Import Libraries

In [1]:

```
import warnings
warnings.filterwarnings('ignore')
from tensorflow.keras import applications
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras import optimizers
from tensorflow.keras.models import Sequential, Model
from tensorflow.keras.layers import Dropout, Flatten, Dense, GlobalAveragePooling2D
from tensorflow.keras import backend as k
from tensorflow.keras.callbacks import ModelCheckpoint, LearningRateScheduler, TensorBo
ard, EarlyStopping
import tensorflow as tf
from matplotlib import pyplot
import numpy as np
from sklearn.metrics import classification_report, confusion_matrix
```

In [2]:

```
from tensorflow.keras.applications import ResNet50
from tensorflow.keras.applications.resnet50 import preprocess_input
```

Add Path and Other Setting

In [18]:

```
# Path To Image Directory
PATH = "./Defect_classes/"

# Image Shape to Be trained
image_size=227

# Batch size to feed in the model
batch_size=16
```

In [19]:

```
# Train Dataset
train_data_dir = f'{PATH}train'

#Validation Dataset
validation_data_dir = f'{PATH}valid'
```

Data Augmentation and Preprocessing

Data Augmentation

For Help open https://towardsdatascience.com/data-augmentation-techniques-in-python-f216ef5eed69 (https://towardsdatascience.com/data-augmentation-techniques-in-python-f216ef5eed69)

In [20]:

```
train_datagen = ImageDataGenerator(preprocessing_function = preprocess_input, #rescale=
1./255
                                   shear_range=0.2,
                                   zoom_range=0.2,
                                   horizontal_flip=True,
                                   rotation_range=10)

test_datagen = ImageDataGenerator(preprocessing_function = preprocess_input)#rescale=
1./255
```

In [21]:

```
# Available options for data augmentation

# ImageDataGenerator(
#     featurewise_center=False, samplewise_center=False,
#     featurewise_std_normalization=False, samplewise_std_normalization=False,
#     zca_whitening=False, zca_epsilon=1e-06, rotation_range=0, width_shift_range=0.0,
#     height_shift_range=0.0, brightness_range=None, shear_range=0.0, zoom_range=0.0,
#     channel_shift_range=0.0, fill_mode='nearest', cval=0.0, horizontal_flip=False,
#     vertical_flip=False, rescale=None, preprocessing_function=None,
#     data_format=None, validation_split=0.0, dtype=None
# )
```

Preprocessing Data

In [22]:

```
train_generator = train_datagen.flow_from_directory(train_data_dir,
                                                    target_size=(image_size, image_size
),
                                                    batch_size=batch_size,
                                                    class_mode='sparse'
                                                   )

validation_generator = test_datagen.flow_from_directory(validation_data_dir,
                                                        shuffle=False,
                                                        target_size=(image_size, image_
size),
                                                        batch_size=batch_size, class_mo
de='sparse'
                                                       )
```

```
Found 2000 images belonging to 2 classes.
Found 400 images belonging to 2 classes.
```

In [23]:

```
# Check Category of classes
train_generator.class_indices
```

Out[23]:

```
{'No_crack': 0, 'crack': 1}
```

In [24]:

```
train_generator.num_classes
```

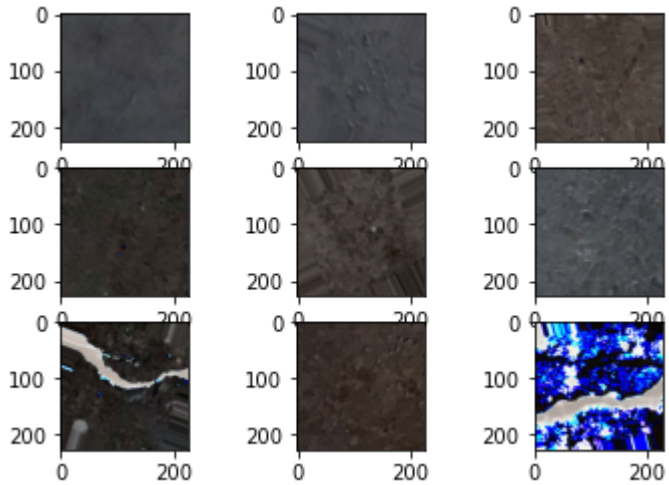
Out[24]:

```
2
```

Visualize few images from Data generated set (Original and augmented images)

In [25]:

```
# generate samples and plot
for i in range(9):
    # define subplot
    pyplot.subplot(330 + 1 + i)
    # generate batch of images
    x,y = train_generator.next()
    # convert to unsigned integers for viewing
    image = x[0].astype('uint8')
    # plot raw pixel data
    pyplot.imshow(image)
# show the figure
pyplot.show()
```



In [26]:

```
# x[i]
```

In [27]:

```
image.shape
```

Out[27]:

```
(227, 227, 3)
```

Define Pretrained Model, Layers and other Parameters

Add Pretrained Model Layer

To find more about Pretrained models open https://keras.io/api/applications/ (https://keras.io/api/applications/)

In [28]:

```
base_model = ResNet50(weights="imagenet", include_top=False, input_shape = (image_size, image_size, 3))
```

```
WARNING:tensorflow:From C:\Users\MARVIN\anaconda3\envs\tensorflow15\lib\site-packages\tensorflow_core\python\ops\resource_variable_ops.py:1630: calling BaseResourceVariable.__init__ (from tensorflow.python.ops.resource_variable_ops) with constraint is deprecated and will be removed in a future version.
Instructions for updating:
If using Keras pass *_constraint arguments to layers.
```

Freeze Pretrained Model

Method 1 (Freeze all layers in pretrained model)

In [29]:

```
# base_model.trainable = False
```

Method 2 (Freeze All layers in Pretarined Model Except Batch Normalization Layers)

In [30]:

```
#Freeze All layers in Pretarined Model Except Batch Normalization Layers
for layer in base_model.layers:
    if layer.__class__.__name__ != "BatchNormalization":
        layer.trainable = False
```

