In [1]:

```
from numpy.random import seed
seed(1)
import tensorflow
tensorflow.random.set_seed(2)
```

In [2]:

```
#Import Stuff here

from sklearn.model_selection import train_test_split

import matplotlib.pyplot as plt

import tensorflow.keras as keras
from tensorflow import Tensor
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Dropout, ReLU, Conv2D, MaxPooling2D, Flatten, GlobalAveragePooling2D
from tensorflow.keras.layers import DepthwiseConv2D, BatchNormalization, Add, Input, AveragePooling2D
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from sklearn.metrics import classification_report, confusion_matrix
import pandas as pd
import numpy as np
from tensorflow.keras.utils import plot_model
from focal_loss import SparseCategoricalFocalLoss
from keras.models import load_model
```

In [3]:

```
#creates a Image Generator from the directories and scales the images by dividing by 255. Also changes the images

def load_data(train_folder = 'data/train/'):

    datagen = ImageDataGenerator(rescale = 1/255)

    train_it = datagen.flow_from_directory (train_folder, target_size = (256, 256),
                                            class_mode = 'sparse', color_mode="rgb", batch_size=64, seed = 1)

    val_it = datagen.flow_from_directory ('data/validation/', target_size = (256, 256),
                                            class_mode = 'sparse', color_mode="rgb", batch_size=64, seed = 1)

    test_it = datagen.flow_from_directory ('data/test/', target_size = (256, 256),
                                            class_mode = 'sparse', color_mode="rgb", batch_size=64, seed = 1,  sh

    return train_it, val_it, test_it

train_it, val_it, test_it = load_data()
```

```
Found 6800 images belonging to 17 classes.
Found 1700 images belonging to 17 classes.
Found 1700 images belonging to 17 classes.
```

In [4]:

```
batchX, batchy = train_it.next()
print('Batch shape=%s, min=%.3f, max=%.3f' % (batchX.shape, batchX.min(), batchX.max()))
```

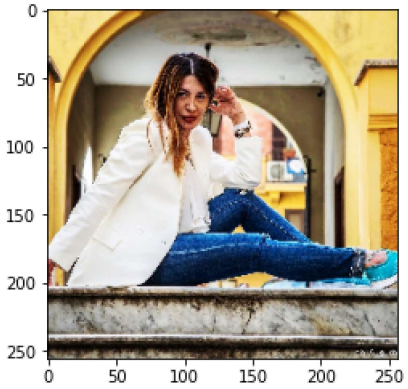
```
Batch shape=(64, 256, 256, 3), min=0.000, max=1.000
```

In [5]:

```
plt.imshow(batchX[0])
```

Out[5]:

```
<matplotlib.image.AxesImage at 0x21f0a7d11f0>
```



In [6]:
```
batchy[63]
```

Out[6]:
```
11.0
```

In [7]:
```
def res_block(x: Tensor, filters: int, kernel_size: int, stride : int):

    output1 = Conv2D (filters, kernel_size = kernel_size, strides = stride, padding = 'same')(x)
 #   output1 = BatchNormalization()(output1)

    output1 = Conv2D (filters, kernel_size = kernel_size, padding = 'same')(output1)

    if stride == 2:
        x = Conv2D (filters, kernel_size = kernel_size, strides = 2, padding = 'same')(x)

    output_added = Add()([x, output1])
    output_added = ReLU() (output_added)
    output_added = BatchNormalization()(output_added)

    return output_added
```

In [8]:
```
def build_model():
    # TODO: build the model,

    inputs = Input(shape=(256, 256, 3, ))

    x = BatchNormalization()(inputs)

    x = Conv2D (64, kernel_size = 3, strides = 1, activation = 'relu', padding = 'same')(x)

    x = res_block(x, filters = 64, kernel_size = 3, stride = 1)
    x = res_block(x, filters = 64, kernel_size = 3, stride = 1)

    x = res_block(x, filters = 128, kernel_size = 3, stride = 2)
    x = res_block(x, filters = 128, kernel_size = 3, stride = 1)


    x = res_block(x, filters = 256, kernel_size = 3, stride = 2)
    x = res_block(x, filters = 256, kernel_size = 3, stride = 1)

    x = res_block(x, filters = 512, kernel_size = 3, stride = 2)
    x = res_block(x, filters = 512, kernel_size = 3, stride = 1)


    x = Conv2D(128, kernel_size= 3, activation = 'relu', padding='same')(x) #added back in
    x = BatchNormalization()(x)

    x = AveragePooling2D(4)(x)
    x = Flatten()(x)


    x = Dense(64, activation = 'relu')(x)
    my_output = Dropout (0.2)(x)

    probs = Dense(17, activation = 'softmax')(my_output)
```

```
    model = keras.Model(inputs= inputs, outputs=probs)

    model.summary()

    return model

model = build_model()
```

```
Model: "model"
```

