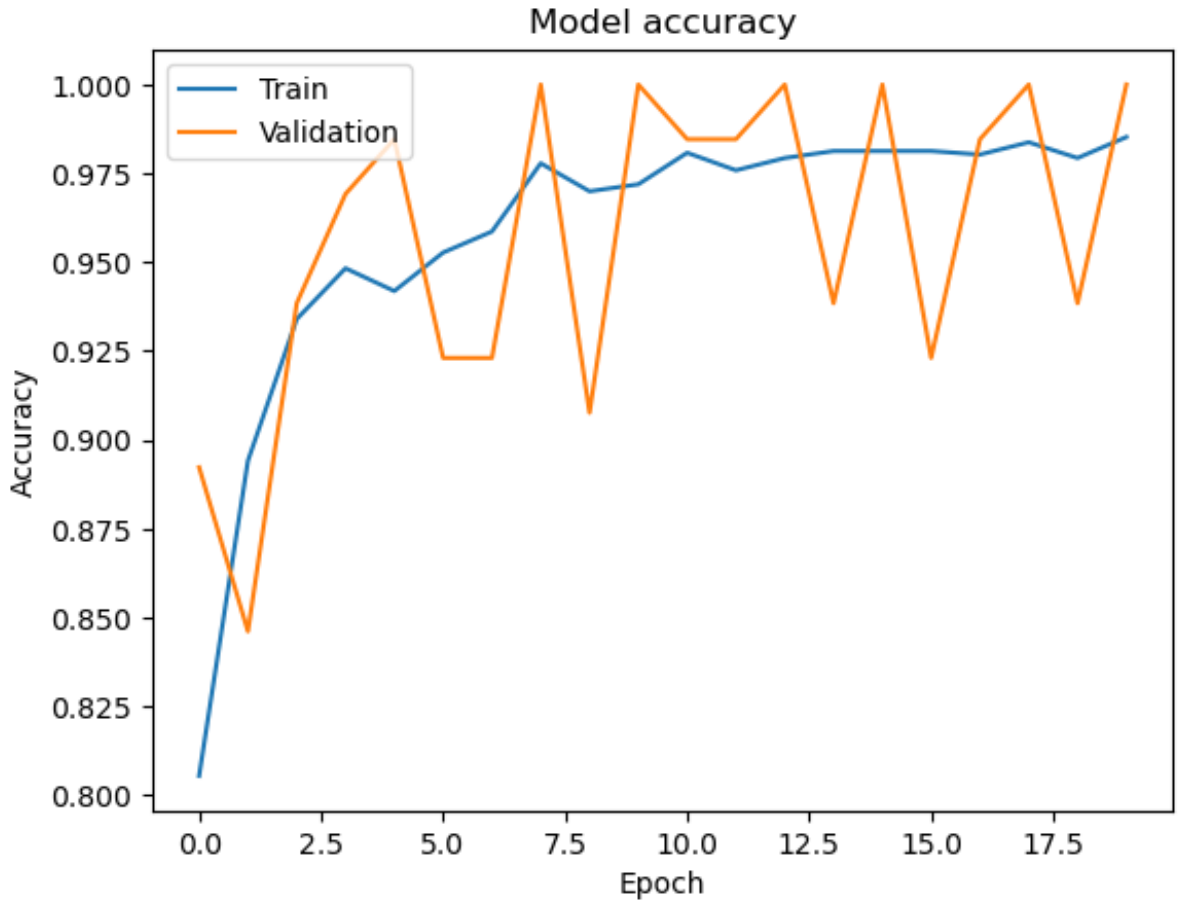
```
=========================
Total params: 11,186,749
Trainable params: 11,096,374
Non-trainable params: 90,375
_________________________________________________________________
_________________________
```

In [23]:
```
model_pre_trained.compile(
  loss='sparse_categorical_crossentropy',
  optimizer="rmsprop",
  metrics=['accuracy']
)

history=model_pre_trained.fit(train2,
                      validation_data=valid2,
                      callbacks=[early_stop],
                      epochs=epochs)
```

```
Epoch 1/20
64/64 [==============================] - 207s 3s/step - loss: 1.2952 - ac
curacy: 0.8055 - val_loss: 1.2895 - val_accuracy: 0.8923
Epoch 2/20
64/64 [==============================] - 187s 3s/step - loss: 0.8317 - ac
curacy: 0.8941 - val_loss: 1.0117 - val_accuracy: 0.8462
Epoch 3/20
64/64 [==============================] - 185s 3s/step - loss: 0.6817 - ac
curacy: 0.9340 - val_loss: 0.5449 - val_accuracy: 0.9385
Epoch 4/20
64/64 [==============================] - 186s 3s/step - loss: 0.5932 - ac
curacy: 0.9483 - val_loss: 0.7787 - val_accuracy: 0.9692
Epoch 5/20
64/64 [==============================] - 188s 3s/step - loss: 0.5932 - ac
curacy: 0.9419 - val_loss: 0.4549 - val_accuracy: 0.9846
Epoch 6/20
64/64 [==============================] - 187s 3s/step - loss: 0.5054 - ac
curacy: 0.9527 - val_loss: 0.5605 - val_accuracy: 0.9231
Epoch 7/20
64/64 [==============================] - 186s 3s/step - loss: 0.4791 - ac
curacy: 0.9586 - val_loss: 0.5376 - val_accuracy: 0.9231
Epoch 8/20
64/64 [==============================] - 187s 3s/step - loss: 0.3898 - ac
curacy: 0.9778 - val_loss: 0.3105 - val_accuracy: 1.0000
Epoch 9/20
64/64 [==============================] - 187s 3s/step - loss: 0.3997 - ac
curacy: 0.9700 - val_loss: 0.4438 - val_accuracy: 0.9077
Epoch 10/20
64/64 [==============================] - 186s 3s/step - loss: 0.3857 - ac
curacy: 0.9719 - val_loss: 0.2887 - val_accuracy: 1.0000
Epoch 11/20
64/64 [==============================] - 186s 3s/step - loss: 0.3381 - ac
curacy: 0.9808 - val_loss: 0.2733 - val_accuracy: 0.9846
Epoch 12/20
64/64 [==============================] - 186s 3s/step - loss: 0.3498 - ac
curacy: 0.9759 - val_loss: 0.3834 - val_accuracy: 0.9846
Epoch 13/20
64/64 [==============================] - 187s 3s/step - loss: 0.3168 - ac
curacy: 0.9793 - val_loss: 0.2254 - val_accuracy: 1.0000
Epoch 14/20
64/64 [==============================] - 187s 3s/step - loss: 0.3035 - ac
curacy: 0.9813 - val_loss: 0.4058 - val_accuracy: 0.9385
Epoch 15/20
64/64 [==============================] - 188s 3s/step - loss: 0.3109 - ac
curacy: 0.9813 - val_loss: 0.2016 - val_accuracy: 1.0000
Epoch 16/20
64/64 [==============================] - 185s 3s/step - loss: 0.2885 - ac
curacy: 0.9813 - val_loss: 0.6689 - val_accuracy: 0.9231
Epoch 17/20
64/64 [==============================] - 187s 3s/step - loss: 0.2977 - ac
curacy: 0.9803 - val_loss: 0.2474 - val_accuracy: 0.9846
Epoch 18/20
```

```
64/64 [==============================] - 187s 3s/step - loss: 0.2913 - ac
curacy: 0.9838 - val_loss: 0.2307 - val_accuracy: 1.0000
Epoch 19/20
64/64 [==============================] - 187s 3s/step - loss: 0.3010 - ac
curacy: 0.9793 - val_loss: 0.6185 - val_accuracy: 0.9385
Epoch 20/20
64/64 [==============================] - 187s 3s/step - loss: 0.2671 - ac
curacy: 0.9852 - val_loss: 0.1886 - val_accuracy: 1.0000
```