In [31]:

```
base_model.summary()
```

```
Model: "resnet50"
__________________________________________________________________________________________________
Layer (type)                    Output Shape         Param #     Connected to
==================================================================================================
input_1 (InputLayer)            [(None, 227, 227, 3) 0
__________________________________________________________________________________________________
conv1_pad (ZeroPadding2D)       (None, 233, 233, 3)  0           input_1[0][0]
__________________________________________________________________________________________________
conv1_conv (Conv2D)             (None, 114, 114, 64) 9472        conv1_pad[0][0]
__________________________________________________________________________________________________
conv1_bn (BatchNormalization)   (None, 114, 114, 64) 256         conv1_conv[0][0]
__________________________________________________________________________________________________
conv1_relu (Activation)         (None, 114, 114, 64) 0           conv1_bn[0][0]
__________________________________________________________________________________________________
pool1_pad (ZeroPadding2D)       (None, 116, 116, 64) 0           conv1_relu[0][0]
__________________________________________________________________________________________________
pool1_pool (MaxPooling2D)       (None, 57, 57, 64)   0           pool1_pad[0][0]
__________________________________________________________________________________________________
conv2_block1_1_conv (Conv2D)    (None, 57, 57, 64)   4160        pool1_pool[0][0]
__________________________________________________________________________________________________
conv2_block1_1_bn (BatchNormali (None, 57, 57, 64)   256         conv2_block1_1_conv[0][0]
__________________________________________________________________________________________________
conv2_block1_1_relu (Activation (None, 57, 57, 64)   0           conv2_block1_1_bn[0][0]
__________________________________________________________________________________________________
conv2_block1_2_conv (Conv2D)    (None, 57, 57, 64)   36928       conv2_block1_1_relu[0][0]
__________________________________________________________________________________________________
conv2_block1_2_bn (BatchNormali (None, 57, 57, 64)   256         conv2_block1_2_conv[0][0]
__________________________________________________________________________________________________
conv2_block1_2_relu (Activation (None, 57, 57, 64)   0           conv2_block1_2_bn[0][0]
__________________________________________________________________________________________________
conv2_block1_0_conv (Conv2D)    (None, 57, 57, 256)  16640       pool1_pool[0][0]
__________________________________________________________________________________________________
```

```
__________________________
conv2_block1_3_conv (Conv2D)    (None, 57, 57, 256)  16640       conv2_blo
ck1_2_relu[0][0]
__________________________________________________________________________
__________________________
conv2_block1_0_bn (BatchNormali (None, 57, 57, 256)  1024        conv2_blo
ck1_0_conv[0][0]
__________________________________________________________________________
__________________________
conv2_block1_3_bn (BatchNormali (None, 57, 57, 256)  1024        conv2_blo
ck1_3_conv[0][0]
__________________________________________________________________________
__________________________
conv2_block1_add (Add)          (None, 57, 57, 256)  0           conv2_blo
ck1_0_bn[0][0]
                                                                 conv2_blo
ck1_3_bn[0][0]
__________________________________________________________________________
__________________________
conv2_block1_out (Activation)   (None, 57, 57, 256)  0           conv2_blo
ck1_add[0][0]
__________________________________________________________________________
__________________________
conv2_block2_1_conv (Conv2D)    (None, 57, 57, 64)   16448       conv2_blo
ck1_out[0][0]
__________________________________________________________________________
__________________________
conv2_block2_1_bn (BatchNormali (None, 57, 57, 64)   256         conv2_blo
ck2_1_conv[0][0]
__________________________________________________________________________
__________________________
conv2_block2_1_relu (Activation (None, 57, 57, 64)   0           conv2_blo
ck2_1_bn[0][0]
__________________________________________________________________________
__________________________
conv2_block2_2_conv (Conv2D)    (None, 57, 57, 64)   36928       conv2_blo
ck2_1_relu[0][0]
__________________________________________________________________________
__________________________
conv2_block2_2_bn (BatchNormali (None, 57, 57, 64)   256         conv2_blo
ck2_2_conv[0][0]
__________________________________________________________________________
__________________________
conv2_block2_2_relu (Activation (None, 57, 57, 64)   0           conv2_blo
ck2_2_bn[0][0]
__________________________________________________________________________
__________________________
conv2_block2_3_conv (Conv2D)    (None, 57, 57, 256)  16640       conv2_blo
ck2_2_relu[0][0]
__________________________________________________________________________
__________________________
conv2_block2_3_bn (BatchNormali (None, 57, 57, 256)  1024        conv2_blo
ck2_3_conv[0][0]
__________________________________________________________________________
__________________________
conv2_block2_add (Add)          (None, 57, 57, 256)  0           conv2_blo
ck1_out[0][0]
                                                                 conv2_blo
ck2_3_bn[0][0]
__________________________________________________________________________
__________________________
```

```
conv2_block2_out (Activation)   (None, 57, 57, 256)  0           conv2_blo
ck2_add[0][0]
__________________________________________________________________________
_____________________
conv2_block3_1_conv (Conv2D)    (None, 57, 57, 64)   16448       conv2_blo
ck2_out[0][0]
__________________________________________________________________________
_____________________
conv2_block3_1_bn (BatchNormali (None, 57, 57, 64)   256         conv2_blo
ck3_1_conv[0][0]
__________________________________________________________________________
_____________________
conv2_block3_1_relu (Activation (None, 57, 57, 64)   0           conv2_blo
ck3_1_bn[0][0]
__________________________________________________________________________
_____________________
conv2_block3_2_conv (Conv2D)    (None, 57, 57, 64)   36928       conv2_blo
ck3_1_relu[0][0]
__________________________________________________________________________
_____________________
conv2_block3_2_bn (BatchNormali (None, 57, 57, 64)   256         conv2_blo
ck3_2_conv[0][0]
__________________________________________________________________________
_____________________
conv2_block3_2_relu (Activation (None, 57, 57, 64)   0           conv2_blo
ck3_2_bn[0][0]
__________________________________________________________________________
_____________________
conv2_block3_3_conv (Conv2D)    (None, 57, 57, 256)  16640       conv2_blo
ck3_2_relu[0][0]
__________________________________________________________________________
_____________________
conv2_block3_3_bn (BatchNormali (None, 57, 57, 256)  1024        conv2_blo
ck3_3_conv[0][0]
__________________________________________________________________________
_____________________
conv2_block3_add (Add)          (None, 57, 57, 256)  0           conv2_blo
ck2_out[0][0]
                                                                 conv2_blo
ck3_3_bn[0][0]
__________________________________________________________________________
_____________________
conv2_block3_out (Activation)   (None, 57, 57, 256)  0           conv2_blo
ck3_add[0][0]
__________________________________________________________________________
_____________________
conv3_block1_1_conv (Conv2D)    (None, 29, 29, 128)  32896       conv2_blo
ck3_out[0][0]
__________________________________________________________________________
_____________________
conv3_block1_1_bn (BatchNormali (None, 29, 29, 128)  512         conv3_blo
ck1_1_conv[0][0]
__________________________________________________________________________
_____________________
conv3_block1_1_relu (Activation (None, 29, 29, 128)  0           conv3_blo
ck1_1_bn[0][0]
__________________________________________________________________________
_____________________
conv3_block1_2_conv (Conv2D)    (None, 29, 29, 128)  147584      conv3_blo
ck1_1_relu[0][0]
__________________________________________________________________________
```

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__________________________
conv3_block1_2_bn (BatchNormali (None, 29, 29, 128)  512         conv3_blo
ck1_2_conv[0][0]
__________________________________________________________________________
__________________________
conv3_block1_2_relu (Activation (None, 29, 29, 128)  0           conv3_blo
ck1_2_bn[0][0]
__________________________________________________________________________
__________________________
conv3_block1_0_conv (Conv2D)    (None, 29, 29, 512)  131584      conv2_blo
ck3_out[0][0]
__________________________________________________________________________
__________________________
conv3_block1_3_conv (Conv2D)    (None, 29, 29, 512)  66048       conv3_blo
ck1_2_relu[0][0]
__________________________________________________________________________
__________________________
conv3_block1_0_bn (BatchNormali (None, 29, 29, 512)  2048        conv3_blo
ck1_0_conv[0][0]
__________________________________________________________________________
__________________________
conv3_block1_3_bn (BatchNormali (None, 29, 29, 512)  2048        conv3_blo
ck1_3_conv[0][0]
__________________________________________________________________________
__________________________
conv3_block1_add (Add)          (None, 29, 29, 512)  0           conv3_blo
ck1_0_bn[0][0]
                                                                 conv3_blo
ck1_3_bn[0][0]
__________________________________________________________________________
__________________________
conv3_block1_out (Activation)   (None, 29, 29, 512)  0           conv3_blo
ck1_add[0][0]
__________________________________________________________________________
__________________________
conv3_block2_1_conv (Conv2D)    (None, 29, 29, 128)  65664       conv3_blo
ck1_out[0][0]
__________________________________________________________________________
__________________________
conv3_block2_1_bn (BatchNormali (None, 29, 29, 128)  512         conv3_blo
ck2_1_conv[0][0]
__________________________________________________________________________
__________________________
conv3_block2_1_relu (Activation (None, 29, 29, 128)  0           conv3_blo
ck2_1_bn[0][0]
__________________________________________________________________________
__________________________
conv3_block2_2_conv (Conv2D)    (None, 29, 29, 128)  147584      conv3_blo
ck2_1_relu[0][0]
__________________________________________________________________________
__________________________
conv3_block2_2_bn (BatchNormali (None, 29, 29, 128)  512         conv3_blo
ck2_2_conv[0][0]
__________________________________________________________________________
__________________________
conv3_block2_2_relu (Activation (None, 29, 29, 128)  0           conv3_blo
ck2_2_bn[0][0]
__________________________________________________________________________
__________________________
conv3_block2_3_conv (Conv2D)    (None, 29, 29, 512)  66048       conv3_blo
ck2_2_relu[0][0]
```