Layer (type)	Output Shape	Param #	Connected to
input_1 (InputLayer)	[(None, 256, 256, 3)]	0	[]
batch_normalization (BatchNormalization)	(None, 256, 256, 3)	12	['input_1[0][0]']
conv2d (Conv2D)	(None, 256, 256, 64)	1792	['batch_normalization[0][0]']
conv2d_1 (Conv2D)	(None, 256, 256, 64)	36928	['conv2d[0][0]']
conv2d_2 (Conv2D)	(None, 256, 256, 64)	36928	['conv2d_1[0][0]']
add (Add)	(None, 256, 256, 64)	0	['conv2d[0][0]', 'conv2d_2[0][0]']
re_lu (ReLU)	(None, 256, 256, 64)	0	['add[0][0]']
batch_normalization_1 (BatchNormalization)	(None, 256, 256, 64)	256	['re_lu[0][0]']
conv2d_3 (Conv2D)	(None, 256, 256, 64)	36928	['batch_normalization_1[0][0]']
conv2d_4 (Conv2D)	(None, 256, 256, 64)	36928	['conv2d_3[0][0]']
add_1 (Add)	(None, 256, 256, 64)	0	['batch_normalization_1[0][0]', 'conv2d_4[0][0]']
re_lu_1 (ReLU)	(None, 256, 256, 64)	0	['add_1[0][0]']
batch_normalization_2 (BatchNormalization)	(None, 256, 256, 64)	256	['re_lu_1[0][0]']
conv2d_5 (Conv2D)	(None, 128, 128, 128)	73856	['batch_normalization_2[0][0]']
conv2d_7 (Conv2D)	(None, 128, 128, 128)	73856	['batch_normalization_2[0][0]']
conv2d_6 (Conv2D)	(None, 128, 128, 128)	147584	['conv2d_5[0][0]']
add_2 (Add)	(None, 128, 128, 128)	0	['conv2d_7[0][0]', 'conv2d_6[0][0]']
re_lu_2 (ReLU)	(None, 128, 128, 128)	0	['add_2[0][0]']
batch_normalization_3 (BatchNormalization)	(None, 128, 128, 128)	512	['re_lu_2[0][0]']
conv2d_8 (Conv2D)	(None, 128, 128, 128)	147584	['batch_normalization_3[0][0]']
conv2d_9 (Conv2D)	(None, 128, 128, 128)	147584	['conv2d_8[0][0]']

```
add_3 (Add)                    (None, 128, 128, 12  0          ['batch_normalization_3[0][0]',
                               8)                               'conv2d_9[0][0]']

re_lu_3 (ReLU)                 (None, 128, 128, 12  0          ['add_3[0][0]']
                               8)

batch_normalization_4 (BatchNo  (None, 128, 128, 12  512       ['re_lu_3[0][0]']
rmalization)                   8)

conv2d_10 (Conv2D)             (None, 64, 64, 256)  295168     ['batch_normalization_4[0][0]']

conv2d_12 (Conv2D)             (None, 64, 64, 256)  295168     ['batch_normalization_4[0][0]']

conv2d_11 (Conv2D)             (None, 64, 64, 256)  590080     ['conv2d_10[0][0]']

add_4 (Add)                    (None, 64, 64, 256)  0          ['conv2d_12[0][0]',
                                                                 'conv2d_11[0][0]']

re_lu_4 (ReLU)                 (None, 64, 64, 256)  0          ['add_4[0][0]']

batch_normalization_5 (BatchNo  (None, 64, 64, 256)  1024      ['re_lu_4[0][0]']
rmalization)

conv2d_13 (Conv2D)             (None, 64, 64, 256)  590080     ['batch_normalization_5[0][0]']

conv2d_14 (Conv2D)             (None, 64, 64, 256)  590080     ['conv2d_13[0][0]']

add_5 (Add)                    (None, 64, 64, 256)  0          ['batch_normalization_5[0][0]',
                                                                 'conv2d_14[0][0]']

re_lu_5 (ReLU)                 (None, 64, 64, 256)  0          ['add_5[0][0]']

batch_normalization_6 (BatchNo  (None, 64, 64, 256)  1024      ['re_lu_5[0][0]']
rmalization)

conv2d_15 (Conv2D)             (None, 32, 32, 512)  1180160    ['batch_normalization_6[0][0]']

conv2d_17 (Conv2D)             (None, 32, 32, 512)  1180160    ['batch_normalization_6[0][0]']

conv2d_16 (Conv2D)             (None, 32, 32, 512)  2359808    ['conv2d_15[0][0]']

add_6 (Add)                    (None, 32, 32, 512)  0          ['conv2d_17[0][0]',
                                                                 'conv2d_16[0][0]']

re_lu_6 (ReLU)                 (None, 32, 32, 512)  0          ['add_6[0][0]']

batch_normalization_7 (BatchNo  (None, 32, 32, 512)  2048      ['re_lu_6[0][0]']
rmalization)

conv2d_18 (Conv2D)             (None, 32, 32, 512)  2359808    ['batch_normalization_7[0][0]']

conv2d_19 (Conv2D)             (None, 32, 32, 512)  2359808    ['conv2d_18[0][0]']

add_7 (Add)                    (None, 32, 32, 512)  0          ['batch_normalization_7[0][0]',
                                                                 'conv2d_19[0][0]']

re_lu_7 (ReLU)                 (None, 32, 32, 512)  0          ['add_7[0][0]']

batch_normalization_8 (BatchNo  (None, 32, 32, 512)  2048      ['re_lu_7[0][0]']
rmalization)

conv2d_20 (Conv2D)             (None, 32, 32, 128)  589952     ['batch_normalization_8[0][0]']

batch_normalization_9 (BatchNo  (None, 32, 32, 128)  512       ['conv2d_20[0][0]']
rmalization)

average_pooling2d (AveragePool  (None, 8, 8, 128)   0          ['batch_normalization_9[0][0]']
ing2D)

flatten (Flatten)              (None, 8192)         0          ['average_pooling2d[0][0]']

dense (Dense)                  (None, 64)           524352     ['flatten[0][0]']

dropout (Dropout)              (None, 64)           0          ['dense[0][0]']
```

```
 dense_1 (Dense)                (None, 17)           1105        ['dropout[0][0]']

==================================================================================================
Total params: 13,663,901
Trainable params: 13,659,799
Non-trainable params: 4,102
__________________________________________________________________________________________________
```