In [24]:
```
# Plot training & validation accuracy values
plt.plot(history.history['accuracy'])
plt.plot(history.history['val_accuracy'])
plt.title('Model accuracy')
plt.ylabel('Accuracy')
plt.xlabel('Epoch')
plt.legend(['Train', 'Validation'], loc='upper left')
plt.show()
```



In [25]:
```
score_pre = model_pre_trained.evaluate(test2, verbose=0)
print('Test loss:', score_pre[0])
print('Test accuracy:', score_pre[1])

predictions = model_pre_trained.predict(test2, verbose=0)
score_pre2 = tf.nn.softmax(predictions[0])

print(
```

```
    "This image is probably the {} with a {:.2f} percent confidence."
    .format(class_names[np.argmax(score_pre2)], 100 * np.max(score_pre2))
)
```

```
Test loss: 0.22559316456317902
Test accuracy: 0.9692307710647583
This image is probably the six of spades with a 17.29 percent confidence.
```

Transfer Learning

In [26]:
```
# Transfer Learning

preprocess_input = tf.keras.applications.mobilenet_v2.preprocess_input
```

In [27]:
```
base_model = tf.keras.applications.MobileNetV2(input_shape=(224, 224, 3),
                                               include_top=False,
                                               weights='imagenet')
```

In [28]:
```
# Feature extraction

# Freeze weights
base_model.trainable = False
base_model.summary()
```

```
Model: "mobilenetv2_1.00_224"
__________________________________________________________________________________________________
 Layer (type)                   Output Shape         Param #     Connected to
==================================================================================================
 input_2 (InputLayer)           [(None, 224, 224, 3  0           []
                                )]

 Conv1 (Conv2D)                 (None, 112, 112, 32  864         ['input_2[0][0]']
                                )

 bn_Conv1 (BatchNormalization)  (None, 112, 112, 32  128         ['Conv1[0][0]']
                                )

 Conv1_relu (ReLU)              (None, 112, 112, 32  0           ['bn_Conv1[0][0]']
                                )

 expanded_conv_depthwise (Depth  (None, 112, 112, 32  288        ['Conv1_relu[0][0]']
 wiseConv2D)                    )

 expanded_conv_depthwise_BN (Ba  (None, 112, 112, 32  128        ['expanded_conv_depthwise[0][0]']
 tchNormalization)              )

 expanded_conv_depthwise_relu (  (None, 112, 112, 32  0          ['expanded_conv_depthwise_BN[0][0
 ReLU)                          )                                ]']

 expanded_conv_project (Conv2D)  (None, 112, 112, 16  512        ['expanded_conv_depthwise_relu[0]
                                )                                [0]']

 expanded_conv_project_BN (Batc  (None, 112, 112, 16  64         ['expanded_conv_project[0][0]']
 hNormalization)                )

 block_1_expand (Conv2D)        (None, 112, 112, 96  1536        ['expanded_conv_project_BN[0][0]'
                                )                                ]

 block_1_expand_BN (BatchNormal  (None, 112, 112, 96  384        ['block_1_expand[0][0]']
 ization)                       )

 block_1_expand_relu (ReLU)     (None, 112, 112, 96  0           ['block_1_expand_BN[0][0]']
```

```
                                )

 block_1_pad (ZeroPadding2D)    (None, 113, 113, 96  0           ['block_
1_expand_relu[0][0]']
                                )

 block_1_depthwise (DepthwiseCo  (None, 56, 56, 96)  864         ['block_
1_pad[0][0]']
 nv2D)

 block_1_depthwise_BN (BatchNor  (None, 56, 56, 96)  384         ['block_
1_depthwise[0][0]']
 malization)

 block_1_depthwise_relu (ReLU)  (None, 56, 56, 96)   0           ['block_
1_depthwise_BN[0][0]']

 block_1_project (Conv2D)       (None, 56, 56, 24)   2304        ['block_
1_depthwise_relu[0][0]']

 block_1_project_BN (BatchNorma  (None, 56, 56, 24)  96          ['block_
1_project[0][0]']
 lization)

 block_2_expand (Conv2D)        (None, 56, 56, 144)  3456        ['block_
1_project_BN[0][0]']

 block_2_expand_BN (BatchNormal  (None, 56, 56, 144)  576        ['block_
2_expand[0][0]']
 ization)

 block_2_expand_relu (ReLU)     (None, 56, 56, 144)  0           ['block_
2_expand_BN[0][0]']

 block_2_depthwise (DepthwiseCo  (None, 56, 56, 144)  1296       ['block_
2_expand_relu[0][0]']
 nv2D)

 block_2_depthwise_BN (BatchNor  (None, 56, 56, 144)  576        ['block_
2_depthwise[0][0]']
 malization)

 block_2_depthwise_relu (ReLU)  (None, 56, 56, 144)  0           ['block_
2_depthwise_BN[0][0]']

 block_2_project (Conv2D)       (None, 56, 56, 24)   3456        ['block_
2_depthwise_relu[0][0]']

 block_2_project_BN (BatchNorma  (None, 56, 56, 24)  96          ['block_
2_project[0][0]']
 lization)
```

```
 block_2_add (Add)              (None, 56, 56, 24)   0           ['block_
1_project_BN[0][0]',
                                                                  'block_
2_project_BN[0][0]']

 block_3_expand (Conv2D)        (None, 56, 56, 144)  3456        ['block_
2_add[0][0]']

 block_3_expand_BN (BatchNormal  (None, 56, 56, 144)  576        ['block_
3_expand[0][0]']
 ization)

 block_3_expand_relu (ReLU)     (None, 56, 56, 144)  0           ['block_
3_expand_BN[0][0]']

 block_3_pad (ZeroPadding2D)    (None, 57, 57, 144)  0           ['block_
3_expand_relu[0][0]']

 block_3_depthwise (DepthwiseCo  (None, 28, 28, 144)  1296       ['block_
3_pad[0][0]']
 nv2D)

 block_3_depthwise_BN (BatchNor  (None, 28, 28, 144)  576        ['block_
3_depthwise[0][0]']
 malization)

 block_3_depthwise_relu (ReLU)  (None, 28, 28, 144)  0           ['block_
3_depthwise_BN[0][0]']

 block_3_project (Conv2D)       (None, 28, 28, 32)   4608        ['block_
3_depthwise_relu[0][0]']

 block_3_project_BN (BatchNorma  (None, 28, 28, 32)  128         ['block_
3_project[0][0]']
 lization)

 block_4_expand (Conv2D)        (None, 28, 28, 192)  6144        ['block_
3_project_BN[0][0]']

 block_4_expand_BN (BatchNormal  (None, 28, 28, 192)  768        ['block_
4_expand[0][0]']
 ization)

 block_4_expand_relu (ReLU)     (None, 28, 28, 192)  0           ['block_
4_expand_BN[0][0]']

 block_4_depthwise (DepthwiseCo  (None, 28, 28, 192)  1728       ['block_
4_expand_relu[0][0]']
 nv2D)

 block_4_depthwise_BN (BatchNor  (None, 28, 28, 192)  768        ['block_
4_depthwise[0][0]']