```
__________________________________________________________________________________________________
____________________________
conv3_block2_3_bn (BatchNormali (None, 29, 29, 512)  2048        conv3_blo
ck2_3_conv[0][0]
__________________________________________________________________________________________________
____________________________
conv3_block2_add (Add)          (None, 29, 29, 512)  0           conv3_blo
ck1_out[0][0]
                                                                 conv3_blo
ck2_3_bn[0][0]
__________________________________________________________________________________________________
____________________________
conv3_block2_out (Activation)   (None, 29, 29, 512)  0           conv3_blo
ck2_add[0][0]
__________________________________________________________________________________________________
____________________________
conv3_block3_1_conv (Conv2D)    (None, 29, 29, 128)  65664       conv3_blo
ck2_out[0][0]
__________________________________________________________________________________________________
____________________________
conv3_block3_1_bn (BatchNormali (None, 29, 29, 128)  512         conv3_blo
ck3_1_conv[0][0]
__________________________________________________________________________________________________
____________________________
conv3_block3_1_relu (Activation (None, 29, 29, 128)  0           conv3_blo
ck3_1_bn[0][0]
__________________________________________________________________________________________________
____________________________
conv3_block3_2_conv (Conv2D)    (None, 29, 29, 128)  147584      conv3_blo
ck3_1_relu[0][0]
__________________________________________________________________________________________________
____________________________
conv3_block3_2_bn (BatchNormali (None, 29, 29, 128)  512         conv3_blo
ck3_2_conv[0][0]
__________________________________________________________________________________________________
____________________________
conv3_block3_2_relu (Activation (None, 29, 29, 128)  0           conv3_blo
ck3_2_bn[0][0]
__________________________________________________________________________________________________
____________________________
conv3_block3_3_conv (Conv2D)    (None, 29, 29, 512)  66048       conv3_blo
ck3_2_relu[0][0]
__________________________________________________________________________________________________
____________________________
conv3_block3_3_bn (BatchNormali (None, 29, 29, 512)  2048        conv3_blo
ck3_3_conv[0][0]
__________________________________________________________________________________________________
____________________________
conv3_block3_add (Add)          (None, 29, 29, 512)  0           conv3_blo
ck2_out[0][0]
                                                                 conv3_blo
ck3_3_bn[0][0]
__________________________________________________________________________________________________
____________________________
conv3_block3_out (Activation)   (None, 29, 29, 512)  0           conv3_blo
ck3_add[0][0]
__________________________________________________________________________________________________
____________________________
conv3_block4_1_conv (Conv2D)    (None, 29, 29, 128)  65664       conv3_blo
ck3_out[0][0]
__________________________________________________________________________________________________
```

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__________________________
conv3_block4_1_bn (BatchNormali (None, 29, 29, 128)  512         conv3_blo
ck4_1_conv[0][0]
__________________________________________________________________________
__________________________
conv3_block4_1_relu (Activation (None, 29, 29, 128)  0           conv3_blo
ck4_1_bn[0][0]
__________________________________________________________________________
__________________________
conv3_block4_2_conv (Conv2D)    (None, 29, 29, 128)  147584      conv3_blo
ck4_1_relu[0][0]
__________________________________________________________________________
__________________________
conv3_block4_2_bn (BatchNormali (None, 29, 29, 128)  512         conv3_blo
ck4_2_conv[0][0]
__________________________________________________________________________
__________________________
conv3_block4_2_relu (Activation (None, 29, 29, 128)  0           conv3_blo
ck4_2_bn[0][0]
__________________________________________________________________________
__________________________
conv3_block4_3_conv (Conv2D)    (None, 29, 29, 512)  66048       conv3_blo
ck4_2_relu[0][0]
__________________________________________________________________________
__________________________
conv3_block4_3_bn (BatchNormali (None, 29, 29, 512)  2048        conv3_blo
ck4_3_conv[0][0]
__________________________________________________________________________
__________________________
conv3_block4_add (Add)          (None, 29, 29, 512)  0           conv3_blo
ck3_out[0][0]
                                                                 conv3_blo

ck4_3_bn[0][0]
__________________________________________________________________________
__________________________
conv3_block4_out (Activation)   (None, 29, 29, 512)  0           conv3_blo
ck4_add[0][0]
__________________________________________________________________________
__________________________
conv4_block1_1_conv (Conv2D)    (None, 15, 15, 256)  131328      conv3_blo
ck4_out[0][0]
__________________________________________________________________________
__________________________
conv4_block1_1_bn (BatchNormali (None, 15, 15, 256)  1024        conv4_blo
ck1_1_conv[0][0]
__________________________________________________________________________
__________________________
conv4_block1_1_relu (Activation (None, 15, 15, 256)  0           conv4_blo
ck1_1_bn[0][0]
__________________________________________________________________________
__________________________
conv4_block1_2_conv (Conv2D)    (None, 15, 15, 256)  590080      conv4_blo
ck1_1_relu[0][0]
__________________________________________________________________________
__________________________
conv4_block1_2_bn (BatchNormali (None, 15, 15, 256)  1024        conv4_blo
ck1_2_conv[0][0]
__________________________________________________________________________
__________________________
conv4_block1_2_relu (Activation (None, 15, 15, 256)  0           conv4_blo
ck1_2_bn[0][0]
```

```
__________________________________________________________________________________________________
__________________________
conv4_block1_0_conv (Conv2D)    (None, 15, 15, 1024) 525312      conv3_blo
ck4_out[0][0]
__________________________________________________________________________________________________
__________________________
conv4_block1_3_conv (Conv2D)    (None, 15, 15, 1024) 263168      conv4_blo
ck1_2_relu[0][0]
__________________________________________________________________________________________________
__________________________
conv4_block1_0_bn (BatchNormali (None, 15, 15, 1024) 4096        conv4_blo
ck1_0_conv[0][0]
__________________________________________________________________________________________________
__________________________
conv4_block1_3_bn (BatchNormali (None, 15, 15, 1024) 4096        conv4_blo
ck1_3_conv[0][0]
__________________________________________________________________________________________________
__________________________
conv4_block1_add (Add)          (None, 15, 15, 1024) 0           conv4_blo
ck1_0_bn[0][0]
                                                                 conv4_blo
ck1_3_bn[0][0]
__________________________________________________________________________________________________
__________________________
conv4_block1_out (Activation)   (None, 15, 15, 1024) 0           conv4_blo
ck1_add[0][0]
__________________________________________________________________________________________________
__________________________
conv4_block2_1_conv (Conv2D)    (None, 15, 15, 256)  262400      conv4_blo
ck1_out[0][0]
__________________________________________________________________________________________________
__________________________
conv4_block2_1_bn (BatchNormali (None, 15, 15, 256)  1024        conv4_blo
ck2_1_conv[0][0]
__________________________________________________________________________________________________
__________________________
conv4_block2_1_relu (Activation (None, 15, 15, 256)  0           conv4_blo
ck2_1_bn[0][0]
__________________________________________________________________________________________________
__________________________
conv4_block2_2_conv (Conv2D)    (None, 15, 15, 256)  590080      conv4_blo
ck2_1_relu[0][0]
__________________________________________________________________________________________________
__________________________
conv4_block2_2_bn (BatchNormali (None, 15, 15, 256)  1024        conv4_blo
ck2_2_conv[0][0]
__________________________________________________________________________________________________
__________________________
conv4_block2_2_relu (Activation (None, 15, 15, 256)  0           conv4_blo
ck2_2_bn[0][0]
__________________________________________________________________________________________________
__________________________
conv4_block2_3_conv (Conv2D)    (None, 15, 15, 1024) 263168      conv4_blo
ck2_2_relu[0][0]
__________________________________________________________________________________________________
__________________________
conv4_block2_3_bn (BatchNormali (None, 15, 15, 1024) 4096        conv4_blo
ck2_3_conv[0][0]
__________________________________________________________________________________________________
__________________________
conv4_block2_add (Add)          (None, 15, 15, 1024) 0           conv4_blo
```

```
ck1_out[0][0]
                                                                 conv4_blo
ck2_3_bn[0][0]
__________________________________________________________________________
_____________________
conv4_block2_out (Activation)   (None, 15, 15, 1024) 0           conv4_blo
ck2_add[0][0]
__________________________________________________________________________
_____________________
conv4_block3_1_conv (Conv2D)    (None, 15, 15, 256)  262400      conv4_blo
ck2_out[0][0]
__________________________________________________________________________
_____________________
conv4_block3_1_bn (BatchNormali (None, 15, 15, 256)  1024        conv4_blo
ck3_1_conv[0][0]
__________________________________________________________________________
_____________________
conv4_block3_1_relu (Activation (None, 15, 15, 256)  0           conv4_blo
ck3_1_bn[0][0]
__________________________________________________________________________
_____________________
conv4_block3_2_conv (Conv2D)    (None, 15, 15, 256)  590080      conv4_blo
ck3_1_relu[0][0]
__________________________________________________________________________
_____________________
conv4_block3_2_bn (BatchNormali (None, 15, 15, 256)  1024        conv4_blo
ck3_2_conv[0][0]
__________________________________________________________________________
_____________________
conv4_block3_2_relu (Activation (None, 15, 15, 256)  0           conv4_blo
ck3_2_bn[0][0]
__________________________________________________________________________
_____________________
conv4_block3_3_conv (Conv2D)    (None, 15, 15, 1024) 263168      conv4_blo
ck3_2_relu[0][0]
__________________________________________________________________________
_____________________
conv4_block3_3_bn (BatchNormali (None, 15, 15, 1024) 4096        conv4_blo
ck3_3_conv[0][0]
__________________________________________________________________________
_____________________
conv4_block3_add (Add)          (None, 15, 15, 1024) 0           conv4_blo
ck2_out[0][0]
                                                                 conv4_blo
ck3_3_bn[0][0]
__________________________________________________________________________
_____________________
conv4_block3_out (Activation)   (None, 15, 15, 1024) 0           conv4_blo
ck3_add[0][0]
__________________________________________________________________________
_____________________
conv4_block4_1_conv (Conv2D)    (None, 15, 15, 256)  262400      conv4_blo
ck3_out[0][0]
__________________________________________________________________________
_____________________
conv4_block4_1_bn (BatchNormali (None, 15, 15, 256)  1024        conv4_blo
ck4_1_conv[0][0]
__________________________________________________________________________
_____________________
conv4_block4_1_relu (Activation (None, 15, 15, 256)  0           conv4_blo
ck4_1_bn[0][0]
```