In [9]:

```python
def compile_model(model):
    # TODO: compile the model

    model.compile(optimizer = keras.optimizers.Adam(learning_rate = 0.0001),
              loss=keras.losses.SparseCategoricalCrossentropy(),
              metrics=['accuracy'])

    return model

def train_model(model, train_it, val_it):
    # TODO: train the model
    callback = keras.callbacks.EarlyStopping(monitor='val_accuracy', patience=5, restore_best_weights= True)

    history = model.fit(train_it, epochs = 50, steps_per_epoch = 107, verbose = 2,
                        validation_data= val_it, validation_steps = 27, callbacks=[callback])
    return model, history


model = compile_model(model)

model, history = train_model(model, train_it, val_it)

len(history.history['loss'])  #
```

```
Epoch 1/50
107/107 - 117s - loss: 1.5612 - accuracy: 0.5196 - val_loss: 8.1866 - val_accuracy: 0.0588 - 117s/epoch - 1s/step
Epoch 2/50
107/107 - 95s - loss: 0.7931 - accuracy: 0.7453 - val_loss: 7.2920 - val_accuracy: 0.0924 - 95s/epoch - 891ms/ste
p
Epoch 3/50
107/107 - 95s - loss: 0.5728 - accuracy: 0.8154 - val_loss: 5.4901 - val_accuracy: 0.1735 - 95s/epoch - 890ms/ste
p
Epoch 4/50
107/107 - 95s - loss: 0.4508 - accuracy: 0.8512 - val_loss: 2.0716 - val_accuracy: 0.4682 - 95s/epoch - 887ms/ste
p
Epoch 5/50
107/107 - 96s - loss: 0.3645 - accuracy: 0.8793 - val_loss: 1.1642 - val_accuracy: 0.6771 - 96s/epoch - 898ms/ste
p
Epoch 6/50
107/107 - 107s - loss: 0.3461 - accuracy: 0.8841 - val_loss: 0.5762 - val_accuracy: 0.8241 - 107s/epoch - 1s/step
Epoch 7/50
107/107 - 97s - loss: 0.2647 - accuracy: 0.9129 - val_loss: 0.4931 - val_accuracy: 0.8529 - 97s/epoch - 910ms/ste
p
Epoch 8/50
107/107 - 95s - loss: 0.2518 - accuracy: 0.9171 - val_loss: 0.5928 - val_accuracy: 0.8465 - 95s/epoch - 887ms/ste
p
Epoch 9/50
107/107 - 95s - loss: 0.2100 - accuracy: 0.9296 - val_loss: 0.9204 - val_accuracy: 0.7765 - 95s/epoch - 886ms/ste
p
Epoch 10/50
107/107 - 95s - loss: 0.2024 - accuracy: 0.9315 - val_loss: 0.5991 - val_accuracy: 0.8476 - 95s/epoch - 887ms/ste
p
Epoch 11/50
107/107 - 95s - loss: 0.1684 - accuracy: 0.9465 - val_loss: 0.8639 - val_accuracy: 0.7882 - 95s/epoch - 885ms/ste
p
Epoch 12/50
107/107 - 95s - loss: 0.1484 - accuracy: 0.9510 - val_loss: 0.7318 - val_accuracy: 0.8159 - 95s/epoch - 886ms/ste
p
```