```

```
 malization)

 block_4_depthwise_relu (ReLU)  (None, 28, 28, 192)  0           ['block_
4_depthwise_BN[0][0]']

 block_4_project (Conv2D)       (None, 28, 28, 32)   6144        ['block_
4_depthwise_relu[0][0]']

 block_4_project_BN (BatchNorma  (None, 28, 28, 32)  128         ['block_
4_project[0][0]']
 lization)

 block_4_add (Add)              (None, 28, 28, 32)   0           ['block_
3_project_BN[0][0]',
                                                                 'block_
4_project_BN[0][0]']

 block_5_expand (Conv2D)        (None, 28, 28, 192)  6144        ['block_
4_add[0][0]']

 block_5_expand_BN (BatchNormal  (None, 28, 28, 192)  768        ['block_
5_expand[0][0]']
 ization)

 block_5_expand_relu (ReLU)     (None, 28, 28, 192)  0           ['block_
5_expand_BN[0][0]']

 block_5_depthwise (DepthwiseCo  (None, 28, 28, 192)  1728       ['block_
5_expand_relu[0][0]']
 nv2D)

 block_5_depthwise_BN (BatchNor  (None, 28, 28, 192)  768        ['block_
5_depthwise[0][0]']
 malization)

 block_5_depthwise_relu (ReLU)  (None, 28, 28, 192)  0           ['block_
5_depthwise_BN[0][0]']

 block_5_project (Conv2D)       (None, 28, 28, 32)   6144        ['block_
5_depthwise_relu[0][0]']

 block_5_project_BN (BatchNorma  (None, 28, 28, 32)  128         ['block_
5_project[0][0]']
 lization)

 block_5_add (Add)              (None, 28, 28, 32)   0           ['block_
4_add[0][0]',
                                                                 'block_
5_project_BN[0][0]']

 block_6_expand (Conv2D)        (None, 28, 28, 192)  6144        ['block_
5_add[0][0]']
```

```
 block_6_expand_BN (BatchNormal  (None, 28, 28, 192)  768        ['block_
6_expand[0][0]']
 ization)

 block_6_expand_relu (ReLU)     (None, 28, 28, 192)  0          ['block_
6_expand_BN[0][0]']

 block_6_pad (ZeroPadding2D)    (None, 29, 29, 192)  0          ['block_
6_expand_relu[0][0]']

 block_6_depthwise (DepthwiseCo  (None, 14, 14, 192)  1728       ['block_
6_pad[0][0]']
 nv2D)

 block_6_depthwise_BN (BatchNor  (None, 14, 14, 192)  768        ['block_
6_depthwise[0][0]']
 malization)

 block_6_depthwise_relu (ReLU)  (None, 14, 14, 192)  0          ['block_
6_depthwise_BN[0][0]']

 block_6_project (Conv2D)       (None, 14, 14, 64)   12288      ['block_
6_depthwise_relu[0][0]']

 block_6_project_BN (BatchNorma  (None, 14, 14, 64)  256        ['block_
6_project[0][0]']
 lization)

 block_7_expand (Conv2D)        (None, 14, 14, 384)  24576      ['block_
6_project_BN[0][0]']

 block_7_expand_BN (BatchNormal  (None, 14, 14, 384)  1536       ['block_
7_expand[0][0]']
 ization)

 block_7_expand_relu (ReLU)     (None, 14, 14, 384)  0          ['block_
7_expand_BN[0][0]']

 block_7_depthwise (DepthwiseCo  (None, 14, 14, 384)  3456       ['block_
7_expand_relu[0][0]']
 nv2D)

 block_7_depthwise_BN (BatchNor  (None, 14, 14, 384)  1536       ['block_
7_depthwise[0][0]']
 malization)

 block_7_depthwise_relu (ReLU)  (None, 14, 14, 384)  0          ['block_
7_depthwise_BN[0][0]']

 block_7_project (Conv2D)       (None, 14, 14, 64)   24576      ['block_
7_depthwise_relu[0][0]']
```

```
 block_7_project_BN (BatchNorma  (None, 14, 14, 64)  256         ['block_
7_project[0][0]']
 lization)

 block_7_add (Add)              (None, 14, 14, 64)   0           ['block_
6_project_BN[0][0]',
                                                                  'block_
7_project_BN[0][0]']

 block_8_expand (Conv2D)        (None, 14, 14, 384)  24576       ['block_
7_add[0][0]']

 block_8_expand_BN (BatchNormal  (None, 14, 14, 384)  1536       ['block_
8_expand[0][0]']
 ization)

 block_8_expand_relu (ReLU)     (None, 14, 14, 384)  0           ['block_
8_expand_BN[0][0]']

 block_8_depthwise (DepthwiseCo  (None, 14, 14, 384)  3456       ['block_
8_expand_relu[0][0]']
 nv2D)

 block_8_depthwise_BN (BatchNor  (None, 14, 14, 384)  1536       ['block_
8_depthwise[0][0]']
 malization)

 block_8_depthwise_relu (ReLU)  (None, 14, 14, 384)  0           ['block_
8_depthwise_BN[0][0]']

 block_8_project (Conv2D)       (None, 14, 14, 64)   24576       ['block_
8_depthwise_relu[0][0]']

 block_8_project_BN (BatchNorma  (None, 14, 14, 64)  256         ['block_
8_project[0][0]']
 lization)

 block_8_add (Add)              (None, 14, 14, 64)   0           ['block_
7_add[0][0]',
                                                                  'block_
8_project_BN[0][0]']

 block_9_expand (Conv2D)        (None, 14, 14, 384)  24576       ['block_
8_add[0][0]']

 block_9_expand_BN (BatchNormal  (None, 14, 14, 384)  1536       ['block_
9_expand[0][0]']
 ization)

 block_9_expand_relu (ReLU)     (None, 14, 14, 384)  0           ['block_
9_expand_BN[0][0]']
```

```
 block_9_depthwise (DepthwiseCo  (None, 14, 14, 384)  3456       ['block_
9_expand_relu[0][0]']
 nv2D)

 block_9_depthwise_BN (BatchNor  (None, 14, 14, 384)  1536       ['block_
9_depthwise[0][0]']
 malization)

 block_9_depthwise_relu (ReLU)  (None, 14, 14, 384)  0          ['block_
9_depthwise_BN[0][0]']

 block_9_project (Conv2D)       (None, 14, 14, 64)   24576      ['block_
9_depthwise_relu[0][0]']

 block_9_project_BN (BatchNorma  (None, 14, 14, 64)  256        ['block_
9_project[0][0]']
 lization)

 block_9_add (Add)              (None, 14, 14, 64)   0          ['block_
8_add[0][0]',
                                                                 'block_
9_project_BN[0][0]']

 block_10_expand (Conv2D)       (None, 14, 14, 384)  24576      ['block_
9_add[0][0]']

 block_10_expand_BN (BatchNorma  (None, 14, 14, 384)  1536      ['block_
10_expand[0][0]']
 lization)

 block_10_expand_relu (ReLU)    (None, 14, 14, 384)  0          ['block_
10_expand_BN[0][0]']

 block_10_depthwise (DepthwiseC  (None, 14, 14, 384)  3456      ['block_
10_expand_relu[0][0]']
 onv2D)

 block_10_depthwise_BN (BatchNo  (None, 14, 14, 384)  1536      ['block_
10_depthwise[0][0]']
 rmalization)

 block_10_depthwise_relu (ReLU)  (None, 14, 14, 384)  0         ['block_
10_depthwise_BN[0][0]']

 block_10_project (Conv2D)      (None, 14, 14, 96)   36864      ['block_
10_depthwise_relu[0][0]']

 block_10_project_BN (BatchNorm  (None, 14, 14, 96)  384        ['block_
10_project[0][0]']
 alization)
```

```
 block_11_expand (Conv2D)       (None, 14, 14, 576)  55296       ['block_