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__________________________________________________________________________________________________
____________________
conv4_block4_2_conv (Conv2D)    (None, 15, 15, 256)  590080      conv4_blo
ck4_1_relu[0][0]
__________________________________________________________________________________________________
____________________
conv4_block4_2_bn (BatchNormali (None, 15, 15, 256)  1024        conv4_blo
ck4_2_conv[0][0]
__________________________________________________________________________________________________
____________________
conv4_block4_2_relu (Activation (None, 15, 15, 256)  0           conv4_blo
ck4_2_bn[0][0]
__________________________________________________________________________________________________
____________________
conv4_block4_3_conv (Conv2D)    (None, 15, 15, 1024) 263168      conv4_blo
ck4_2_relu[0][0]
__________________________________________________________________________________________________
____________________
conv4_block4_3_bn (BatchNormali (None, 15, 15, 1024) 4096        conv4_blo
ck4_3_conv[0][0]
__________________________________________________________________________________________________
____________________
conv4_block4_add (Add)          (None, 15, 15, 1024) 0           conv4_blo
ck3_out[0][0]
                                                                 conv4_blo
ck4_3_bn[0][0]
__________________________________________________________________________________________________
____________________
conv4_block4_out (Activation)   (None, 15, 15, 1024) 0           conv4_blo
ck4_add[0][0]
__________________________________________________________________________________________________
____________________
conv4_block5_1_conv (Conv2D)    (None, 15, 15, 256)  262400      conv4_blo
ck4_out[0][0]
__________________________________________________________________________________________________
____________________
conv4_block5_1_bn (BatchNormali (None, 15, 15, 256)  1024        conv4_blo
ck5_1_conv[0][0]
__________________________________________________________________________________________________
____________________
conv4_block5_1_relu (Activation (None, 15, 15, 256)  0           conv4_blo
ck5_1_bn[0][0]
__________________________________________________________________________________________________
____________________
conv4_block5_2_conv (Conv2D)    (None, 15, 15, 256)  590080      conv4_blo
ck5_1_relu[0][0]
__________________________________________________________________________________________________
____________________
conv4_block5_2_bn (BatchNormali (None, 15, 15, 256)  1024        conv4_blo
ck5_2_conv[0][0]
__________________________________________________________________________________________________
____________________
conv4_block5_2_relu (Activation (None, 15, 15, 256)  0           conv4_blo
ck5_2_bn[0][0]
__________________________________________________________________________________________________
____________________
conv4_block5_3_conv (Conv2D)    (None, 15, 15, 1024) 263168      conv4_blo
ck5_2_relu[0][0]
__________________________________________________________________________________________________
____________________
conv4_block5_3_bn (BatchNormali (None, 15, 15, 1024) 4096        conv4_blo
```

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ck5_3_conv[0][0]
__________________________________________________________________________________
_____________________________
conv4_block5_add (Add)          (None, 15, 15, 1024) 0           conv4_blo
ck4_out[0][0]
                                                                 conv4_blo
ck5_3_bn[0][0]
__________________________________________________________________________________
_____________________________
conv4_block5_out (Activation)   (None, 15, 15, 1024) 0           conv4_blo
ck5_add[0][0]
__________________________________________________________________________________
_____________________________
conv4_block6_1_conv (Conv2D)    (None, 15, 15, 256)  262400      conv4_blo
ck5_out[0][0]
__________________________________________________________________________________
_____________________________
conv4_block6_1_bn (BatchNormali (None, 15, 15, 256)  1024        conv4_blo
ck6_1_conv[0][0]
__________________________________________________________________________________
_____________________________
conv4_block6_1_relu (Activation (None, 15, 15, 256)  0           conv4_blo
ck6_1_bn[0][0]
__________________________________________________________________________________
_____________________________
conv4_block6_2_conv (Conv2D)    (None, 15, 15, 256)  590080      conv4_blo
ck6_1_relu[0][0]
__________________________________________________________________________________
_____________________________
conv4_block6_2_bn (BatchNormali (None, 15, 15, 256)  1024        conv4_blo
ck6_2_conv[0][0]
__________________________________________________________________________________
_____________________________
conv4_block6_2_relu (Activation (None, 15, 15, 256)  0           conv4_blo
ck6_2_bn[0][0]
__________________________________________________________________________________
_____________________________
conv4_block6_3_conv (Conv2D)    (None, 15, 15, 1024) 263168      conv4_blo
ck6_2_relu[0][0]
__________________________________________________________________________________
_____________________________
conv4_block6_3_bn (BatchNormali (None, 15, 15, 1024) 4096        conv4_blo
ck6_3_conv[0][0]
__________________________________________________________________________________
_____________________________
conv4_block6_add (Add)          (None, 15, 15, 1024) 0           conv4_blo
ck5_out[0][0]
                                                                 conv4_blo
ck6_3_bn[0][0]
__________________________________________________________________________________
_____________________________
conv4_block6_out (Activation)   (None, 15, 15, 1024) 0           conv4_blo
ck6_add[0][0]
__________________________________________________________________________________
_____________________________
conv5_block1_1_conv (Conv2D)    (None, 8, 8, 512)    524800      conv4_blo
ck6_out[0][0]
__________________________________________________________________________________
_____________________________
conv5_block1_1_bn (BatchNormali (None, 8, 8, 512)    2048        conv5_blo
ck1_1_conv[0][0]
```

```
__________________________________________________________________________________________________
____________________
conv5_block1_1_relu (Activation (None, 8, 8, 512)    0           conv5_blo
ck1_1_bn[0][0]
__________________________________________________________________________________________________
____________________
conv5_block1_2_conv (Conv2D)    (None, 8, 8, 512)    2359808     conv5_blo
ck1_1_relu[0][0]
__________________________________________________________________________________________________
____________________
conv5_block1_2_bn (BatchNormali (None, 8, 8, 512)    2048        conv5_blo
ck1_2_conv[0][0]
__________________________________________________________________________________________________
____________________
conv5_block1_2_relu (Activation (None, 8, 8, 512)    0           conv5_blo
ck1_2_bn[0][0]
__________________________________________________________________________________________________
____________________
conv5_block1_0_conv (Conv2D)    (None, 8, 8, 2048)   2099200     conv4_blo
ck6_out[0][0]
__________________________________________________________________________________________________
____________________
conv5_block1_3_conv (Conv2D)    (None, 8, 8, 2048)   1050624     conv5_blo
ck1_2_relu[0][0]
__________________________________________________________________________________________________
____________________
conv5_block1_0_bn (BatchNormali (None, 8, 8, 2048)   8192        conv5_blo
ck1_0_conv[0][0]
__________________________________________________________________________________________________
____________________
conv5_block1_3_bn (BatchNormali (None, 8, 8, 2048)   8192        conv5_blo
ck1_3_conv[0][0]
__________________________________________________________________________________________________
____________________
conv5_block1_add (Add)          (None, 8, 8, 2048)   0           conv5_blo
ck1_0_bn[0][0]
                                                                 conv5_blo
ck1_3_bn[0][0]
__________________________________________________________________________________________________
____________________
conv5_block1_out (Activation)   (None, 8, 8, 2048)   0           conv5_blo
ck1_add[0][0]
__________________________________________________________________________________________________
____________________
conv5_block2_1_conv (Conv2D)    (None, 8, 8, 512)    1049088     conv5_blo
ck1_out[0][0]
__________________________________________________________________________________________________
____________________
conv5_block2_1_bn (BatchNormali (None, 8, 8, 512)    2048        conv5_blo
ck2_1_conv[0][0]
__________________________________________________________________________________________________
____________________
conv5_block2_1_relu (Activation (None, 8, 8, 512)    0           conv5_blo
ck2_1_bn[0][0]
__________________________________________________________________________________________________
____________________
conv5_block2_2_conv (Conv2D)    (None, 8, 8, 512)    2359808     conv5_blo
ck2_1_relu[0][0]
__________________________________________________________________________________________________
____________________
conv5_block2_2_bn (BatchNormali (None, 8, 8, 512)    2048        conv5_blo
```

```
ck2_2_conv[0][0]
__________________________________________________________________________________
_________________________
conv5_block2_2_relu (Activation (None, 8, 8, 512)    0           conv5_blo
ck2_2_bn[0][0]
__________________________________________________________________________________
_________________________
conv5_block2_3_conv (Conv2D)    (None, 8, 8, 2048)   1050624     conv5_blo
ck2_2_relu[0][0]
__________________________________________________________________________________
_________________________
conv5_block2_3_bn (BatchNormali (None, 8, 8, 2048)   8192        conv5_blo
ck2_3_conv[0][0]
__________________________________________________________________________________
_________________________
conv5_block2_add (Add)          (None, 8, 8, 2048)   0           conv5_blo
ck1_out[0][0]
                                                                 conv5_blo
ck2_3_bn[0][0]
__________________________________________________________________________________
_________________________
conv5_block2_out (Activation)   (None, 8, 8, 2048)   0           conv5_blo
ck2_add[0][0]
__________________________________________________________________________________
_________________________
conv5_block3_1_conv (Conv2D)    (None, 8, 8, 512)    1049088     conv5_blo
ck2_out[0][0]
__________________________________________________________________________________
_________________________
conv5_block3_1_bn (BatchNormali (None, 8, 8, 512)    2048        conv5_blo
ck3_1_conv[0][0]
__________________________________________________________________________________
_________________________
conv5_block3_1_relu (Activation (None, 8, 8, 512)    0           conv5_blo
ck3_1_bn[0][0]
__________________________________________________________________________________
_________________________
conv5_block3_2_conv (Conv2D)    (None, 8, 8, 512)    2359808     conv5_blo
ck3_1_relu[0][0]
__________________________________________________________________________________
_________________________
conv5_block3_2_bn (BatchNormali (None, 8, 8, 512)    2048        conv5_blo
ck3_2_conv[0][0]
__________________________________________________________________________________
_________________________
conv5_block3_2_relu (Activation (None, 8, 8, 512)    0           conv5_blo
ck3_2_bn[0][0]
__________________________________________________________________________________
_________________________
conv5_block3_3_conv (Conv2D)    (None, 8, 8, 2048)   1050624     conv5_blo
ck3_2_relu[0][0]
__________________________________________________________________________________
_________________________
conv5_block3_3_bn (BatchNormali (None, 8, 8, 2048)   8192        conv5_blo
ck3_3_conv[0][0]
__________________________________________________________________________________
_________________________
conv5_block3_add (Add)          (None, 8, 8, 2048)   0           conv5_blo
ck2_out[0][0]
                                                                 conv5_blo
ck3_3_bn[0][0]
```

```
__________________________________________________________________________________
_____________________
conv5_block3_out (Activation)   (None, 8, 8, 2048)   0           conv5_blo
ck3_add[0][0]
==================================================================================
========================
Total params: 23,587,712
Trainable params: 53,120
Non-trainable params: 23,534,592
__________________________________________________________________________________
_____________________
```

In [32]:

```
# #Adding custom Layers

# x = base_model.output
# x = Flatten()(x)
# x = Dense(256, activation="relu")(x)
# x = Dropout(0.3)(x)
# x = Dense(124, activation="relu")(x)
# out = Dense(2, activation="softmax")(x)
```

In [33]:

```
#Fastai Like Converging last few layers

avg = tf.keras.layers.GlobalAveragePooling2D()(base_model.output)
mx = tf.keras.layers.GlobalMaxPooling2D()(base_model.output)
out = tf.keras.layers.Concatenate()([avg, mx])
out = tf.keras.layers.BatchNormalization()(out)
out = tf.keras.layers.Dropout(0)(out)
out = tf.keras.layers.Dense(512, activation="relu")(out)
out = tf.keras.layers.BatchNormalization()(out)
out = tf.keras.layers.Dropout(0)(out)
out = tf.keras.layers.Dense(2, activation="softmax")(out)
```