Out[9]:

```
12
```

In [10]:

```python
def eval_model(model, test_it):
    # TODO: evaluate the model

    test_loss, test_accuracy = model.evaluate (test_it, steps = 27)
```

```
    return test_loss, test_accuracy

test_loss, test_accuracy = eval_model(model, test_it)
```

```
27/27 [==============================] - 22s 802ms/step - loss: 0.4317 - accuracy: 0.8676
```

In [11]:
```
test_it.reset()
preds = model.predict(test_it, steps = 27)
```

In [12]:
```
y_predict = np.argmax(preds,axis=1)
```

In [13]:
```
print(classification_report(test_it.classes, y_predict, target_names=test_it.class_indices))
```

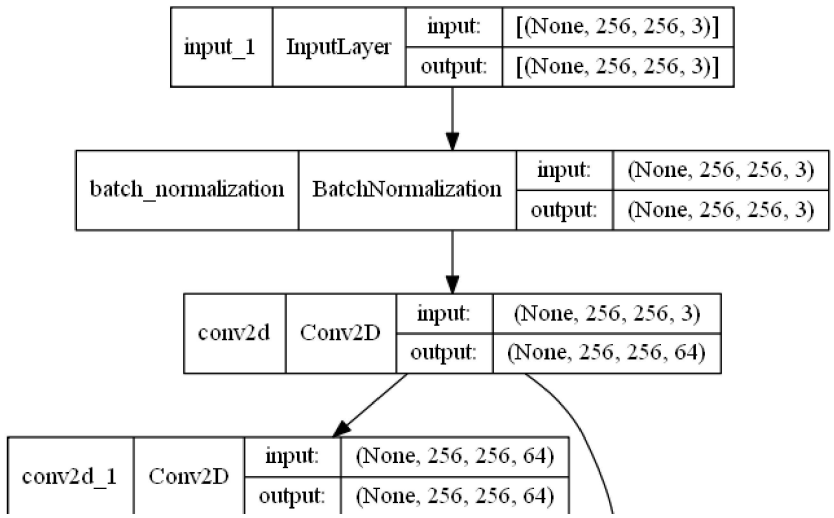
```
              precision    recall  f1-score   support

        1977       0.94      0.98      0.96       100
       Amaro       0.77      0.83      0.80       100
     Brannan       0.83      0.95      0.88       100
   Clarendon       0.84      0.75      0.79       100
     Gingham       0.83      1.00      0.90       100
       He-Fe       0.93      0.85      0.89       100
      Hudson       0.92      0.90      0.91       100
       Lo-Fi       0.73      0.82      0.77       100
     Mayfair       0.79      0.95      0.86       100
   Nashville       0.99      0.85      0.91       100
    Original       0.69      0.60      0.64       100
    Perpetua       0.93      0.81      0.87       100
       Sutro       0.89      0.97      0.93       100
     Toaster       0.98      0.93      0.95       100
    Valencia       0.83      0.68      0.75       100
      Willow       0.98      0.98      0.98       100
     X-ProII       0.96      0.90      0.93       100

    accuracy                           0.87      1700
   macro avg       0.87      0.87      0.87      1700
weighted avg       0.87      0.87      0.87      1700
```