10_project_BN[0][0]']

 block_11_expand_BN (BatchNorma  (None, 14, 14, 576)  2304       ['block_
11_expand[0][0]']
 lization)

 block_11_expand_relu (ReLU)    (None, 14, 14, 576)  0          ['block_
11_expand_BN[0][0]']

 block_11_depthwise (DepthwiseC  (None, 14, 14, 576)  5184       ['block_
11_expand_relu[0][0]']
 onv2D)

 block_11_depthwise_BN (BatchNo  (None, 14, 14, 576)  2304       ['block_
11_depthwise[0][0]']
 rmalization)

 block_11_depthwise_relu (ReLU)  (None, 14, 14, 576)  0          ['block_
11_depthwise_BN[0][0]']

 block_11_project (Conv2D)      (None, 14, 14, 96)   55296       ['block_
11_depthwise_relu[0][0]']

 block_11_project_BN (BatchNorm  (None, 14, 14, 96)  384         ['block_
11_project[0][0]']
 alization)

 block_11_add (Add)             (None, 14, 14, 96)   0          ['block_
10_project_BN[0][0]',
                                                                 'block_
11_project_BN[0][0]']

 block_12_expand (Conv2D)       (None, 14, 14, 576)  55296       ['block_
11_add[0][0]']

 block_12_expand_BN (BatchNorma  (None, 14, 14, 576)  2304       ['block_
12_expand[0][0]']
 lization)

 block_12_expand_relu (ReLU)    (None, 14, 14, 576)  0          ['block_
12_expand_BN[0][0]']

 block_12_depthwise (DepthwiseC  (None, 14, 14, 576)  5184       ['block_
12_expand_relu[0][0]']
 onv2D)

 block_12_depthwise_BN (BatchNo  (None, 14, 14, 576)  2304       ['block_
12_depthwise[0][0]']
 rmalization)

 block_12_depthwise_relu (ReLU)  (None, 14, 14, 576)  0          ['block_
```

```
12_depthwise_BN[0][0]']

 block_12_project (Conv2D)      (None, 14, 14, 96)   55296       ['block_
12_depthwise_relu[0][0]']

 block_12_project_BN (BatchNorm  (None, 14, 14, 96)  384         ['block_
12_project[0][0]']
 alization)

 block_12_add (Add)             (None, 14, 14, 96)   0           ['block_
11_add[0][0]',
                                                                  'block_
12_project_BN[0][0]']

 block_13_expand (Conv2D)       (None, 14, 14, 576)  55296       ['block_
12_add[0][0]']

 block_13_expand_BN (BatchNorma  (None, 14, 14, 576)  2304       ['block_
13_expand[0][0]']
 lization)

 block_13_expand_relu (ReLU)    (None, 14, 14, 576)  0           ['block_
13_expand_BN[0][0]']

 block_13_pad (ZeroPadding2D)   (None, 15, 15, 576)  0           ['block_
13_expand_relu[0][0]']

 block_13_depthwise (DepthwiseC  (None, 7, 7, 576)   5184        ['block_
13_pad[0][0]']
 onv2D)

 block_13_depthwise_BN (BatchNo  (None, 7, 7, 576)   2304        ['block_
13_depthwise[0][0]']
 rmalization)

 block_13_depthwise_relu (ReLU)  (None, 7, 7, 576)   0           ['block_
13_depthwise_BN[0][0]']

 block_13_project (Conv2D)      (None, 7, 7, 160)    92160       ['block_
13_depthwise_relu[0][0]']

 block_13_project_BN (BatchNorm  (None, 7, 7, 160)   640         ['block_
13_project[0][0]']
 alization)

 block_14_expand (Conv2D)       (None, 7, 7, 960)    153600      ['block_
13_project_BN[0][0]']

 block_14_expand_BN (BatchNorma  (None, 7, 7, 960)   3840        ['block_
14_expand[0][0]']
 lization)
```

```
 block_14_expand_relu (ReLU)    (None, 7, 7, 960)    0           ['block_
14_expand_BN[0][0]']

 block_14_depthwise (DepthwiseC  (None, 7, 7, 960)   8640        ['block_
14_expand_relu[0][0]']
 onv2D)

 block_14_depthwise_BN (BatchNo  (None, 7, 7, 960)   3840        ['block_
14_depthwise[0][0]']
 rmalization)

 block_14_depthwise_relu (ReLU)  (None, 7, 7, 960)   0           ['block_
14_depthwise_BN[0][0]']

 block_14_project (Conv2D)      (None, 7, 7, 160)    153600      ['block_
14_depthwise_relu[0][0]']

 block_14_project_BN (BatchNorm  (None, 7, 7, 160)   640         ['block_
14_project[0][0]']
 alization)

 block_14_add (Add)             (None, 7, 7, 160)    0           ['block_
13_project_BN[0][0]',
                                                                  'block_
14_project_BN[0][0]']

 block_15_expand (Conv2D)       (None, 7, 7, 960)    153600      ['block_
14_add[0][0]']

 block_15_expand_BN (BatchNorma  (None, 7, 7, 960)   3840        ['block_
15_expand[0][0]']
 lization)

 block_15_expand_relu (ReLU)    (None, 7, 7, 960)    0           ['block_
15_expand_BN[0][0]']

 block_15_depthwise (DepthwiseC  (None, 7, 7, 960)   8640        ['block_
15_expand_relu[0][0]']
 onv2D)

 block_15_depthwise_BN (BatchNo  (None, 7, 7, 960)   3840        ['block_
15_depthwise[0][0]']
 rmalization)

 block_15_depthwise_relu (ReLU)  (None, 7, 7, 960)   0           ['block_
15_depthwise_BN[0][0]']

 block_15_project (Conv2D)      (None, 7, 7, 160)    153600      ['block_
15_depthwise_relu[0][0]']

 block_15_project_BN (BatchNorm  (None, 7, 7, 160)   640         ['block_
15_project[0][0]']
```

```
 alization)

 block_15_add (Add)             (None, 7, 7, 160)    0           ['block_
14_add[0][0]',
                                                                  'block_
15_project_BN[0][0]']

 block_16_expand (Conv2D)       (None, 7, 7, 960)    153600      ['block_
15_add[0][0]']

 block_16_expand_BN (BatchNorma  (None, 7, 7, 960)   3840        ['block_
16_expand[0][0]']
 lization)

 block_16_expand_relu (ReLU)    (None, 7, 7, 960)    0           ['block_
16_expand_BN[0][0]']

 block_16_depthwise (DepthwiseC  (None, 7, 7, 960)   8640        ['block_
16_expand_relu[0][0]']
 onv2D)

 block_16_depthwise_BN (BatchNo  (None, 7, 7, 960)   3840        ['block_
16_depthwise[0][0]']
 rmalization)

 block_16_depthwise_relu (ReLU)  (None, 7, 7, 960)   0           ['block_
16_depthwise_BN[0][0]']

 block_16_project (Conv2D)      (None, 7, 7, 320)    307200      ['block_
16_depthwise_relu[0][0]']

 block_16_project_BN (BatchNorm  (None, 7, 7, 320)   1280        ['block_
16_project[0][0]']
 alization)

 Conv_1 (Conv2D)                (None, 7, 7, 1280)   409600      ['block_
16_project_BN[0][0]']

 Conv_1_bn (BatchNormalization)  (None, 7, 7, 1280)  5120        ['Conv_1
[0][0]']

 out_relu (ReLU)                (None, 7, 7, 1280)   0           ['Conv_1
_bn[0][0]']

==================================================================================
==========================
Total params: 2,257,984
Trainable params: 0
Non-trainable params: 2,257,984
__________________________________________________________________________________
_________________________
```