In [34]:

```
# creating the final model by combining pretrained model and custom layers.
model_final = Model(inputs = base_model.input, outputs = out)
```

Define optimizer, Loss and Early Stopping

In [35]:

```
# compile the model
# optimizer = tf.keras.optimizers.Adam(lr=0.003)
optimizer = tf.keras.optimizers.Adam()
model_final.compile(loss = "sparse_categorical_crossentropy", optimizer = optimizer, me
trics=["accuracy"])
```

In [36]:

```
model_final.summary()
```

```
Model: "model"
__________________________________________________________________________________________________
Layer (type)                    Output Shape         Param #     Connected to
==================================================================================================
input_1 (InputLayer)            [(None, 227, 227, 3) 0
__________________________________________________________________________________________________
conv1_pad (ZeroPadding2D)       (None, 233, 233, 3)  0           input_1[0][0]
__________________________________________________________________________________________________
conv1_conv (Conv2D)             (None, 114, 114, 64) 9472        conv1_pad[0][0]
__________________________________________________________________________________________________
conv1_bn (BatchNormalization)   (None, 114, 114, 64) 256         conv1_conv[0][0]
__________________________________________________________________________________________________
conv1_relu (Activation)         (None, 114, 114, 64) 0           conv1_bn[0][0]
__________________________________________________________________________________________________
pool1_pad (ZeroPadding2D)       (None, 116, 116, 64) 0           conv1_relu[0][0]
__________________________________________________________________________________________________
pool1_pool (MaxPooling2D)       (None, 57, 57, 64)   0           pool1_pad[0][0]
__________________________________________________________________________________________________
conv2_block1_1_conv (Conv2D)    (None, 57, 57, 64)   4160        pool1_pool[0][0]
__________________________________________________________________________________________________
conv2_block1_1_bn (BatchNormali (None, 57, 57, 64)   256         conv2_block1_1_conv[0][0]
__________________________________________________________________________________________________
conv2_block1_1_relu (Activation (None, 57, 57, 64)   0           conv2_block1_1_bn[0][0]
__________________________________________________________________________________________________
conv2_block1_2_conv (Conv2D)    (None, 57, 57, 64)   36928       conv2_block1_1_relu[0][0]
__________________________________________________________________________________________________
conv2_block1_2_bn (BatchNormali (None, 57, 57, 64)   256         conv2_block1_2_conv[0][0]
__________________________________________________________________________________________________
conv2_block1_2_relu (Activation (None, 57, 57, 64)   0           conv2_block1_2_bn[0][0]
__________________________________________________________________________________________________
conv2_block1_0_conv (Conv2D)    (None, 57, 57, 256)  16640       pool1_pool[0][0]
__________________________________________________________________________________________________
```

```
__________________________
conv2_block1_3_conv (Conv2D)    (None, 57, 57, 256)  16640       conv2_blo
ck1_2_relu[0][0]
__________________________________________________________________________
__________________________
conv2_block1_0_bn (BatchNormali (None, 57, 57, 256)  1024        conv2_blo
ck1_0_conv[0][0]
__________________________________________________________________________
__________________________
conv2_block1_3_bn (BatchNormali (None, 57, 57, 256)  1024        conv2_blo
ck1_3_conv[0][0]
__________________________________________________________________________
__________________________
conv2_block1_add (Add)          (None, 57, 57, 256)  0           conv2_blo
ck1_0_bn[0][0]
                                                                 conv2_blo
ck1_3_bn[0][0]
__________________________________________________________________________
__________________________
conv2_block1_out (Activation)   (None, 57, 57, 256)  0           conv2_blo
ck1_add[0][0]
__________________________________________________________________________
__________________________
conv2_block2_1_conv (Conv2D)    (None, 57, 57, 64)   16448       conv2_blo
ck1_out[0][0]
__________________________________________________________________________
__________________________
conv2_block2_1_bn (BatchNormali (None, 57, 57, 64)   256         conv2_blo
ck2_1_conv[0][0]
__________________________________________________________________________
__________________________
conv2_block2_1_relu (Activation (None, 57, 57, 64)   0           conv2_blo
ck2_1_bn[0][0]
__________________________________________________________________________
__________________________
conv2_block2_2_conv (Conv2D)    (None, 57, 57, 64)   36928       conv2_blo
ck2_1_relu[0][0]
__________________________________________________________________________
__________________________
conv2_block2_2_bn (BatchNormali (None, 57, 57, 64)   256         conv2_blo
ck2_2_conv[0][0]
__________________________________________________________________________
__________________________
conv2_block2_2_relu (Activation (None, 57, 57, 64)   0           conv2_blo
ck2_2_bn[0][0]
__________________________________________________________________________
__________________________
conv2_block2_3_conv (Conv2D)    (None, 57, 57, 256)  16640       conv2_blo
ck2_2_relu[0][0]
__________________________________________________________________________
__________________________
conv2_block2_3_bn (BatchNormali (None, 57, 57, 256)  1024        conv2_blo
ck2_3_conv[0][0]
__________________________________________________________________________
__________________________
conv2_block2_add (Add)          (None, 57, 57, 256)  0           conv2_blo
ck1_out[0][0]
                                                                 conv2_blo
ck2_3_bn[0][0]
__________________________________________________________________________
__________________________
```

```
conv2_block2_out (Activation)   (None, 57, 57, 256)  0           conv2_blo
ck2_add[0][0]
__________________________________________________________________________
_____________________
conv2_block3_1_conv (Conv2D)    (None, 57, 57, 64)   16448       conv2_blo
ck2_out[0][0]
__________________________________________________________________________
_____________________
conv2_block3_1_bn (BatchNormali (None, 57, 57, 64)   256         conv2_blo
ck3_1_conv[0][0]
__________________________________________________________________________
_____________________
conv2_block3_1_relu (Activation (None, 57, 57, 64)   0           conv2_blo
ck3_1_bn[0][0]
__________________________________________________________________________
_____________________
conv2_block3_2_conv (Conv2D)    (None, 57, 57, 64)   36928       conv2_blo
ck3_1_relu[0][0]
__________________________________________________________________________
_____________________
conv2_block3_2_bn (BatchNormali (None, 57, 57, 64)   256         conv2_blo
ck3_2_conv[0][0]
__________________________________________________________________________
_____________________
conv2_block3_2_relu (Activation (None, 57, 57, 64)   0           conv2_blo
ck3_2_bn[0][0]
__________________________________________________________________________
_____________________
conv2_block3_3_conv (Conv2D)    (None, 57, 57, 256)  16640       conv2_blo
ck3_2_relu[0][0]
__________________________________________________________________________
_____________________
conv2_block3_3_bn (BatchNormali (None, 57, 57, 256)  1024        conv2_blo
ck3_3_conv[0][0]
__________________________________________________________________________
_____________________
conv2_block3_add (Add)          (None, 57, 57, 256)  0           conv2_blo
ck2_out[0][0]
                                                                 conv2_blo
ck3_3_bn[0][0]
__________________________________________________________________________
_____________________
conv2_block3_out (Activation)   (None, 57, 57, 256)  0           conv2_blo
ck3_add[0][0]
__________________________________________________________________________
_____________________
conv3_block1_1_conv (Conv2D)    (None, 29, 29, 128)  32896       conv2_blo
ck3_out[0][0]
__________________________________________________________________________
_____________________
conv3_block1_1_bn (BatchNormali (None, 29, 29, 128)  512         conv3_blo
ck1_1_conv[0][0]
__________________________________________________________________________
_____________________
conv3_block1_1_relu (Activation (None, 29, 29, 128)  0           conv3_blo
ck1_1_bn[0][0]
__________________________________________________________________________
_____________________
conv3_block1_2_conv (Conv2D)    (None, 29, 29, 128)  147584      conv3_blo
ck1_1_relu[0][0]
__________________________________________________________________________
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__________________________
conv3_block1_2_bn (BatchNormali (None, 29, 29, 128)  512         conv3_blo
ck1_2_conv[0][0]
__________________________________________________________________________
__________________________
conv3_block1_2_relu (Activation (None, 29, 29, 128)  0           conv3_blo
ck1_2_bn[0][0]
__________________________________________________________________________
__________________________
conv3_block1_0_conv (Conv2D)    (None, 29, 29, 512)  131584      conv2_blo
ck3_out[0][0]
__________________________________________________________________________
__________________________
conv3_block1_3_conv (Conv2D)    (None, 29, 29, 512)  66048       conv3_blo
ck1_2_relu[0][0]
__________________________________________________________________________
__________________________
conv3_block1_0_bn (BatchNormali (None, 29, 29, 512)  2048        conv3_blo
ck1_0_conv[0][0]
__________________________________________________________________________
__________________________
conv3_block1_3_bn (BatchNormali (None, 29, 29, 512)  2048        conv3_blo
ck1_3_conv[0][0]
__________________________________________________________________________
__________________________
conv3_block1_add (Add)          (None, 29, 29, 512)  0           conv3_blo
ck1_0_bn[0][0]
                                                                 conv3_blo
ck1_3_bn[0][0]
__________________________________________________________________________
__________________________
conv3_block1_out (Activation)   (None, 29, 29, 512)  0           conv3_blo
ck1_add[0][0]
__________________________________________________________________________
__________________________
conv3_block2_1_conv (Conv2D)    (None, 29, 29, 128)  65664       conv3_blo
ck1_out[0][0]
__________________________________________________________________________
__________________________
conv3_block2_1_bn (BatchNormali (None, 29, 29, 128)  512         conv3_blo
ck2_1_conv[0][0]
__________________________________________________________________________
__________________________
conv3_block2_1_relu (Activation (None, 29, 29, 128)  0           conv3_blo
ck2_1_bn[0][0]
__________________________________________________________________________
__________________________
conv3_block2_2_conv (Conv2D)    (None, 29, 29, 128)  147584      conv3_blo
ck2_1_relu[0][0]
__________________________________________________________________________
__________________________
conv3_block2_2_bn (BatchNormali (None, 29, 29, 128)  512         conv3_blo
ck2_2_conv[0][0]
__________________________________________________________________________
__________________________
conv3_block2_2_relu (Activation (None, 29, 29, 128)  0           conv3_blo
ck2_2_bn[0][0]
__________________________________________________________________________
__________________________
conv3_block2_3_conv (Conv2D)    (None, 29, 29, 512)  66048       conv3_blo
ck2_2_relu[0][0]
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__________________________________________________________________________________________________
____________________________
conv3_block2_3_bn (BatchNormali (None, 29, 29, 512)  2048        conv3_blo
ck2_3_conv[0][0]
__________________________________________________________________________________________________
____________________________
conv3_block2_add (Add)          (None, 29, 29, 512)  0           conv3_blo
ck1_out[0][0]
                                                                 conv3_blo
ck2_3_bn[0][0]
__________________________________________________________________________________________________
____________________________
conv3_block2_out (Activation)   (None, 29, 29, 512)  0           conv3_blo
ck2_add[0][0]
__________________________________________________________________________________________________
____________________________
conv3_block3_1_conv (Conv2D)    (None, 29, 29, 128)  65664       conv3_blo
ck2_out[0][0]
__________________________________________________________________________________________________
____________________________
conv3_block3_1_bn (BatchNormali (None, 29, 29, 128)  512         conv3_blo
ck3_1_conv[0][0]
__________________________________________________________________________________________________
____________________________
conv3_block3_1_relu (Activation (None, 29, 29, 128)  0           conv3_blo
ck3_1_bn[0][0]
__________________________________________________________________________________________________
____________________________
conv3_block3_2_conv (Conv2D)    (None, 29, 29, 128)  147584      conv3_blo
ck3_1_relu[0][0]
__________________________________________________________________________________________________
____________________________
conv3_block3_2_bn (BatchNormali (None, 29, 29, 128)  512         conv3_blo
ck3_2_conv[0][0]
__________________________________________________________________________________________________
____________________________
conv3_block3_2_relu (Activation (None, 29, 29, 128)  0           conv3_blo
ck3_2_bn[0][0]
__________________________________________________________________________________________________
____________________________
conv3_block3_3_conv (Conv2D)    (None, 29, 29, 512)  66048       conv3_blo
ck3_2_relu[0][0]
__________________________________________________________________________________________________
____________________________
conv3_block3_3_bn (BatchNormali (None, 29, 29, 512)  2048        conv3_blo
ck3_3_conv[0][0]
__________________________________________________________________________________________________
____________________________
conv3_block3_add (Add)          (None, 29, 29, 512)  0           conv3_blo
ck2_out[0][0]
                                                                 conv3_blo
ck3_3_bn[0][0]
__________________________________________________________________________________________________
____________________________
conv3_block3_out (Activation)   (None, 29, 29, 512)  0           conv3_blo
ck3_add[0][0]
__________________________________________________________________________________________________
____________________________
conv3_block4_1_conv (Conv2D)    (None, 29, 29, 128)  65664       conv3_blo
ck3_out[0][0]
__________________________________________________________________________________________________
```

```
__________________________
conv3_block4_1_bn (BatchNormali (None, 29, 29, 128)  512         conv3_blo
ck4_1_conv[0][0]
__________________________________________________________________________
__________________________
conv3_block4_1_relu (Activation (None, 29, 29, 128)  0           conv3_blo
ck4_1_bn[0][0]
__________________________________________________________________________
__________________________
conv3_block4_2_conv (Conv2D)    (None, 29, 29, 128)  147584      conv3_blo
ck4_1_relu[0][0]
__________________________________________________________________________
__________________________
conv3_block4_2_bn (BatchNormali (None, 29, 29, 128)  512         conv3_blo
ck4_2_conv[0][0]
__________________________________________________________________________
__________________________
conv3_block4_2_relu (Activation (None, 29, 29, 128)  0           conv3_blo
ck4_2_bn[0][0]
__________________________________________________________________________
__________________________
conv3_block4_3_conv (Conv2D)    (None, 29, 29, 512)  66048       conv3_blo
ck4_2_relu[0][0]
__________________________________________________________________________
__________________________
conv3_block4_3_bn (BatchNormali (None, 29, 29, 512)  2048        conv3_blo
ck4_3_conv[0][0]
__________________________________________________________________________
__________________________
conv3_block4_add (Add)          (None, 29, 29, 512)  0           conv3_blo
ck3_out[0][0]
                                                                 conv3_blo

ck4_3_bn[0][0]
__________________________________________________________________________
__________________________
conv3_block4_out (Activation)   (None, 29, 29, 512)  0           conv3_blo
ck4_add[0][0]
__________________________________________________________________________
__________________________
conv4_block1_1_conv (Conv2D)    (None, 15, 15, 256)  131328      conv3_blo
ck4_out[0][0]
__________________________________________________________________________
__________________________
conv4_block1_1_bn (BatchNormali (None, 15, 15, 256)  1024        conv4_blo
ck1_1_conv[0][0]
__________________________________________________________________________
__________________________
conv4_block1_1_relu (Activation (None, 15, 15, 256)  0           conv4_blo
ck1_1_bn[0][0]
__________________________________________________________________________
__________________________
conv4_block1_2_conv (Conv2D)    (None, 15, 15, 256)  590080      conv4_blo
ck1_1_relu[0][0]
__________________________________________________________________________
__________________________
conv4_block1_2_bn (BatchNormali (None, 15, 15, 256)  1024        conv4_blo
ck1_2_conv[0][0]
__________________________________________________________________________
__________________________
conv4_block1_2_relu (Activation (None, 15, 15, 256)  0           conv4_blo
ck1_2_bn[0][0]
```

```
__________________________________________________________________________________________________
__________________________
conv4_block1_0_conv (Conv2D)    (None, 15, 15, 1024) 525312      conv3_blo
ck4_out[0][0]
__________________________________________________________________________________________________
__________________________
conv4_block1_3_conv (Conv2D)    (None, 15, 15, 1024) 263168      conv4_blo
ck1_2_relu[0][0]
__________________________________________________________________________________________________
__________________________
conv4_block1_0_bn (BatchNormali (None, 15, 15, 1024) 4096        conv4_blo
ck1_0_conv[0][0]
__________________________________________________________________________________________________
__________________________
conv4_block1_3_bn (BatchNormali (None, 15, 15, 1024) 4096        conv4_blo
ck1_3_conv[0][0]
__________________________________________________________________________________________________
__________________________
conv4_block1_add (Add)          (None, 15, 15, 1024) 0           conv4_blo
ck1_0_bn[0][0]
                                                                 conv4_blo
ck1_3_bn[0][0]
__________________________________________________________________________________________________
__________________________
conv4_block1_out (Activation)   (None, 15, 15, 1024) 0           conv4_blo
ck1_add[0][0]
__________________________________________________________________________________________________
__________________________
conv4_block2_1_conv (Conv2D)    (None, 15, 15, 256)  262400      conv4_blo
ck1_out[0][0]
__________________________________________________________________________________________________
__________________________
conv4_block2_1_bn (BatchNormali (None, 15, 15, 256)  1024        conv4_blo
ck2_1_conv[0][0]
__________________________________________________________________________________________________
__________________________
conv4_block2_1_relu (Activation (None, 15, 15, 256)  0           conv4_blo
ck2_1_bn[0][0]
__________________________________________________________________________________________________
__________________________
conv4_block2_2_conv (Conv2D)    (None, 15, 15, 256)  590080      conv4_blo
ck2_1_relu[0][0]
__________________________________________________________________________________________________
__________________________
conv4_block2_2_bn (BatchNormali (None, 15, 15, 256)  1024        conv4_blo
ck2_2_conv[0][0]
__________________________________________________________________________________________________
__________________________
conv4_block2_2_relu (Activation (None, 15, 15, 256)  0           conv4_blo
ck2_2_bn[0][0]
__________________________________________________________________________________________________
__________________________
conv4_block2_3_conv (Conv2D)    (None, 15, 15, 1024) 263168      conv4_blo
ck2_2_relu[0][0]
__________________________________________________________________________________________________
__________________________
conv4_block2_3_bn (BatchNormali (None, 15, 15, 1024) 4096        conv4_blo
ck2_3_conv[0][0]
__________________________________________________________________________________________________
__________________________
conv4_block2_add (Add)          (None, 15, 15, 1024) 0           conv4_blo
```

```
ck1_out[0][0]
                                                                 conv4_blo
ck2_3_bn[0][0]
__________________________________________________________________________
_____________________
conv4_block2_out (Activation)   (None, 15, 15, 1024) 0           conv4_blo
ck2_add[0][0]
__________________________________________________________________________
_____________________
conv4_block3_1_conv (Conv2D)    (None, 15, 15, 256)  262400      conv4_blo
ck2_out[0][0]
__________________________________________________________________________
_____________________
conv4_block3_1_bn (BatchNormali (None, 15, 15, 256)  1024        conv4_blo
ck3_1_conv[0][0]
__________________________________________________________________________
_____________________
conv4_block3_1_relu (Activation (None, 15, 15, 256)  0           conv4_blo
ck3_1_bn[0][0]
__________________________________________________________________________
_____________________
conv4_block3_2_conv (Conv2D)    (None, 15, 15, 256)  590080      conv4_blo
ck3_1_relu[0][0]
__________________________________________________________________________
_____________________
conv4_block3_2_bn (BatchNormali (None, 15, 15, 256)  1024        conv4_blo
ck3_2_conv[0][0]
__________________________________________________________________________
_____________________
conv4_block3_2_relu (Activation (None, 15, 15, 256)  0           conv4_blo
ck3_2_bn[0][0]
__________________________________________________________________________
_____________________
conv4_block3_3_conv (Conv2D)    (None, 15, 15, 1024) 263168      conv4_blo
ck3_2_relu[0][0]
__________________________________________________________________________
_____________________
conv4_block3_3_bn (BatchNormali (None, 15, 15, 1024) 4096        conv4_blo
ck3_3_conv[0][0]
__________________________________________________________________________
_____________________
conv4_block3_add (Add)          (None, 15, 15, 1024) 0           conv4_blo
ck2_out[0][0]
                                                                 conv4_blo
ck3_3_bn[0][0]
__________________________________________________________________________
_____________________
conv4_block3_out (Activation)   (None, 15, 15, 1024) 0           conv4_blo
ck3_add[0][0]
__________________________________________________________________________
_____________________
conv4_block4_1_conv (Conv2D)    (None, 15, 15, 256)  262400      conv4_blo
ck3_out[0][0]
__________________________________________________________________________
_____________________
conv4_block4_1_bn (BatchNormali (None, 15, 15, 256)  1024        conv4_blo
ck4_1_conv[0][0]
__________________________________________________________________________
_____________________
conv4_block4_1_relu (Activation (None, 15, 15, 256)  0           conv4_blo
ck4_1_bn[0][0]
```

```
__________________________________________________________________________________________________
____________________
conv4_block4_2_conv (Conv2D)    (None, 15, 15, 256)  590080      conv4_blo
ck4_1_relu[0][0]
__________________________________________________________________________________________________
____________________
conv4_block4_2_bn (BatchNormali (None, 15, 15, 256)  1024        conv4_blo
ck4_2_conv[0][0]
__________________________________________________________________________________________________
____________________
conv4_block4_2_relu (Activation (None, 15, 15, 256)  0           conv4_blo
ck4_2_bn[0][0]
__________________________________________________________________________________________________
____________________
conv4_block4_3_conv (Conv2D)    (None, 15, 15, 1024) 263168      conv4_blo
ck4_2_relu[0][0]
__________________________________________________________________________________________________
____________________
conv4_block4_3_bn (BatchNormali (None, 15, 15, 1024) 4096        conv4_blo
ck4_3_conv[0][0]
__________________________________________________________________________________________________
____________________
conv4_block4_add (Add)          (None, 15, 15, 1024) 0           conv4_blo
ck3_out[0][0]
                                                                 conv4_blo
ck4_3_bn[0][0]
__________________________________________________________________________________________________
____________________
conv4_block4_out (Activation)   (None, 15, 15, 1024) 0           conv4_blo
ck4_add[0][0]
__________________________________________________________________________________________________
____________________
conv4_block5_1_conv (Conv2D)    (None, 15, 15, 256)  262400      conv4_blo
ck4_out[0][0]
__________________________________________________________________________________________________
____________________
conv4_block5_1_bn (BatchNormali (None, 15, 15, 256)  1024        conv4_blo
ck5_1_conv[0][0]
__________________________________________________________________________________________________
____________________
conv4_block5_1_relu (Activation (None, 15, 15, 256)  0           conv4_blo
ck5_1_bn[0][0]
__________________________________________________________________________________________________
____________________
conv4_block5_2_conv (Conv2D)    (None, 15, 15, 256)  590080      conv4_blo
ck5_1_relu[0][0]
__________________________________________________________________________________________________
____________________
conv4_block5_2_bn (BatchNormali (None, 15, 15, 256)  1024        conv4_blo
ck5_2_conv[0][0]
__________________________________________________________________________________________________
____________________
conv4_block5_2_relu (Activation (None, 15, 15, 256)  0           conv4_blo
ck5_2_bn[0][0]
__________________________________________________________________________________________________
____________________
conv4_block5_3_conv (Conv2D)    (None, 15, 15, 1024) 263168      conv4_blo
ck5_2_relu[0][0]
__________________________________________________________________________________________________
____________________
conv4_block5_3_bn (BatchNormali (None, 15, 15, 1024) 4096        conv4_blo
```

```
ck5_3_conv[0][0]
__________________________________________________________________________________
_____________________________
conv4_block5_add (Add)          (None, 15, 15, 1024) 0           conv4_blo
ck4_out[0][0]
                                                                 conv4_blo
ck5_3_bn[0][0]
__________________________________________________________________________________
_____________________________
conv4_block5_out (Activation)   (None, 15, 15, 1024) 0           conv4_blo
ck5_add[0][0]
__________________________________________________________________________________
_____________________________
conv4_block6_1_conv (Conv2D)    (None, 15, 15, 256)  262400      conv4_blo
ck5_out[0][0]
__________________________________________________________________________________
_____________________________
conv4_block6_1_bn (BatchNormali (None, 15, 15, 256)  1024        conv4_blo
ck6_1_conv[0][0]
__________________________________________________________________________________
_____________________________
conv4_block6_1_relu (Activation (None, 15, 15, 256)  0           conv4_blo
ck6_1_bn[0][0]
__________________________________________________________________________________
_____________________________
conv4_block6_2_conv (Conv2D)    (None, 15, 15, 256)  590080      conv4_blo
ck6_1_relu[0][0]
__________________________________________________________________________________
_____________________________
conv4_block6_2_bn (BatchNormali (None, 15, 15, 256)  1024        conv4_blo
ck6_2_conv[0][0]
__________________________________________________________________________________
_____________________________
conv4_block6_2_relu (Activation (None, 15, 15, 256)  0           conv4_blo
ck6_2_bn[0][0]
__________________________________________________________________________________
_____________________________
conv4_block6_3_conv (Conv2D)    (None, 15, 15, 1024) 263168      conv4_blo
ck6_2_relu[0][0]
__________________________________________________________________________________
_____________________________
conv4_block6_3_bn (BatchNormali (None, 15, 15, 1024) 4096        conv4_blo
ck6_3_conv[0][0]
__________________________________________________________________________________
_____________________________
conv4_block6_add (Add)          (None, 15, 15, 1024) 0           conv4_blo
ck5_out[0][0]
                                                                 conv4_blo
ck6_3_bn[0][0]
__________________________________________________________________________________
_____________________________
conv4_block6_out (Activation)   (None, 15, 15, 1024) 0           conv4_blo
ck6_add[0][0]
__________________________________________________________________________________
_____________________________
conv5_block1_1_conv (Conv2D)    (None, 8, 8, 512)    524800      conv4_blo
ck6_out[0][0]
__________________________________________________________________________________
_____________________________
conv5_block1_1_bn (BatchNormali (None, 8, 8, 512)    2048        conv5_blo
ck1_1_conv[0][0]
```

```
__________________________________________________________________________________________________
____________________
conv5_block1_1_relu (Activation (None, 8, 8, 512)    0           conv5_blo
ck1_1_bn[0][0]
__________________________________________________________________________________________________
____________________
conv5_block1_2_conv (Conv2D)    (None, 8, 8, 512)    2359808     conv5_blo
ck1_1_relu[0][0]
__________________________________________________________________________________________________
____________________
conv5_block1_2_bn (BatchNormali (None, 8, 8, 512)    2048        conv5_blo
ck1_2_conv[0][0]
__________________________________________________________________________________________________
____________________
conv5_block1_2_relu (Activation (None, 8, 8, 512)    0           conv5_blo
ck1_2_bn[0][0]
__________________________________________________________________________________________________
____________________
conv5_block1_0_conv (Conv2D)    (None, 8, 8, 2048)   2099200     conv4_blo
ck6_out[0][0]
__________________________________________________________________________________________________
____________________
conv5_block1_3_conv (Conv2D)    (None, 8, 8, 2048)   1050624     conv5_blo
ck1_2_relu[0][0]
__________________________________________________________________________________________________
____________________
conv5_block1_0_bn (BatchNormali (None, 8, 8, 2048)   8192        conv5_blo
ck1_0_conv[0][0]
__________________________________________________________________________________________________
____________________
conv5_block1_3_bn (BatchNormali (None, 8, 8, 2048)   8192        conv5_blo
ck1_3_conv[0][0]
__________________________________________________________________________________________________
____________________
conv5_block1_add (Add)          (None, 8, 8, 2048)   0           conv5_blo
ck1_0_bn[0][0]
                                                                 conv5_blo
ck1_3_bn[0][0]
__________________________________________________________________________________________________
____________________
conv5_block1_out (Activation)   (None, 8, 8, 2048)   0           conv5_blo
ck1_add[0][0]
__________________________________________________________________________________________________
____________________
conv5_block2_1_conv (Conv2D)    (None, 8, 8, 512)    1049088     conv5_blo
ck1_out[0][0]
__________________________________________________________________________________________________
____________________
conv5_block2_1_bn (BatchNormali (None, 8, 8, 512)    2048        conv5_blo
ck2_1_conv[0][0]
__________________________________________________________________________________________________
____________________
conv5_block2_1_relu (Activation (None, 8, 8, 512)    0           conv5_blo
ck2_1_bn[0][0]
__________________________________________________________________________________________________
____________________
conv5_block2_2_conv (Conv2D)    (None, 8, 8, 512)    2359808     conv5_blo
ck2_1_relu[0][0]
__________________________________________________________________________________________________
____________________
conv5_block2_2_bn (BatchNormali (None, 8, 8, 512)    2048        conv5_blo
```

```
ck2_2_conv[0][0]
__________________________________________________________________________________
_________________________
conv5_block2_2_relu (Activation (None, 8, 8, 512)    0           conv5_blo
ck2_2_bn[0][0]
__________________________________________________________________________________
_________________________
conv5_block2_3_conv (Conv2D)    (None, 8, 8, 2048)   1050624     conv5_blo
ck2_2_relu[0][0]
__________________________________________________________________________________
_________________________
conv5_block2_3_bn (BatchNormali (None, 8, 8, 2048)   8192        conv5_blo
ck2_3_conv[0][0]
__________________________________________________________________________________
_________________________
conv5_block2_add (Add)          (None, 8, 8, 2048)   0           conv5_blo
ck1_out[0][0]
                                                                 conv5_blo
ck2_3_bn[0][0]
__________________________________________________________________________________
_________________________
conv5_block2_out (Activation)   (None, 8, 8, 2048)   0           conv5_blo
ck2_add[0][0]
__________________________________________________________________________________
_________________________
conv5_block3_1_conv (Conv2D)    (None, 8, 8, 512)    1049088     conv5_blo
ck2_out[0][0]
__________________________________________________________________________________
_________________________
conv5_block3_1_bn (BatchNormali (None, 8, 8, 512)    2048        conv5_blo
ck3_1_conv[0][0]
__________________________________________________________________________________
_________________________
conv5_block3_1_relu (Activation (None, 8, 8, 512)    0           conv5_blo
ck3_1_bn[0][0]
__________________________________________________________________________________
_________________________
conv5_block3_2_conv (Conv2D)    (None, 8, 8, 512)    2359808     conv5_blo
ck3_1_relu[0][0]
__________________________________________________________________________________
_________________________
conv5_block3_2_bn (BatchNormali (None, 8, 8, 512)    2048        conv5_blo
ck3_2_conv[0][0]
__________________________________________________________________________________
_________________________
conv5_block3_2_relu (Activation (None, 8, 8, 512)    0           conv5_blo
ck3_2_bn[0][0]
__________________________________________________________________________________
_________________________
conv5_block3_3_conv (Conv2D)    (None, 8, 8, 2048)   1050624     conv5_blo
ck3_2_relu[0][0]
__________________________________________________________________________________
_________________________
conv5_block3_3_bn (BatchNormali (None, 8, 8, 2048)   8192        conv5_blo
ck3_3_conv[0][0]
__________________________________________________________________________________
_________________________
conv5_block3_add (Add)          (None, 8, 8, 2048)   0           conv5_blo
ck2_out[0][0]
                                                                 conv5_blo
ck3_3_bn[0][0]
```

```
__________________________________________________________________________________________________
conv5_block3_out (Activation)   (None, 8, 8, 2048)   0           conv5_block3_add[0][0]
__________________________________________________________________________________________________
global_average_pooling2d (Globa (None, 2048)         0           conv5_block3_out[0][0]
__________________________________________________________________________________________________
global_max_pooling2d (GlobalMax (None, 2048)         0           conv5_block3_out[0][0]
__________________________________________________________________________________________________
concatenate (Concatenate)       (None, 4096)         0           global_average_pooling2d[0][0]
                                                                 global_max_pooling2d[0][0]
__________________________________________________________________________________________________
batch_normalization (BatchNorma (None, 4096)         16384       concatenate[0][0]
__________________________________________________________________________________________________
dropout (Dropout)               (None, 4096)         0           batch_normalization[0][0]
__________________________________________________________________________________________________
dense (Dense)                   (None, 512)          2097664     dropout[0][0]
__________________________________________________________________________________________________
batch_normalization_1 (BatchNor (None, 512)          2048        dense[0][0]
__________________________________________________________________________________________________
dropout_1 (Dropout)             (None, 512)          0           batch_normalization_1[0][0]
__________________________________________________________________________________________________
dense_1 (Dense)                 (None, 2)            1026        dropout_1[0][0]
==================================================================================================
Total params: 25,704,834
Trainable params: 2,161,026
Non-trainable params: 23,543,808
__________________________________________________________________________________________________
```

For more info on Early Stopping https://machinelearningmastery.com/how-to-stop-training-deep-neural-networks-at-the-right-time-using-early-stopping/ (https://machinelearningmastery.com/how-to-stop-training-deep-neural-networks-at-the-right-time-using-early-stopping/)

In [37]:

```
# simple early stopping
es = EarlyStopping(monitor='val_acc', mode='max', verbose=1)
```

In [38]:

```
mc = ModelCheckpoint('best_model.h5', monitor='val_accuracy', mode='max', verbose=1, sa
ve_best_only=True)
```

Train Your Model

Our aim is to get higher accuracy and generalize better https://deeplearningdemystified.com/article/fdl-5 (https://deeplearningdemystified.com/article/fdl-5)

In [41]:

```
#Set number of Epochs (Cycles to run)
epochs = 1
```

In [42]:

```
history=model_final.fit_generator(train_generator,steps_per_epoch=train_generator.n //
batch_size,epochs=epochs,
                                  validation_data=validation_generator,
                                  validation_steps=validation_generator.n // batch_size
,
                                  verbose=1
                                  #callbacks=[es, mc]
                                 )
```

```
125/125 [==============================] - 1719s 14s/step - loss: 0.1050 -
acc: 0.9775 - val_loss: 0.0091 - val_acc: 0.9975
```

Tips:

Overfitting if: training loss << validation loss

Underfitting if: training loss >> validation loss

Just right if training loss ~ validation loss

Fine Tunning

In [44]:

```
model_final.trainable = True

# It's important to recompile your model after you make any changes
# to the `trainable` attribute of any inner layer, so that your changes
# are take into account
model_final.compile(optimizer=tf.keras.optimizers.Adam(1e-5),  # Very low learning rate
              loss="sparse_categorical_crossentropy",
              metrics=["accuracy"])
```

Visualize failed prediction from train and valid dataset

In [43]:

```
import matplotlib.pyplot as plt
import matplotlib.image as mpimg
```

In [54]:

```
# View images with failed prediction from validation dataset
interpret = test_datagen.flow_from_directory(validation_data_dir,
                                                shuffle=False,
                                                target_size=(image_size, image_
size),
                                                batch_size = 1,
                                                class_mode='sparse'
                                               )
```

```
Found 400 images belonging to 2 classes.
```

In [54]:

```
# View images with failed prediction from trian dataset
# interpret = test_datagen.flow_from_directory(train_data_dir,
#                                                 shuffle=False,
#                                                 target_size=(image_size, imag
e_size),
#                                                 batch_size = 1,
#                                                 class_mode='sparse'
#                                                )
```

```
Found 1000 images belonging to 2 classes.
```

In [55]:

```
y_pred =model_final.predict_generator(interpret)
y_pred_ind = np.argmax(y_pred, axis=1)
```

In [56]:

```
print(confusion_matrix(interpret.classes, y_pred_ind))
```

```
[[199   1]
 [  0 200]]
```

In [57]:

```
fnames = interpret.filenames
errors = np.where(y_pred_ind != interpret.classes)[0]
for i in errors:
    print(fnames[i])
```

```
No_crack\01161.jpg
```

In [58]:

```
errors
```

Out[58]:

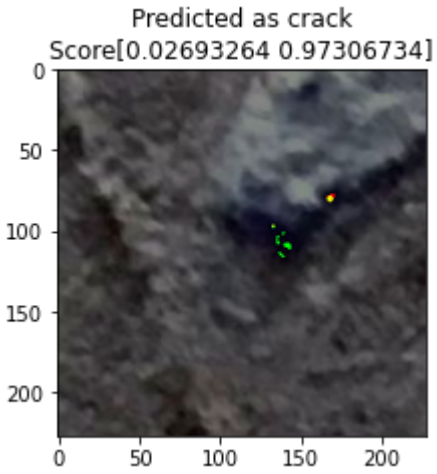
```
array([160], dtype=int64)
```

In [59]:

```
import numpy as np
import matplotlib.pyplot as plt

labels = {0 : 'No_crack', 1 : 'crack'}
rows = 5
cols = 3
axes=[]
fig=plt.figure(figsize=(15, 15))

for a in range(len(errors)):
    # generate batch of images
    x,y = interpret[errors[a]]
    # convert to unsigned integers for viewing
    image = x[0].astype('uint8')
    axes.append( fig.add_subplot(rows, cols, a+1) )
    subplot_title=("Predicted as "+str(labels[y_pred_ind[errors[a]]]+ '\n' + "Score" +
str(y_pred[errors[a]])))
    axes[-1].set_title(subplot_title)
    plt.imshow(image)
fig.tight_layout()
plt.show()
```



In [60]:

```
str(y_pred[errors[a]][y_pred_ind[a]])
```

Out[60]:

```
'0.026932642'
```

In [61]:

```
len(fnames)
```

Out[61]:

```
400
```

Save .H5 File

In [53]:

```
model_final.save('crackclassifier_model.h5')
```

In [ ]:

```

```