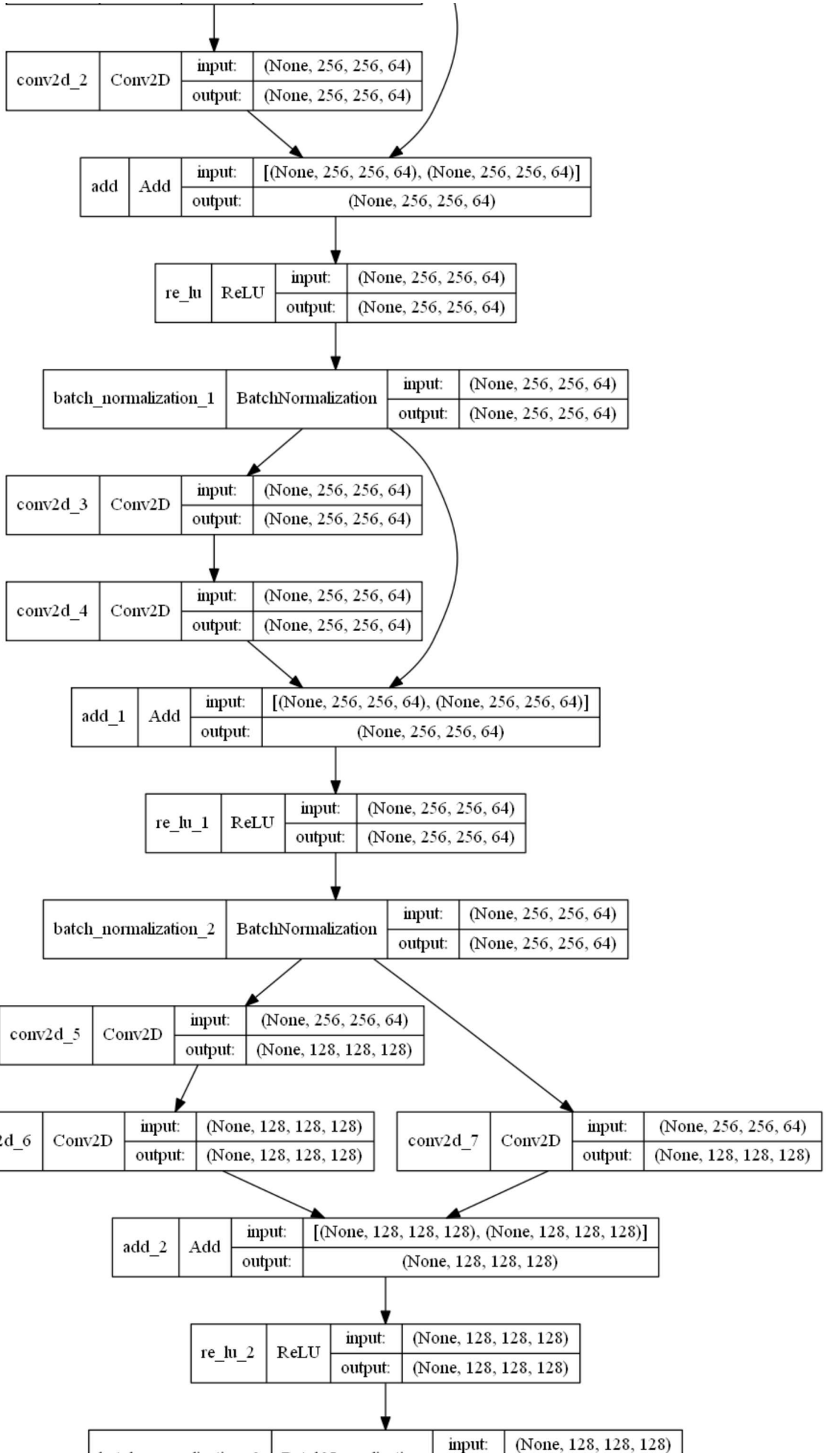
In [19]:
```
error_count = 0

for x in range (0,len(y_predict)):
    if y_predict[x] != test_it.classes[x]:
        error_count += 1

error_count
```