In [29]:
```
# Add classification head
image_batch, label_batch = next(iter(train))
feature_batch = base_model(image_batch)

global_average_layer = tf.keras.layers.GlobalAveragePooling2D()
feature_batch_average = global_average_layer(feature_batch)
print(feature_batch_average.shape)
```

```
(32, 1280)
```

In [30]:
```
# Convert features to a single prediction per image
prediction_layer = tf.keras.layers.Dense(1)
prediction_batch = prediction_layer(feature_batch_average)
print(prediction_batch.shape)
```

```
(32, 1)
```

In [31]:
```
# Build the model

# To get the shape for preprocess_input
data_augmentation = tf.keras.Sequential()

inputs = tf.keras.Input(shape=(224, 224, 3))
x = data_augmentation(inputs)
x = preprocess_input(x)
x = base_model(x, training=False)
x = global_average_layer(x)
x = tf.keras.layers.Dropout(0.2)(x)
output = prediction_layer(x)
model_TL = tf.keras.Model(inputs, output)
```

In [32]:
```
# Compile the model
# Have to use from_logits since no softmax used
base_learning_rate = 0.0001
model_TL.compile(optimizer=tf.keras.optimizers.Adam(learning_rate=base_le
                 loss=tf.keras.losses.CategoricalCrossentropy(from_logits
                 metrics=['accuracy'])

model_TL.summary()
```

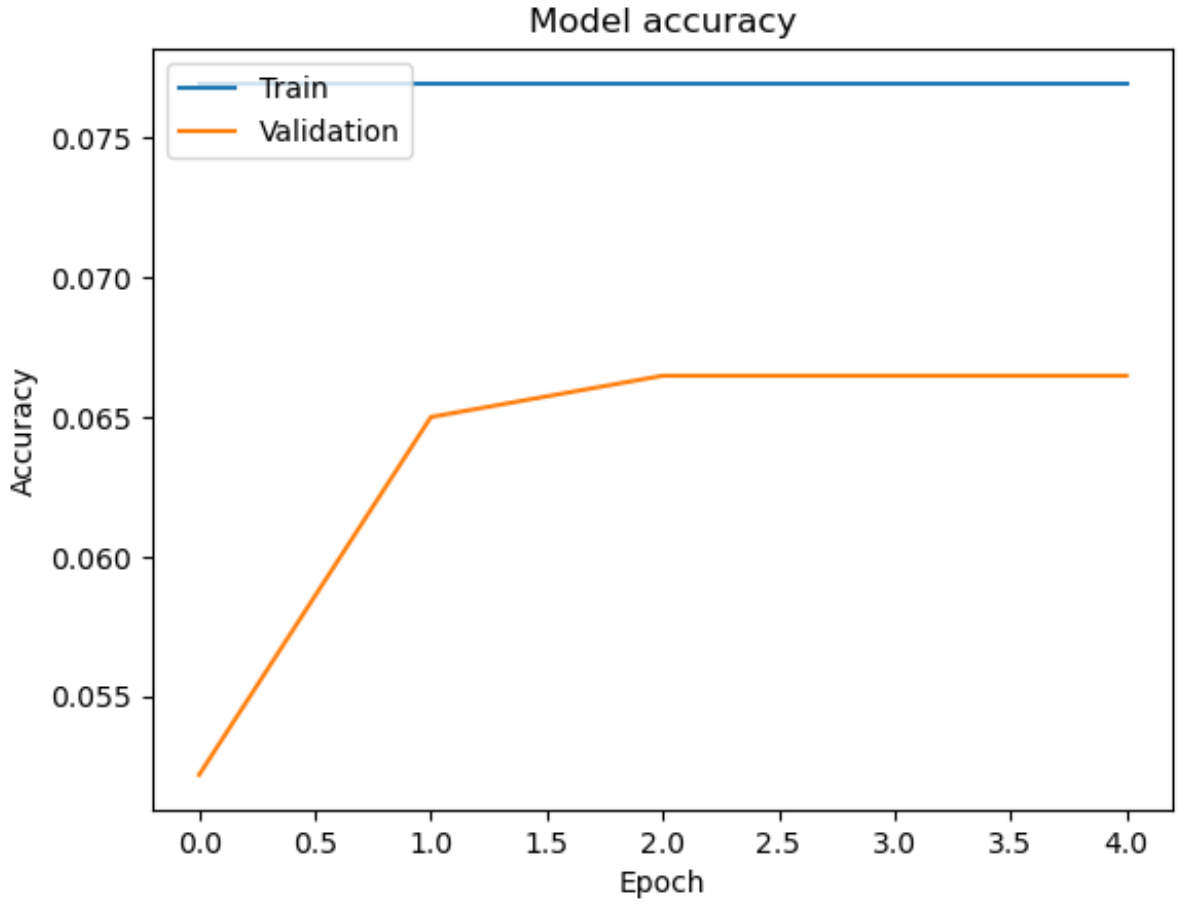
```
Model: "model_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_3 (InputLayer)        [(None, 224, 224, 3)]     0

 sequential_2 (Sequential)   multiple                  0

 tf.math.truediv (TFOpLambda  (None, 224, 224, 3)      0
 )

 tf.math.subtract (TFOpLambd  (None, 224, 224, 3)      0
 a)

 mobilenetv2_1.00_224 (Funct  (None, 7, 7, 1280)       2257984
 ional)

 global_average_pooling2d (G  (None, 1280)             0
 lobalAveragePooling2D)

 dropout_2 (Dropout)         (None, 1280)              0

 dense_5 (Dense)             (None, 1)                 1281

=================================================================
Total params: 2,259,265
Trainable params: 1,281
Non-trainable params: 2,257,984
_________________________________________________________________
```

In [33]:

```
# Train the model
# Five epochs chosen since early stop varies around here
initial_epochs = 5

history=model_TL.fit(train,
                     validation_data=valid,
                     epochs=initial_epochs)
```

```
Epoch 1/5
64/64 [==============================] - 15s 195ms/step - loss: 0.0000e+0
0 - accuracy: 0.0522 - val_loss: 0.0000e+00 - val_accuracy: 0.0769
Epoch 2/5
64/64 [==============================] - 12s 187ms/step - loss: 0.0000e+0
0 - accuracy: 0.0650 - val_loss: 0.0000e+00 - val_accuracy: 0.0769
Epoch 3/5
64/64 [==============================] - 12s 190ms/step - loss: 0.0000e+0
0 - accuracy: 0.0665 - val_loss: 0.0000e+00 - val_accuracy: 0.0769
Epoch 4/5
64/64 [==============================] - 12s 195ms/step - loss: 0.0000e+0
0 - accuracy: 0.0665 - val_loss: 0.0000e+00 - val_accuracy: 0.0769
Epoch 5/5
64/64 [==============================] - 12s 192ms/step - loss: 0.0000e+0
0 - accuracy: 0.0665 - val_loss: 0.0000e+00 - val_accuracy: 0.0769
```

In [34]:
```
# Save accuracy and valid accuracy for fine tuning
acc = history.history['accuracy']
val_acc = history.history['val_accuracy']

# Plot training & validation accuracy values
plt.plot(val_acc)
plt.plot(acc)
plt.title('Model accuracy')
plt.ylabel('Accuracy')
plt.xlabel('Epoch')
plt.legend(['Train', 'Validation'], loc='upper left')
plt.show()
```



In [35]:
```
score_TL = model_TL.evaluate(test, verbose=0)
print('Test loss:', score_TL[0])
print('Test accuracy:', score_TL[1])

predictions = model_TL.predict(test, verbose=0)
score_TL2 = tf.nn.softmax(predictions[0])

print(
    "This image is probably the {} with a {:.2f} percent confidence."
    .format(class_names[np.argmax(score_TL2)], 100 * np.max(score_TL2))
)
```

```
Test loss: 0.0
Test accuracy: 0.07692307978868484
WARNING:tensorflow:5 out of the last 13 calls to <function Model.make_pre
dict_function.<locals>.predict_function at 0x000001238A5891F0> triggered
tf.function retracing. Tracing is expensive and the excessive number of t
racings could be due to (1) creating @tf.function repeatedly in a loop,
(2) passing tensors with different shapes, (3) passing Python objects ins
tead of tensors. For (1), please define your @tf.function outside of the
loop. For (2), @tf.function has reduce_retracing=True option that can avo
id unnecessary retracing. For (3), please refer to https://www.tensorflo
w.org/guide/function#controlling_retracing and https://www.tensorflow.or
g/api_docs/python/tf/function for  more details.
This image is probably the ace of spades with a 100.00 percent confidenc
e.
```

In [36]:
```
# Fine tuning

# Un-freeze
base_model.trainable = True
```

In [37]:
```
# Fine-tune starting at this layer
fine_tune_at = 100

# Freeze all layers before 'fine_tune_at' layer
for layer in base_model.layers[:fine_tune_at]:
    layer.trainable = False
```

In [38]:
```
model_TL.compile(optimizer=tf.keras.optimizers.RMSprop(learning_rate=base
                 loss=tf.keras.losses.CategoricalCrossentropy(from_logits
                 metrics=['accuracy'])

model_TL.summary()
```

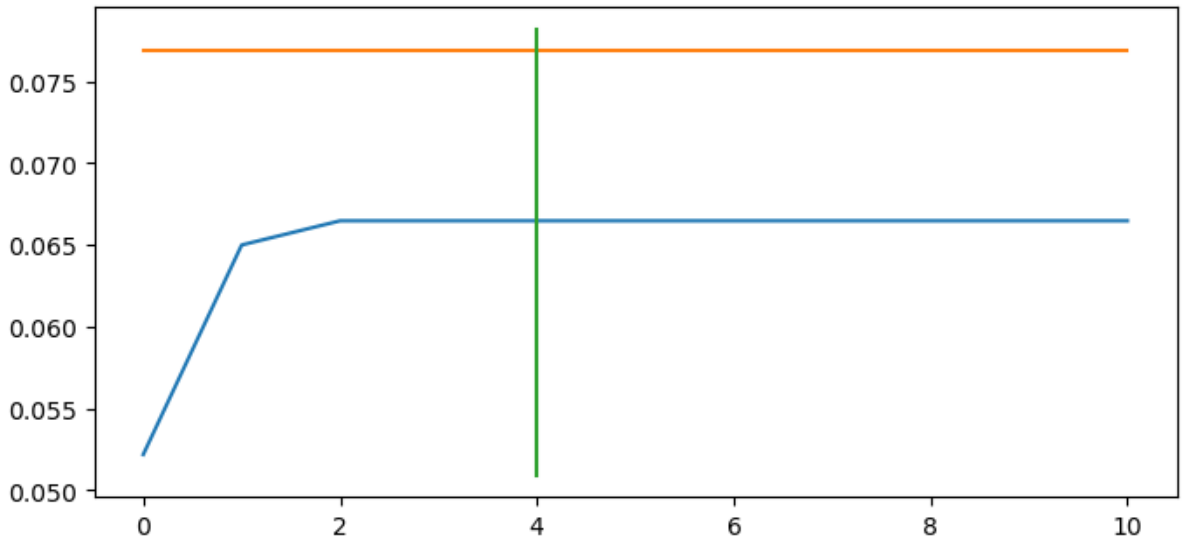
```
Model: "model_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_3 (InputLayer)        [(None, 224, 224, 3)]     0

 sequential_2 (Sequential)   multiple                  0

 tf.math.truediv (TFOpLambda  (None, 224, 224, 3)      0
 )

 tf.math.subtract (TFOpLambd  (None, 224, 224, 3)      0
 a)

 mobilenetv2_1.00_224 (Funct  (None, 7, 7, 1280)       2257984
 ional)

 global_average_pooling2d (G  (None, 1280)             0
 lobalAveragePooling2D)

 dropout_2 (Dropout)         (None, 1280)              0

 dense_5 (Dense)             (None, 1)                 1281

=================================================================
Total params: 2,259,265
Trainable params: 1,862,721
Non-trainable params: 396,544
_________________________________________________________________
```

In [39]:

```
fine_tune_epochs = 5
total_epochs = fine_tune_epochs + initial_epochs

history_fine=model_TL.fit(train,
                          validation_data=valid,
                          callbacks=[early_stop],
                          epochs=total_epochs,
                          initial_epoch=history.epoch[-1])
```

```
Epoch 5/10
64/64 [==============================] - 22s 281ms/step - loss: 0.0000e+0
0 - accuracy: 0.0665 - val_loss: 0.0000e+00 - val_accuracy: 0.0769
Epoch 6/10
64/64 [==============================] - 18s 280ms/step - loss: 0.0000e+0
0 - accuracy: 0.0665 - val_loss: 0.0000e+00 - val_accuracy: 0.0769
Epoch 7/10
64/64 [==============================] - 17s 272ms/step - loss: 0.0000e+0
0 - accuracy: 0.0665 - val_loss: 0.0000e+00 - val_accuracy: 0.0769
Epoch 8/10
64/64 [==============================] - 18s 273ms/step - loss: 0.0000e+0
0 - accuracy: 0.0665 - val_loss: 0.0000e+00 - val_accuracy: 0.0769
Epoch 9/10
64/64 [==============================] - 18s 277ms/step - loss: 0.0000e+0
0 - accuracy: 0.0665 - val_loss: 0.0000e+00 - val_accuracy: 0.0769
Epoch 10/10
64/64 [==============================] - 17s 270ms/step - loss: 0.0000e+0
0 - accuracy: 0.0665 - val_loss: 0.0000e+00 - val_accuracy: 0.0769
Epoch 10: early stopping
```

In [40]:
```
# Updating original with fine tuned values
acc += history_fine.history['accuracy']
val_acc += history_fine.history['val_accuracy']

plt.figure(figsize=(8, 8))
plt.subplot(2, 1, 1)
plt.plot(acc, label='Training Accuracy')
plt.plot(val_acc, label='Validation Accuracy')
plt.plot([initial_epochs-1, initial_epochs-1], plt.ylim(), label='Fine Tu
plt.show()
```



Orange is 'Train' and the blue is 'Validation'. The green line represents where the fine tuning starts.

In [41]:
```
score_TL = model_TL.evaluate(test, verbose=0)
```

```
print('Test loss:', score_TL[0])
print('Test accuracy:', score_TL[1])

predictions = model_TL.predict(test, verbose=0)
score_TL2 = tf.nn.softmax(predictions[0])

print(
    "This image is probably the {} with a {:.2f} percent confidence."
    .format(class_names[np.argmax(score_TL2)], 100 * np.max(score_TL2))
)
```

```
Test loss: 0.0
Test accuracy: 0.07692307978868484
WARNING:tensorflow:5 out of the last 13 calls to <function Model.make_pre
dict_function.<locals>.predict_function at 0x0000012133378D30> triggered
tf.function retracing. Tracing is expensive and the excessive number of t
racings could be due to (1) creating @tf.function repeatedly in a loop,
(2) passing tensors with different shapes, (3) passing Python objects ins
tead of tensors. For (1), please define your @tf.function outside of the
loop. For (2), @tf.function has reduce_retracing=True option that can avo
id unnecessary retracing. For (3), please refer to https://www.tensorflo
w.org/guide/function#controlling_retracing and https://www.tensorflow.or
g/api_docs/python/tf/function for  more details.
This image is probably the ace of spades with a 100.00 percent confidenc
e.
```

Model Analysis

For the image classification that was carried out, different models were used. They were the basic Sequential model, CNN, VGG19, a pre-trained model (EfficientNet B3), and transfer learning using MobileNetV2. It was desired to do RNN and LSMT, however I was not able to get the correct input shape despite trying some transformations.

The basic sequential model had only one hidden layer. This was to reduce the amount of time it would take for the model to be trained. Softmax was the final activation function and 'sparse_categorical_crossentroyp' was done. For some reason however, the model trained very poorly only resulting in approximately a 0.09 accuracy and a straight 0.0769 validation accuracy. This ended up being one of the worst models due to very high loss, very low accuracy, and the prediction confidence of the model was only 7.74 percent confident it was the correct card. It could be either the result of a poorly built model, or it is the dataset itself.

For CNN, the results were much better, granted more functions were applied to the neural network. After fitting the model, it can be seen that the model was able to achieve a high 0.99 accuracy and 0.89 valid accuracy when being trained with the validation dataset. However, when the model was evaluated with the

test dataset, the resulting loss was also high with a decently high test accuracy. This is possibly due to overfitting of the model. Predictions were a little better as it was able to predict with approximately an 18.47 percent confidence.

The VGG-19 model is an advanced version of CNN that is 19 layers deep. It has pre-determined layers and mantains a good understanding of the shape, color, and structure of an image. It is a deep learning algorithm that has been pre-trained on many different images. Due to the number of layers, the training itself took 45 minutes, and only because it stopped early to prevent overfitting. Training with the validation dataset, it achieved a high accuracy of nearly 1 with a validation accuracy of 0.94. However, evaluating and making predictions with the model, it ended up with a very high loss. Approximately similar test accuracy versus CNN, and the same confidence. Again, this is most likely due to overfitting. It also seems my results varies since I ran training the VGG19 model multiple times, and loss has gone down as low as approximately 0.9 before. I am not sure what caused this huge jump in loss with the test dataset.

For the pre-trained model, I used the one made by the creator of the dataset. Their model was based on the EfficientNet architecture with a scaled up baseline network by 3. EfficientNet is also a CNN architecture as well that utilizes a scaling method that uniformly scales with the dimensions of an input image. This is done by using a compound coefficient. I also had to rescale the images to 200x200 since that were the dimensions of his model. The model was also used to predict which rank a card is regardless of suit and had a F-score of approximately 0.95. In this pre-trained model, there were even more layers involved and training the model took over an 1 hour. Training the model, accuracy was approximately 0.99 and the validation accuracy somehow reached 1, which makes me believe overfitting has occured again. Even plotting the results, valdation accuracy has a really weird zig-zag pattern while interweaving along the training accuracy. Despite this, it somehow achieves a very low loss and a high accuracy when compared with the test dataset. It still maintains a low confidence.

The last model to be tested is the transfer learning model. Specifically, the model used for transfer learning is MobileNetV2. Transfer learning is taking a model that was trained on one dataset, and using it on a different problem. In this case, MobileNetV2 is a CNN that is 53 layers deep. The version used is a pre-trained model that has already been trained on a large database of real world images. There are two processes that can be done within transfer learning: feature extraction and fine tuning. Feature extraction is using the previous data from the

pretrained model to see new, meaningful ones from the dataset it is being applied to. Fine tuning is allowing a few of the top layers to be unfrozen and train in tandem the new layers found from fine tuning with the old layers from feature extraction to result in more precise accuracy. Applying feature extraction, the accuracy and validation accuracy remains a low 0.07 and 0.08 respectively. This is similar to the basic sequential model results. When the model is used to evaluate and predict images, it results in the best predictions. Test loss and accuracy is 0 and 0.08, but the prediction is very confident with a 100 percent. This might be because the model is technically already pretrained on other images, and it most likely knows how to classify cards. Fine tuning was applied as well, but the same results in accuracy and validation accuracy occurs.

Resources Used

Dataset: https://www.kaggle.com/datasets/gpiosenka/cards-image-datasetclassification?select=14card+types-14-%28200+X+200%29-94.61.h5

Sequential model, CNN model setup, and testing models: https://www.tensorflow.org/tutorials/images/classification

VGG19 model: https://www.analyticsvidhya.com/blog/2021/07/step-by-step-guide-for-image-classification-on-custom-datasets/

Getting Labels: https://www.analyticsvidhya.com/blog/2021/07/step-by-step-guide-for-image-classification-on-custom-datasets/

Target classes graphed: https://pub.towardsai.net/multiclass-image-classification-hands-on-with-keras-and-tensoflow-e1cf434f3467

Plotting the models and syntax: https://github.com/kjmazidi/Machine_Learning_2nd_edition/tree/master/Part_7_Neu

Transfer learning: https://www.tensorflow.org/tutorials/images/transfer_learning#feature_extraction