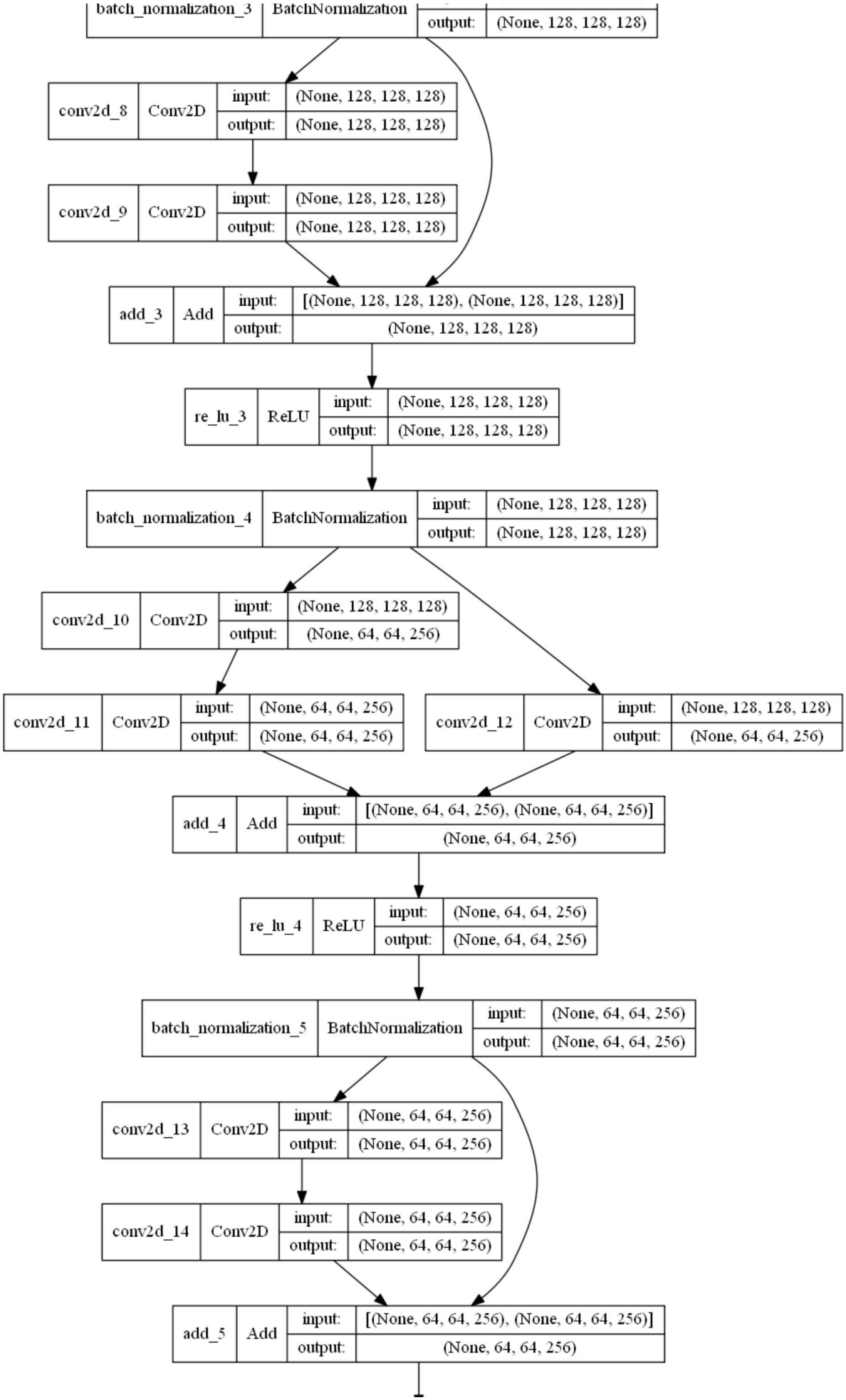
Out[19]:
```
225
```

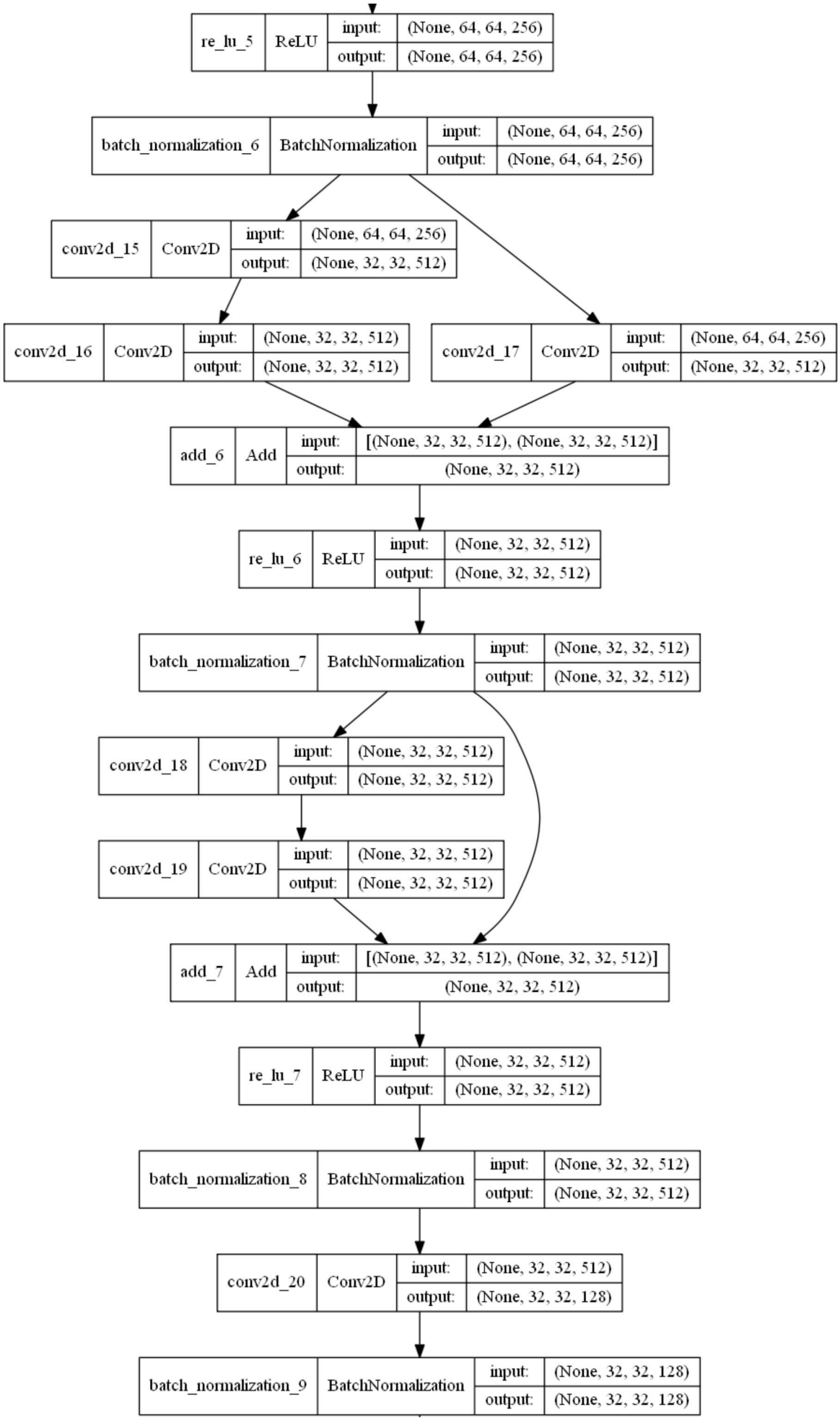
In [15]:
```
plot_model (model, 'model.png', show_shapes=True)
```

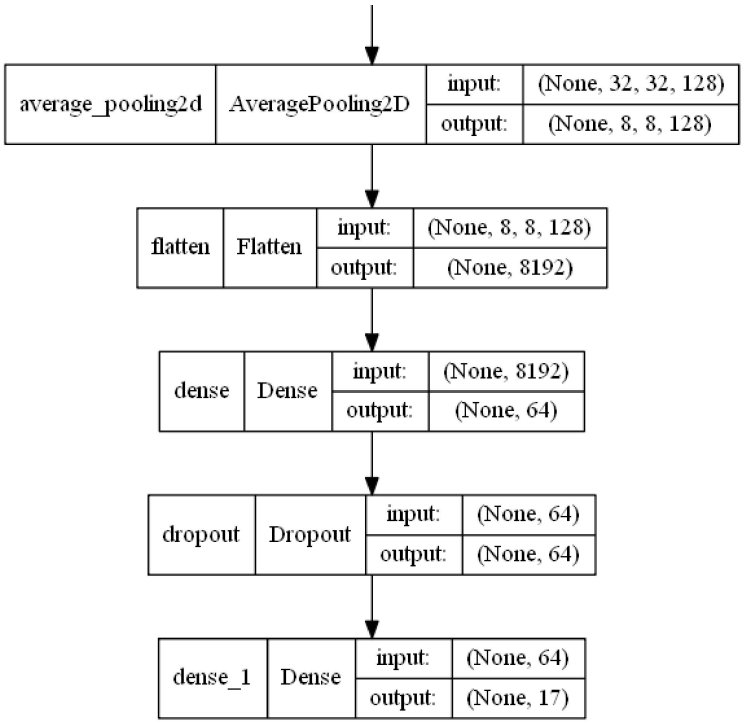
Out[15]:




conv2d_2 Conv2D input: (None, 256, 256, 64) output: (None, 256, 256, 64)
add Add input: [(None, 256, 256, 64), (None, 256, 256, 64)] output: (None, 256, 256, 64)
re_lu ReLU input: (None, 256, 256, 64) output: (None, 256, 256, 64)
batch_normalization_1 BatchNormalization input: (None, 256, 256, 64) output: (None, 256, 256, 64)
conv2d_3 Conv2D input: (None, 256, 256, 64) output: (None, 256, 256, 64)
conv2d_4 Conv2D input: (None, 256, 256, 64) output: (None, 256, 256, 64)
add_1 Add input: [(None, 256, 256, 64), (None, 256, 256, 64)] output: (None, 256, 256, 64)
re_lu_1 ReLU input: (None, 256, 256, 64) output: (None, 256, 256, 64)
batch_normalization_2 BatchNormalization input: (None, 256, 256, 64) output: (None, 256, 256, 64)
conv2d_5 Conv2D input: (None, 256, 256, 64) output: (None, 128, 128, 128)
conv2d_6 Conv2D input: (None, 128, 128, 128) output: (None, 128, 128, 128)
conv2d_7 Conv2D input: (None, 256, 256, 64) output: (None, 128, 128, 128)
add_2 Add input: [(None, 128, 128, 128), (None, 128, 128, 128)] output: (None, 128, 128, 128)
re_lu_2 ReLU input: (None, 128, 128, 128) output: (None, 128, 128, 128)
input: (None, 128, 128, 128)


batch_normalization_3 BatchNormalization output: (None, 128, 128, 128)
conv2d_8 Conv2D input: (None, 128, 128, 128) output: (None, 128, 128, 128)
conv2d_9 Conv2D input: (None, 128, 128, 128) output: (None, 128, 128, 128)
add_3 Add input: [(None, 128, 128, 128), (None, 128, 128, 128)] output: (None, 128, 128, 128)
re_lu_3 ReLU input: (None, 128, 128, 128) output: (None, 128, 128, 128)
batch_normalization_4 BatchNormalization input: (None, 128, 128, 128) output: (None, 128, 128, 128)
conv2d_10 Conv2D input: (None, 128, 128, 128) output: (None, 64, 64, 256)
conv2d_11 Conv2D input: (None, 64, 64, 256) output: (None, 64, 64, 256)
conv2d_12 Conv2D input: (None, 128, 128, 128) output: (None, 64, 64, 256)
add_4 Add input: [(None, 64, 64, 256), (None, 64, 64, 256)] output: (None, 64, 64, 256)
re_lu_4 ReLU input: (None, 64, 64, 256) output: (None, 64, 64, 256)
batch_normalization_5 BatchNormalization input: (None, 64, 64, 256) output: (None, 64, 64, 256)
conv2d_13 Conv2D input: (None, 64, 64, 256) output: (None, 64, 64, 256)
conv2d_14 Conv2D input: (None, 64, 64, 256) output: (None, 64, 64, 256)
add_5 Add input: [(None, 64, 64, 256), (None, 64, 64, 256)] output: (None, 64, 64, 256)


re_lu_5 ReLU input: (None, 64, 64, 256) output: (None, 64, 64, 256)
batch_normalization_6 BatchNormalization input: (None, 64, 64, 256) output: (None, 64, 64, 256)
conv2d_15 Conv2D input: (None, 64, 64, 256) output: (None, 32, 32, 512)
conv2d_16 Conv2D input: (None, 32, 32, 512) output: (None, 32, 32, 512)
conv2d_17 Conv2D input: (None, 64, 64, 256) output: (None, 32, 32, 512)
add_6 Add input: [(None, 32, 32, 512), (None, 32, 32, 512)] output: (None, 32, 32, 512)
re_lu_6 ReLU input: (None, 32, 32, 512) output: (None, 32, 32, 512)
batch_normalization_7 BatchNormalization input: (None, 32, 32, 512) output: (None, 32, 32, 512)
conv2d_18 Conv2D input: (None, 32, 32, 512) output: (None, 32, 32, 512)
conv2d_19 Conv2D input: (None, 32, 32, 512) output: (None, 32, 32, 512)
add_7 Add input: [(None, 32, 32, 512), (None, 32, 32, 512)] output: (None, 32, 32, 512)
re_lu_7 ReLU input: (None, 32, 32, 512) output: (None, 32, 32, 512)
batch_normalization_8 BatchNormalization input: (None, 32, 32, 512) output: (None, 32, 32, 512)
conv2d_20 Conv2D input: (None, 32, 32, 512) output: (None, 32, 32, 128)
batch_normalization_9 BatchNormalization input: (None, 32, 32, 128) output: (None, 32, 32, 128)



In [17]:
```
model.save('ResNet_original_87_final.h5', overwrite=True,
    include_optimizer=True)
```

In [ ]: