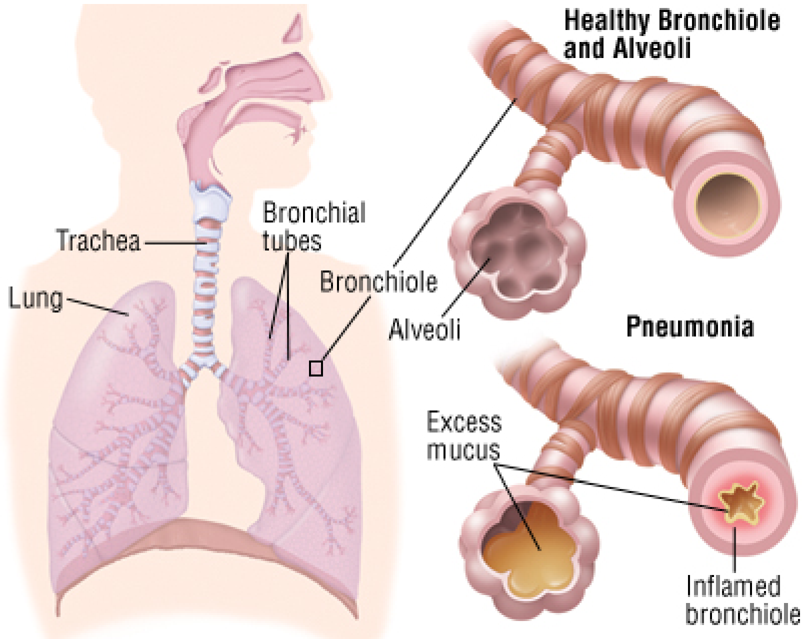
What is Pneumonia ?

From Mayo Clinic's Article on pneumonia

Pneumonia is an infection that inflames the air sacs in one or both lungs. The air sacs may fill with fluid or pus (purulent material), causing cough with phlegm or pus, fever, chills, and difficulty breathing. A variety of organisms, including bacteria, viruses and fungi, can cause pneumonia.

Pneumonia can range in seriousness from mild to life-threatening. It is most serious for infants and young children, people older than age 65, and people with health problems or weakened immune systems.

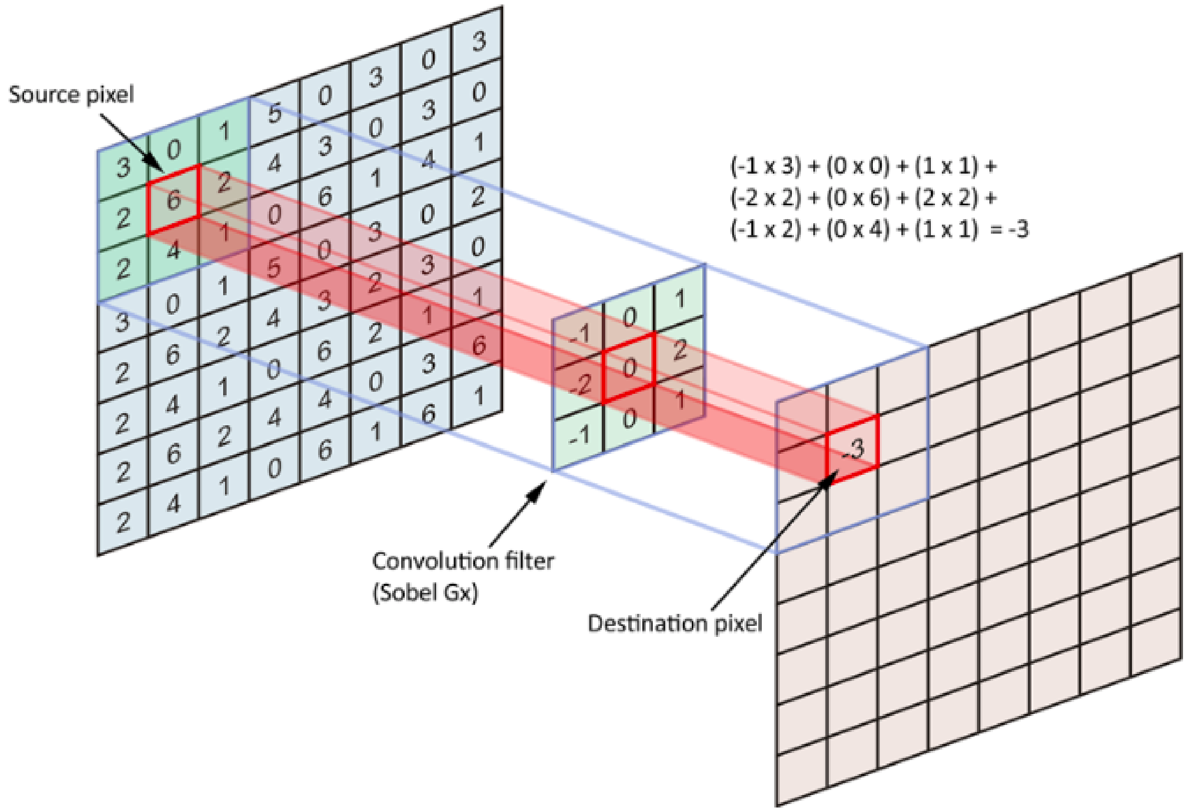


Pneumonia Detection with Convolutional Neural Networks

Computer Vision can be realized using Convolutional neural networks (CNN) They are neural networks making features extraction over an image before classifying it. The feature extraction performed consists of three basic operations:

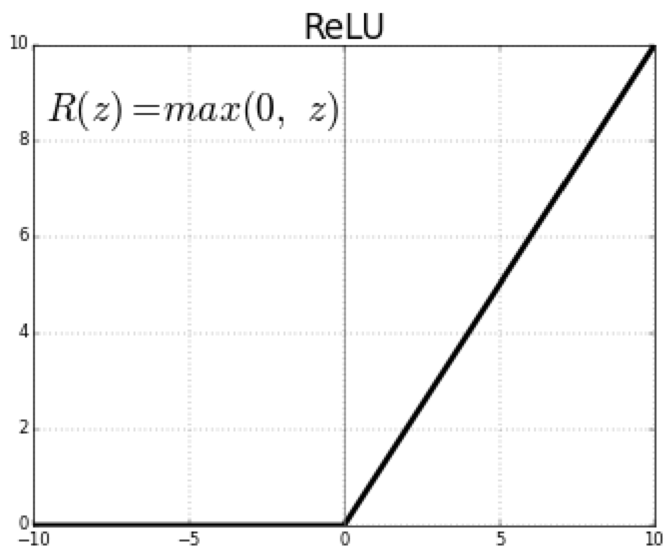
- Filter an image for a particular feature (convolution)
- Detect that feature within the filtered image (using the ReLU activation)
- Condense the image to enhance the features (maximum pooling)

The convolution process is illustrated below

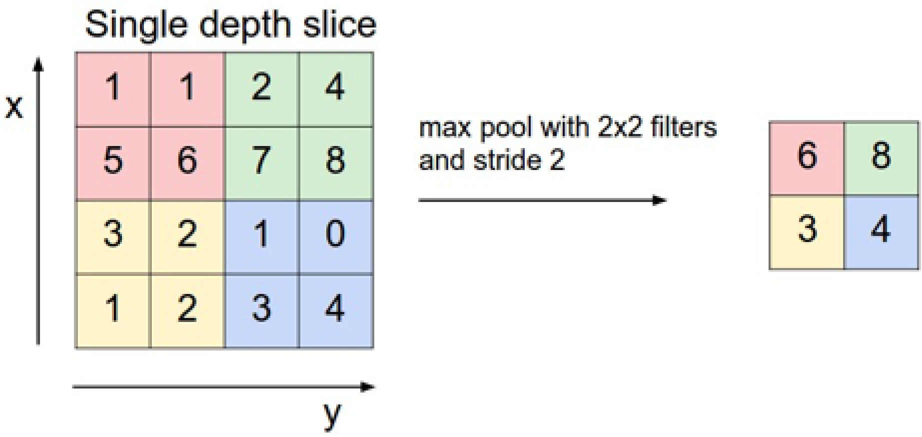


Using convolution filters with different dimensions or values results in differents features extracted

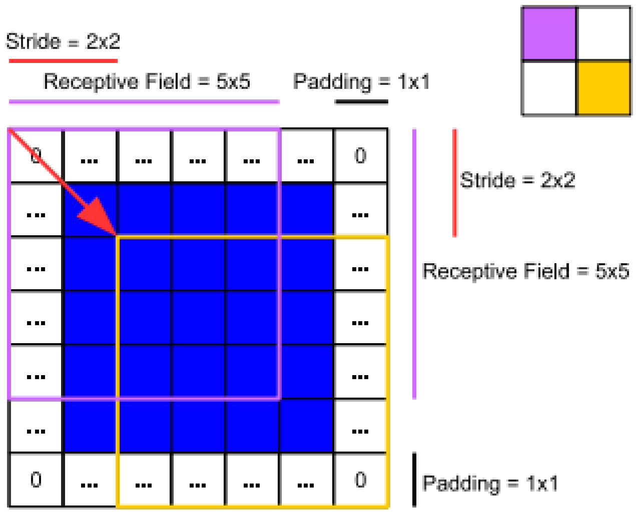
Features are then detected using the reLu activation on each destination pixel.



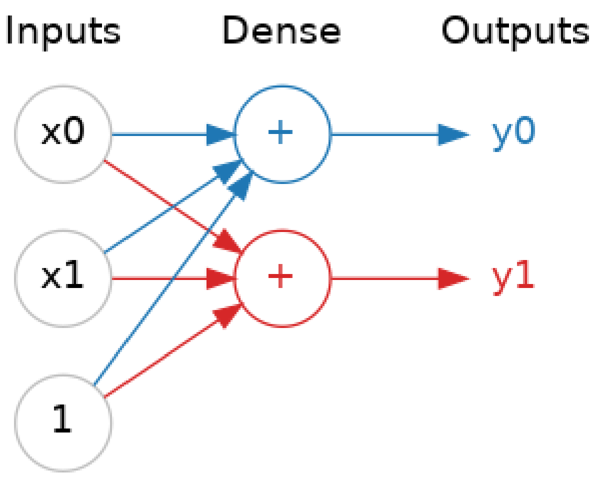
Features are the enhanced with MaxPool layers



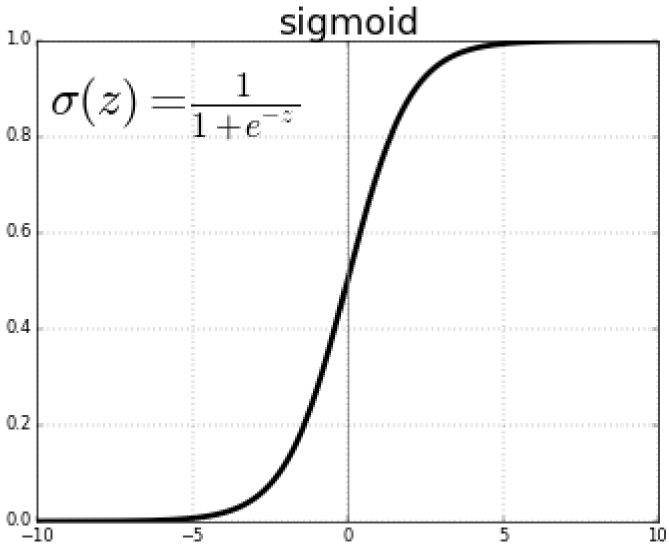
The stride parameters determines the distance between each filters. The padding one determines if we ignore the borderline pixels or not (adding zeros helps the neural network to get information on the border)



The outputs are then concatened in Dense layers



By using a sigmoid activation, the neural network determines which class the image belongs to



Import Packages and Functions

We'll make use of the following packages:

- numpy and pandas is what we'll use to manipulate our data
- matplotlib.pyplot and seaborn will be used to produce plots for visualization
- util will provide the locally defined utility functions that have been provided for this assignment We will also use several modules from the keras framework for building deep learning models.

Run the next cell to import all the necessary packages.

In [1]:
```
import os
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
import tensorflow as tf
from tensorflow import keras

os.listdir("chest_xray")
```

Out[1]:
```
['chest_xray', 'test', 'train', 'val', '__MACOSX']
```

In [2]:
```
len(os.listdir("chest_xray/train/PNEUMONIA"))
```

Out[2]:
```
3875
```

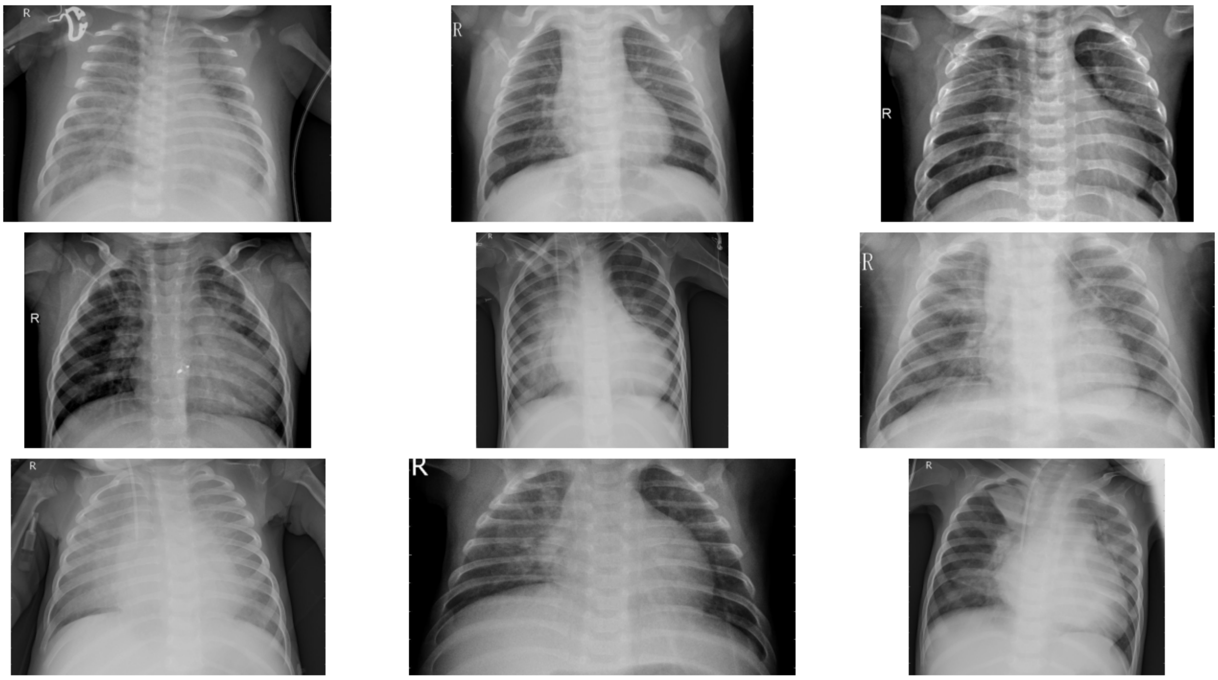
The dataset is divided into three sets: 1) Train set 2) Validation set and 3) Test set.

Data Visualization

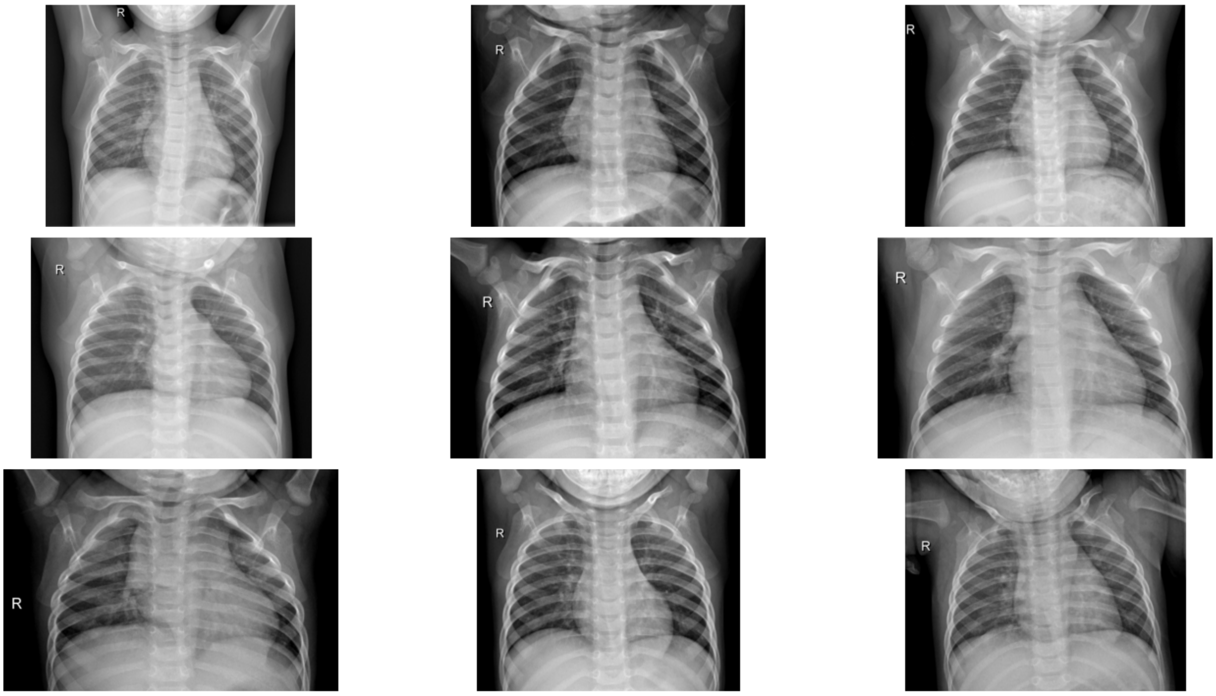
In [3]:
```
train_dir = "chest_xray/train"
test_dir = "chest_xray/test"
```

```
val_dir = "chest_xray/val"

print("Train set:\n========================================")
num_pneumonia = len(os.listdir(os.path.join(train_dir, 'PNEUMONIA')))
num_normal = len(os.listdir(os.path.join(train_dir, 'NORMAL')))
print(f"PNEUMONIA={num_pneumonia}")
print(f"NORMAL={num_normal}")

print("Test set:\n========================================")
print(f"PNEUMONIA={len(os.listdir(os.path.join(test_dir, 'PNEUMONIA')))}")
print(f"NORMAL={len(os.listdir(os.path.join(test_dir, 'NORMAL')))}")

print("Validation set:\n========================================")
print(f"PNEUMONIA={len(os.listdir(os.path.join(val_dir, 'PNEUMONIA')))}")
print(f"NORMAL={len(os.listdir(os.path.join(val_dir, 'NORMAL')))}")

pneumonia = os.listdir("chest_xray/train/PNEUMONIA")
pneumonia_dir = "chest_xray/train/PNEUMONIA"

plt.figure(figsize=(20, 10))

for i in range(9):
    plt.subplot(3, 3, i + 1)
    img = plt.imread(os.path.join(pneumonia_dir, pneumonia[i]))
    plt.imshow(img, cmap='gray')
    plt.axis('off')

plt.tight_layout()
```

```
Train set:
========================================
PNEUMONIA=3875
NORMAL=1341
Test set:
========================================
PNEUMONIA=390
NORMAL=234
Validation set:
========================================
PNEUMONIA=8
NORMAL=8
```

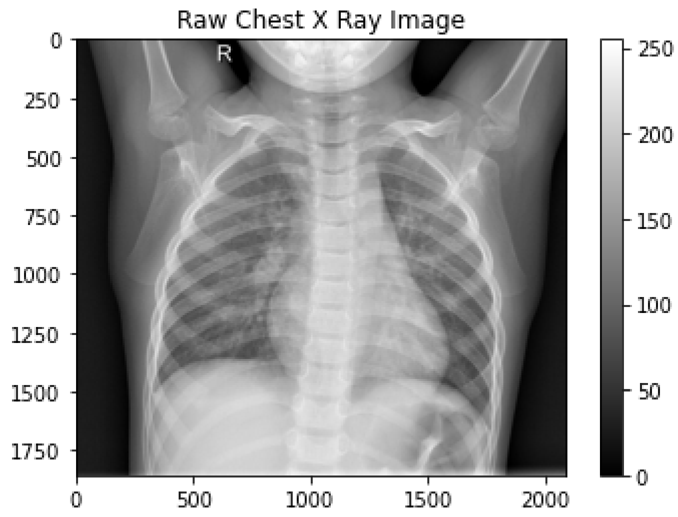


In [4]:
```
normal = os.listdir("chest_xray/train/NORMAL")
normal_dir = "chest_xray/train/NORMAL"

plt.figure(figsize=(20, 10))

for i in range(9):
    plt.subplot(3, 3, i + 1)
    img = plt.imread(os.path.join(normal_dir, normal[i]))
    plt.imshow(img, cmap='gray')
    plt.axis('off')

plt.tight_layout()
```



In [5]:
```
normal_img = os.listdir("chest_xray/train/NORMAL")[0]
normal_dir = "chest_xray/train/NORMAL"
sample_img = plt.imread(os.path.join(normal_dir, normal_img))
plt.imshow(sample_img, cmap='gray')
plt.colorbar()
plt.title('Raw Chest X Ray Image')

print(f"The dimensions of the image are {sample_img.shape[0]} pixels width and {samp
print(f"The maximum pixel value is {sample_img.max():.4f} and the minimum is {sample
print(f"The mean value of the pixels is {sample_img.mean():.4f} and the standard dev
```

```
The dimensions of the image are 1858 pixels width and 2090 pixels height, one single
color channel.
The maximum pixel value is 255.0000 and the minimum is 0.0000
The mean value of the pixels is 128.9075 and the standard deviation is 62.3010
```



Ivestigate pixel value distribution

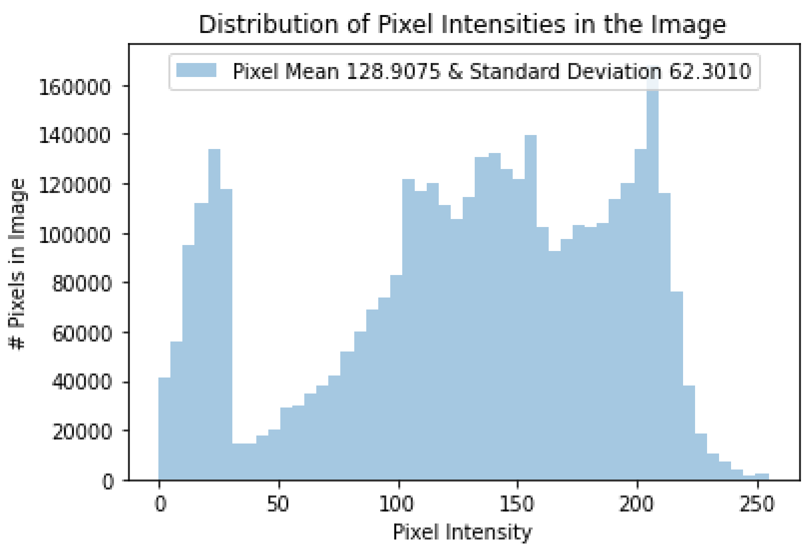
In [6]:

```
sns.distplot(sample_img.ravel(),
             label=f"Pixel Mean {np.mean(sample_img):.4f} & Standard Deviation {np.st
plt.legend(loc='upper center')
plt.title('Distribution of Pixel Intensities in the Image')
plt.xlabel('Pixel Intensity')
plt.ylabel('# Pixels in Image')
```

```
C:\Users\MCHOME\.conda\envs\pbl\lib\site-packages\seaborn\distributions.py:2619: Fut
ureWarning: `distplot` is a deprecated function and will be removed in a future vers
ion. Please adapt your code to use either `displot` (a figure-level function with si
milar flexibility) or `histplot` (an axes-level function for histograms).
  warnings.warn(msg, FutureWarning)
```

Out[6]:

```
Text(0, 0.5, '# Pixels in Image')
```



2. Image Preprocessing

Before training, we'll first modify your images to be better suited for training a convolutional neural network. For this task we'll use the Keras ImageDataGenerator function to perform data preprocessing and data augmentation.

This class also provides support for basic data augmentation such as random horizontal flipping of images. We also use the generator to transform the values in each batch so that their mean is 0 and their standard deviation is 1 (this will faciliate model training by standardizing the input distribution). The generator also converts our single channel X-ray images (gray-scale) to a three-channel format by repeating the values in the image across all channels (we will want this because the pre-trained model that we'll use requires three-channel inputs).

In [7]:

```
from keras.preprocessing.image import ImageDataGenerator

image_generator = ImageDataGenerator(
    rotation_range=20,
    width_shift_range=0.1,
    shear_range=0.1,
    zoom_range=0.1,
    samplewise_center=True,
    samplewise_std_normalization=True
)
```

Build a separate generator fo valid and test sets

Now we need to build a new generator for validation and t esting data.

Why can't use the same generator as for the training data?

Look back at the generator we wrote for the training data.

It normalizes each image per batch, meaning thatit uses batch statistics. We should not do this with the test and validation data, since in a real life scenario we don't process incoming images a batch at a time (we process one image at a time). Knowing the average per batch of test data would effectively give our model an advantage (The model should not have any information about the test data). What we need to do is to normalize incomming test data using the statistics computed from the training set.

In [8]:

```
train = image_generator.flow_from_directory(train_dir,
                                            batch_size=8,
                                            shuffle=True,
                                            class_mode='binary',
                                            target_size=(180, 180))

validation = image_generator.flow_from_directory(val_dir,
                                                batch_size=1,
                                                shuffle=False,
                                                class_mode='binary',
                                                target_size=(180, 180))

test = image_generator.flow_from_directory(test_dir,
                                           batch_size=1,
                                           shuffle=False,
                                           class_mode='binary',
                                           target_size=(180, 180))
```

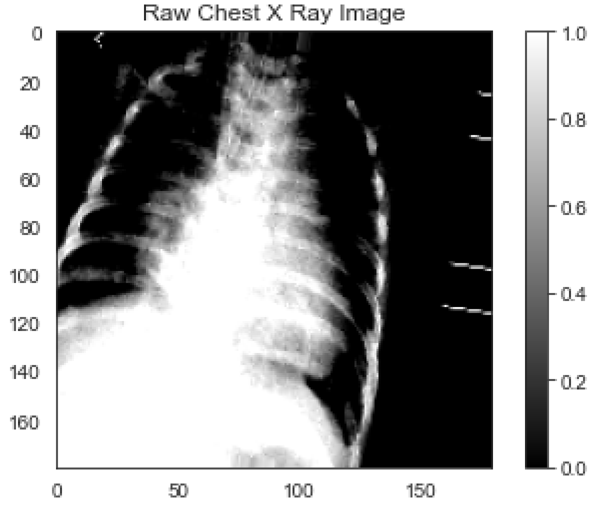
```
Found 5216 images belonging to 2 classes.
Found 16 images belonging to 2 classes.
```

```
Found 624 images belonging to 2 classes.
```

In [9]:

```
sns.set_style('white')
generated_image, label = train.__getitem__(0)
plt.imshow(generated_image[0], cmap='gray')
plt.colorbar()
plt.title('Raw Chest X Ray Image')

print(f"The dimensions of the image are {generated_image.shape[1]} pixels width and
print(f"The maximum pixel value is {generated_image.max():.4f} and the minimum is {g
print(f"The mean value of the pixels is {generated_image.mean():.4f} and the standar
```

```
Clipping input data to the valid range for imshow with RGB data ([0..1] for floats o
r [0..255] for integers).
The dimensions of the image are 180 pixels width and 180 pixels height, one single c
olor channel.
The maximum pixel value is 2.4701 and the minimum is -3.2370
The mean value of the pixels is -0.0000 and the standard deviation is 1.0000
```

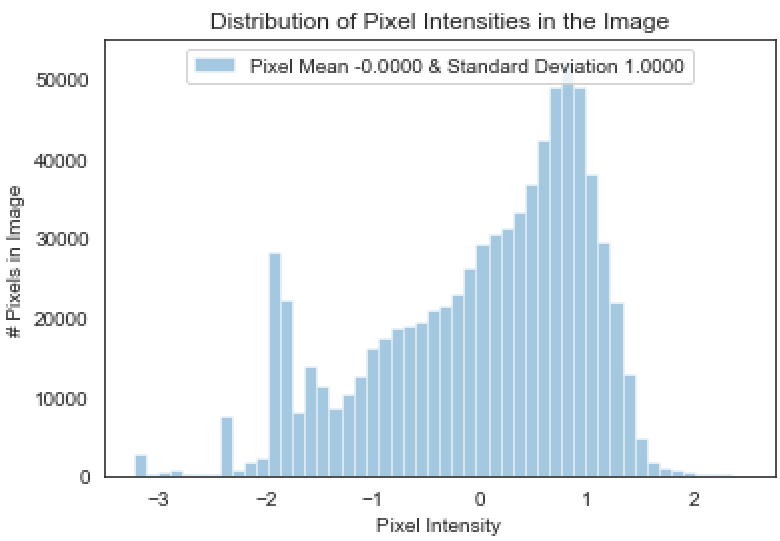


In [10]:

```
sns.distplot(generated_image.ravel(),
             label=f"Pixel Mean {np.mean(generated_image):.4f} & Standard Deviation {
plt.legend(loc='upper center')
plt.title('Distribution of Pixel Intensities in the Image')
plt.xlabel('Pixel Intensity')
plt.ylabel('# Pixels in Image')
```

Out[10]:

```
Text(0, 0.5, '# Pixels in Image')
```



Building a CNN model

Impact of imbalance data on loss function

Loss Function:

$$\mathcal{L}_{cross-entropy}(x_i) = -(y_i \log(f(x_i)) + (1-y_i)\log(1-f(x_i))),$$

We can rewrite the the overall average cross-entropy loss over the entire training set `D` of size `N` as follows:

$$\mathcal{L}_{cross-entropy}(\mathcal{D}) = -\frac{1}{N}\Big(\sum_{\text{positive examples}} \log(f(x_i)) + \sum_{\text{negative examples}} \log(1-f(x_i)) \Big).$$

When we have an imbalance data, using a normal loss function will result a model that bias toward the dominating class. One solution is to use a weighted loss function. Using weighted loss function will balance the contribution in the loss function.

$$\mathcal{L}^{w}_{cross-entropy}(x) = -(w_p y \log(f(x)) + w_n(1-y)\log(1-f(x))).$$

In [11]:

```
# Class weights

weight_for_0 = num_pneumonia / (num_normal + num_pneumonia)
weight_for_1 = num_normal / (num_normal + num_pneumonia)

class_weight = {0: weight_for_0, 1: weight_for_1}

print(f"Weight for class 0: {weight_for_0:.2f}")
print(f"Weight for class 1: {weight_for_1:.2f}")
```

```
Weight for class 0: 0.74
Weight for class 1: 0.26
```

In [12]:

```
from keras.models import Sequential
from keras.layers import Dense, Conv2D, MaxPool2D, Dropout, Flatten, BatchNormalizat


model = Sequential()

model.add(Conv2D(filters=32, kernel_size=(3, 3), input_shape=(180, 180, 3), activati
model.add(BatchNormalization())
model.add(Conv2D(filters=32, kernel_size=(3, 3), input_shape=(180, 180, 3), activati
model.add(BatchNormalization())
model.add(MaxPool2D(pool_size=(2, 2)))

model.add(Conv2D(filters=64, kernel_size=(3, 3), activation='relu'))
model.add(BatchNormalization())
model.add(Conv2D(filters=64, kernel_size=(3, 3), activation='relu'))
model.add(BatchNormalization())
model.add(MaxPool2D(pool_size=(2, 2)))

model.add(Conv2D(filters=128, kernel_size=(3, 3), activation='relu'))
model.add(BatchNormalization())
model.add(Conv2D(filters=128, kernel_size=(3, 3), activation='relu'))
model.add(BatchNormalization())
model.add(MaxPool2D(pool_size=(2, 2)))
```

```
model.add(Flatten())
model.add(Dense(128, activation='relu'))
model.add(Dropout(0.2))

model.add(Dense(1, activation='sigmoid'))

model.compile(loss='binary_crossentropy',
              optimizer='adam',
              metrics=['accuracy'])
```

In [13]:

```
model.summary()
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d (Conv2D)              (None, 178, 178, 32)      896
_________________________________________________________________
batch_normalization (BatchNo (None, 178, 178, 32)      128
_________________________________________________________________
conv2d_1 (Conv2D)            (None, 176, 176, 32)      9248
_________________________________________________________________
batch_normalization_1 (Batch (None, 176, 176, 32)      128
_________________________________________________________________
max_pooling2d (MaxPooling2D) (None, 88, 88, 32)        0
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 86, 86, 64)        18496
_________________________________________________________________
batch_normalization_2 (Batch (None, 86, 86, 64)        256
_________________________________________________________________
conv2d_3 (Conv2D)            (None, 84, 84, 64)        36928
_________________________________________________________________
batch_normalization_3 (Batch (None, 84, 84, 64)        256
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 42, 42, 64)        0
_________________________________________________________________
conv2d_4 (Conv2D)            (None, 40, 40, 128)       73856
_________________________________________________________________
batch_normalization_4 (Batch (None, 40, 40, 128)       512
_________________________________________________________________
conv2d_5 (Conv2D)            (None, 38, 38, 128)       147584
_________________________________________________________________
batch_normalization_5 (Batch (None, 38, 38, 128)       512
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 19, 19, 128)       0
_________________________________________________________________
flatten (Flatten)            (None, 46208)             0
_________________________________________________________________
dense (Dense)                (None, 128)               5914752
_________________________________________________________________
dropout (Dropout)            (None, 128)               0
_________________________________________________________________
dense_1 (Dense)              (None, 1)                 129
=================================================================
Total params: 6,203,681
Trainable params: 6,202,785
Non-trainable params: 896
_________________________________________________________________
```

In [14]:

```
r = model.fit(
    train,
    epochs=10,
```

```
    validation_data=validation,
    class_weight=class_weight,
    steps_per_epoch=100,
    validation_steps=25,
)
```

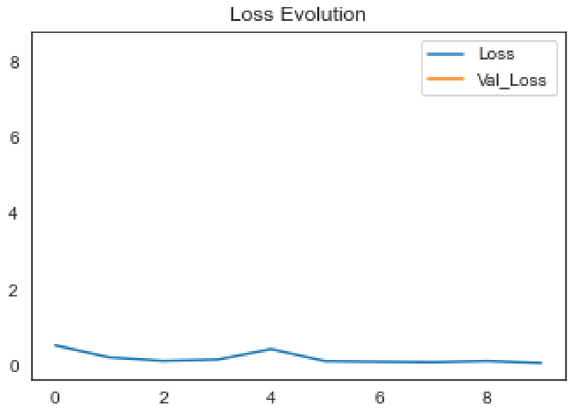
```
Epoch 1/10
100/100 [==============================] - ETA: 0s - loss: 0.5413 - accuracy: 0.7850
WARNING:tensorflow:Your input ran out of data; interrupting training. Make sure that
your dataset or generator can generate at least `steps_per_epoch * epochs` batches
(in this case, 25 batches). You may need to use the repeat() function when building
your dataset.
100/100 [==============================] - 316s 3s/step - loss: 0.5413 - accuracy:
0.7850 - val_loss: 8.3759 - val_accuracy: 0.5625
Epoch 2/10
100/100 [==============================] - 291s 3s/step - loss: 0.2271 - accuracy:
0.8687
Epoch 3/10
100/100 [==============================] - 289s 3s/step - loss: 0.1325 - accuracy:
0.8575
Epoch 4/10
100/100 [==============================] - 293s 3s/step - loss: 0.1650 - accuracy:
0.8475
Epoch 5/10
100/100 [==============================] - 290s 3s/step - loss: 0.4424 - accuracy:
0.8562
Epoch 6/10
100/100 [==============================] - 292s 3s/step - loss: 0.1272 - accuracy:
0.8512
Epoch 7/10
100/100 [==============================] - 298s 3s/step - loss: 0.1121 - accuracy:
0.9062
Epoch 8/10
100/100 [==============================] - 291s 3s/step - loss: 0.1004 - accuracy:
0.8850
Epoch 9/10
100/100 [==============================] - 298s 3s/step - loss: 0.1313 - accuracy:
0.8938
Epoch 10/10
100/100 [==============================] - 286s 3s/step - loss: 0.0761 - accuracy:
0.9212
```

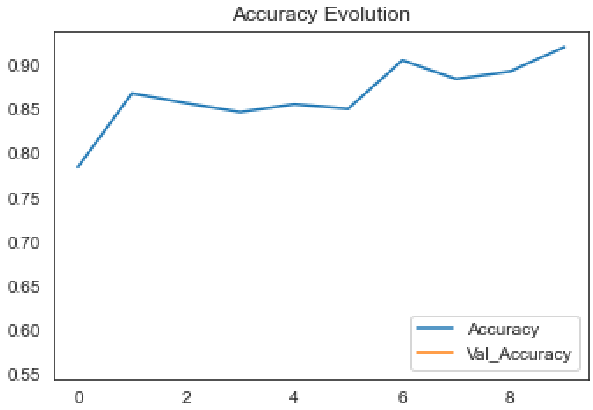
In [15]:

```
plt.figure(figsize=(12, 8))

plt.subplot(2, 2, 1)
plt.plot(r.history['loss'], label='Loss')
plt.plot(r.history['val_loss'], label='Val_Loss')
plt.legend()
plt.title('Loss Evolution')

plt.subplot(2, 2, 2)
plt.plot(r.history['accuracy'], label='Accuracy')
plt.plot(r.history['val_accuracy'], label='Val_Accuracy')
plt.legend()
plt.title('Accuracy Evolution')
```

Out[15]:

```
Text(0.5, 1.0, 'Accuracy Evolution')
```





In [16]:

```
evaluation = model.evaluate(test)
print(f"Test Accuracy: {evaluation[1] * 100:.2f}%")

evaluation = model.evaluate(train)
print(f"Train Accuracy: {evaluation[1] * 100:.2f}%")
```

```
624/624 [==============================] - 68s 108ms/step - loss: 0.5916 - accuracy:
0.7997
Test Accuracy: 79.97%
652/652 [==============================] - 561s 861ms/step - loss: 0.6874 - accurac
y: 0.7795
Train Accuracy: 77.95%
```

In [17]:

```
from sklearn.metrics import confusion_matrix, classification_report

pred = model.predict(test)

print(confusion_matrix(test.classes, pred > 0.5))
pd.DataFrame(classification_report(test.classes, pred > 0.5, output_dict=True))
```

```
[[209  25]
 [104 286]]
```

Out[17]:

	0	1	accuracy	macro avg	weighted avg
precision	0.667732	0.919614	0.793269	0.793673	0.825158
recall	0.893162	0.733333	0.793269	0.813248	0.793269
f1-score	0.764168	0.815977	0.793269	0.790073	0.796549
support	234.000000	390.000000	0.793269	624.000000	624.000000

In [18]:

```
print(confusion_matrix(test.classes, pred > 0.7))
pd.DataFrame(classification_report(test.classes, pred > 0.7, output_dict=True))
```

```
[[220  14]
 [141 249]]
```

Out[18]:

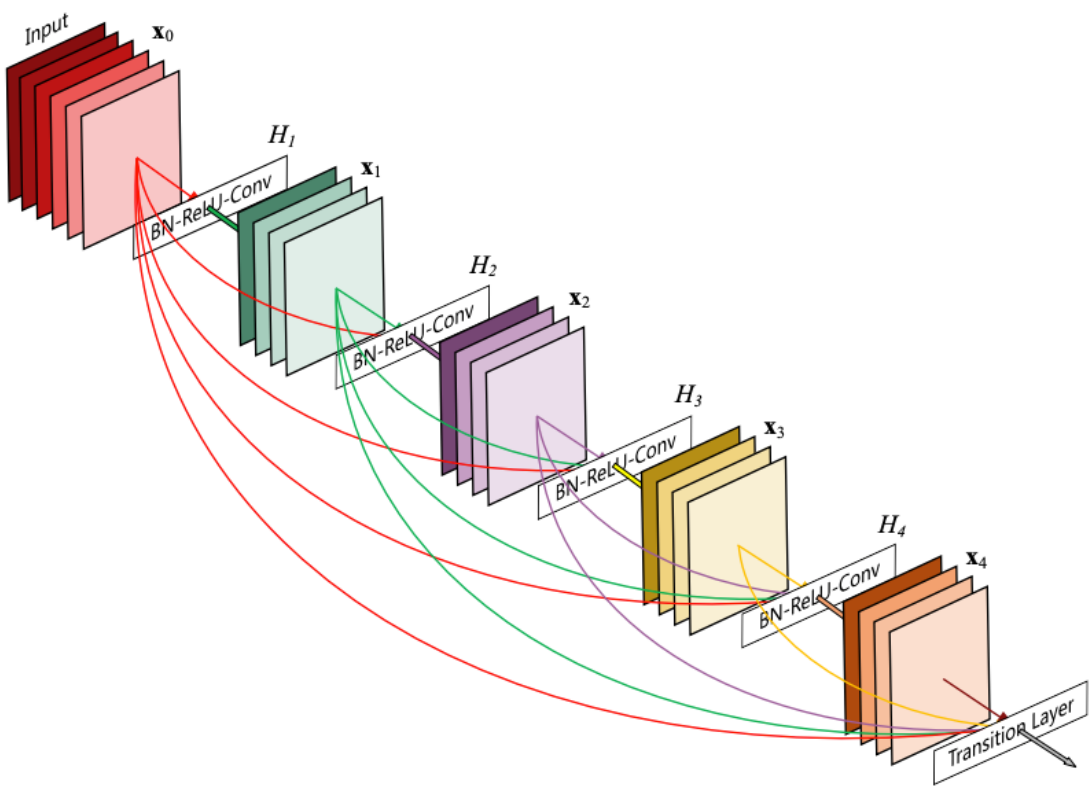
	0	1	accuracy	macro avg	weighted avg
precision	0.609418	0.946768	0.751603	0.778093	0.820262
recall	0.940171	0.638462	0.751603	0.789316	0.751603
f1-score	0.739496	0.762634	0.751603	0.751065	0.753957
support	234.000000	390.000000	0.751603	624.000000	624.000000

Transfer Learning

DenseNet

Densenet is a convolutional network where each layer is connected to all other layers that are deeper in the network:

- The first layer is connected to the 2nd, 3rd, 4th etc.
- The second layer is conected to the 3rd, 4th, 5th etc.



for more information about the DenseNet Architecture visit this website : https://keras.io/api/applications/densenet/

In [19]:

```
from keras.applications.densenet import DenseNet121
from keras.layers import Dense, GlobalAveragePooling2D
from keras.models import Model
from keras import backend as K

base_model = DenseNet121(input_shape=(180, 180, 3), include_top=False, weights='imag

base_model.summary()
```

```
Model: "densenet121"
__________________________________________________________________________________________________
Layer (type)                    Output Shape         Param #     Connected to
==================================================================================================
input_1 (InputLayer)            [(None, 180, 180, 3) 0
__________________________________________________________________________________________________
```

```
zero_padding2d (ZeroPadding2D)  (None, 186, 186, 3)  0           input_1[0][0]
__________________________________________________________________________________
________________
conv1/conv (Conv2D)             (None, 90, 90, 64)   9408        zero_padding2d[0]
[0]
__________________________________________________________________________________
________________
conv1/bn (BatchNormalization)   (None, 90, 90, 64)   256         conv1/conv[0][0]
__________________________________________________________________________________
________________
conv1/relu (Activation)         (None, 90, 90, 64)   0           conv1/bn[0][0]
__________________________________________________________________________________
________________
zero_padding2d_1 (ZeroPadding2D (None, 92, 92, 64)   0           conv1/relu[0][0]
__________________________________________________________________________________
________________
pool1 (MaxPooling2D)            (None, 45, 45, 64)   0           zero_padding2d_1[0]
[0]
__________________________________________________________________________________
________________
conv2_block1_0_bn (BatchNormali (None, 45, 45, 64)   256         pool1[0][0]
__________________________________________________________________________________
________________
conv2_block1_0_relu (Activation (None, 45, 45, 64)   0           conv2_block1_0_bn
[0][0]
__________________________________________________________________________________
________________
conv2_block1_1_conv (Conv2D)    (None, 45, 45, 128)  8192        conv2_block1_0_relu
[0][0]
__________________________________________________________________________________
________________
conv2_block1_1_bn (BatchNormali (None, 45, 45, 128)  512         conv2_block1_1_conv
[0][0]
__________________________________________________________________________________
________________
conv2_block1_1_relu (Activation (None, 45, 45, 128)  0           conv2_block1_1_bn
[0][0]
__________________________________________________________________________________
________________
conv2_block1_2_conv (Conv2D)    (None, 45, 45, 32)   36864       conv2_block1_1_relu
[0][0]
__________________________________________________________________________________
________________
conv2_block1_concat (Concatenat (None, 45, 45, 96)   0           pool1[0][0]
                                                                 conv2_block1_2_conv

[0][0]
__________________________________________________________________________________
________________
conv2_block2_0_bn (BatchNormali (None, 45, 45, 96)   384         conv2_block1_concat
[0][0]
__________________________________________________________________________________
________________
conv2_block2_0_relu (Activation (None, 45, 45, 96)   0           conv2_block2_0_bn
[0][0]
__________________________________________________________________________________
________________
conv2_block2_1_conv (Conv2D)    (None, 45, 45, 128)  12288       conv2_block2_0_relu
[0][0]
__________________________________________________________________________________
________________
conv2_block2_1_bn (BatchNormali (None, 45, 45, 128)  512         conv2_block2_1_conv
[0][0]
__________________________________________________________________________________
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conv2_block2_1_relu (Activation (None, 45, 45, 128)  0           conv2_block2_1_bn
[0][0]
__________________________________________________________________________________________________
conv2_block2_2_conv (Conv2D)    (None, 45, 45, 32)   36864       conv2_block2_1_relu
[0][0]
__________________________________________________________________________________________________
conv2_block2_concat (Concatenat (None, 45, 45, 128)  0           conv2_block1_concat
[0][0]
                                                                 conv2_block2_2_conv
[0][0]
__________________________________________________________________________________________________
conv2_block3_0_bn (BatchNormali (None, 45, 45, 128)  512         conv2_block2_concat
[0][0]
__________________________________________________________________________________________________
conv2_block3_0_relu (Activation (None, 45, 45, 128)  0           conv2_block3_0_bn
[0][0]
__________________________________________________________________________________________________
conv2_block3_1_conv (Conv2D)    (None, 45, 45, 128)  16384       conv2_block3_0_relu
[0][0]
__________________________________________________________________________________________________
conv2_block3_1_bn (BatchNormali (None, 45, 45, 128)  512         conv2_block3_1_conv
[0][0]
__________________________________________________________________________________________________
conv2_block3_1_relu (Activation (None, 45, 45, 128)  0           conv2_block3_1_bn
[0][0]
__________________________________________________________________________________________________
conv2_block3_2_conv (Conv2D)    (None, 45, 45, 32)   36864       conv2_block3_1_relu
[0][0]
__________________________________________________________________________________________________
conv2_block3_concat (Concatenat (None, 45, 45, 160)  0           conv2_block2_concat
[0][0]
                                                                 conv2_block3_2_conv
[0][0]
__________________________________________________________________________________________________
conv2_block4_0_bn (BatchNormali (None, 45, 45, 160)  640         conv2_block3_concat
[0][0]
__________________________________________________________________________________________________
conv2_block4_0_relu (Activation (None, 45, 45, 160)  0           conv2_block4_0_bn
[0][0]
__________________________________________________________________________________________________
conv2_block4_1_conv (Conv2D)    (None, 45, 45, 128)  20480       conv2_block4_0_relu
[0][0]
__________________________________________________________________________________________________
conv2_block4_1_bn (BatchNormali (None, 45, 45, 128)  512         conv2_block4_1_conv
[0][0]
__________________________________________________________________________________________________
conv2_block4_1_relu (Activation (None, 45, 45, 128)  0           conv2_block4_1_bn
[0][0]
__________________________________________________________________________________________________
```

```
conv2_block4_2_conv (Conv2D)    (None, 45, 45, 32)   36864       conv2_block4_1_relu
[0][0]
__________________________________________________________________________________
______________
conv2_block4_concat (Concatenat (None, 45, 45, 192)  0           conv2_block3_concat
[0][0]
                                                                 conv2_block4_2_conv
[0][0]
__________________________________________________________________________________
______________
conv2_block5_0_bn (BatchNormali (None, 45, 45, 192)  768         conv2_block4_concat
[0][0]
__________________________________________________________________________________
______________
conv2_block5_0_relu (Activation (None, 45, 45, 192)  0           conv2_block5_0_bn
[0][0]
__________________________________________________________________________________
______________
conv2_block5_1_conv (Conv2D)    (None, 45, 45, 128)  24576       conv2_block5_0_relu
[0][0]
__________________________________________________________________________________
______________
conv2_block5_1_bn (BatchNormali (None, 45, 45, 128)  512         conv2_block5_1_conv
[0][0]
__________________________________________________________________________________
______________
conv2_block5_1_relu (Activation (None, 45, 45, 128)  0           conv2_block5_1_bn
[0][0]
__________________________________________________________________________________
______________
conv2_block5_2_conv (Conv2D)    (None, 45, 45, 32)   36864       conv2_block5_1_relu
[0][0]
__________________________________________________________________________________
______________
conv2_block5_concat (Concatenat (None, 45, 45, 224)  0           conv2_block4_concat
[0][0]
                                                                 conv2_block5_2_conv
[0][0]
__________________________________________________________________________________
______________
conv2_block6_0_bn (BatchNormali (None, 45, 45, 224)  896         conv2_block5_concat
[0][0]
__________________________________________________________________________________
______________
conv2_block6_0_relu (Activation (None, 45, 45, 224)  0           conv2_block6_0_bn
[0][0]
__________________________________________________________________________________
______________
conv2_block6_1_conv (Conv2D)    (None, 45, 45, 128)  28672       conv2_block6_0_relu
[0][0]
__________________________________________________________________________________
______________
conv2_block6_1_bn (BatchNormali (None, 45, 45, 128)  512         conv2_block6_1_conv
[0][0]
__________________________________________________________________________________
______________
conv2_block6_1_relu (Activation (None, 45, 45, 128)  0           conv2_block6_1_bn
[0][0]
__________________________________________________________________________________
______________
conv2_block6_2_conv (Conv2D)    (None, 45, 45, 32)   36864       conv2_block6_1_relu
[0][0]
__________________________________________________________________________________
______________
```

```
conv2_block6_concat (Concatenat (None, 45, 45, 256)  0           conv2_block5_concat
[0][0]
                                                                 conv2_block6_2_conv
[0][0]
__________________________________________________________________________________
________________
pool2_bn (BatchNormalization)   (None, 45, 45, 256)  1024        conv2_block6_concat
[0][0]
__________________________________________________________________________________
________________
pool2_relu (Activation)         (None, 45, 45, 256)  0           pool2_bn[0][0]
__________________________________________________________________________________
________________
pool2_conv (Conv2D)             (None, 45, 45, 128)  32768       pool2_relu[0][0]
__________________________________________________________________________________
________________
pool2_pool (AveragePooling2D)   (None, 22, 22, 128)  0           pool2_conv[0][0]
__________________________________________________________________________________
________________
conv3_block1_0_bn (BatchNormali (None, 22, 22, 128)  512         pool2_pool[0][0]
__________________________________________________________________________________
________________
conv3_block1_0_relu (Activation (None, 22, 22, 128)  0           conv3_block1_0_bn
[0][0]
__________________________________________________________________________________
________________
conv3_block1_1_conv (Conv2D)    (None, 22, 22, 128)  16384       conv3_block1_0_relu
[0][0]
__________________________________________________________________________________
________________
conv3_block1_1_bn (BatchNormali (None, 22, 22, 128)  512         conv3_block1_1_conv
[0][0]
__________________________________________________________________________________
________________
conv3_block1_1_relu (Activation (None, 22, 22, 128)  0           conv3_block1_1_bn
[0][0]
__________________________________________________________________________________
________________
conv3_block1_2_conv (Conv2D)    (None, 22, 22, 32)   36864       conv3_block1_1_relu
[0][0]
__________________________________________________________________________________
________________
conv3_block1_concat (Concatenat (None, 22, 22, 160)  0           pool2_pool[0][0]
                                                                 conv3_block1_2_conv
[0][0]
__________________________________________________________________________________
________________
conv3_block2_0_bn (BatchNormali (None, 22, 22, 160)  640         conv3_block1_concat
[0][0]
__________________________________________________________________________________
________________
conv3_block2_0_relu (Activation (None, 22, 22, 160)  0           conv3_block2_0_bn
[0][0]
__________________________________________________________________________________
________________
conv3_block2_1_conv (Conv2D)    (None, 22, 22, 128)  20480       conv3_block2_0_relu
[0][0]
__________________________________________________________________________________
________________
conv3_block2_1_bn (BatchNormali (None, 22, 22, 128)  512         conv3_block2_1_conv
[0][0]
__________________________________________________________________________________
________________
conv3_block2_1_relu (Activation (None, 22, 22, 128)  0           conv3_block2_1_bn
```

```
[0][0]
__________________________________________________________________________________________________
conv3_block2_2_conv (Conv2D)    (None, 22, 22, 32)   36864       conv3_block2_1_relu[0][0]
__________________________________________________________________________________________________
conv3_block2_concat (Concatenat (None, 22, 22, 192)  0           conv3_block1_concat[0][0]
                                                                 conv3_block2_2_conv[0][0]
__________________________________________________________________________________________________
conv3_block3_0_bn (BatchNormali (None, 22, 22, 192)  768         conv3_block2_concat[0][0]
__________________________________________________________________________________________________
conv3_block3_0_relu (Activation (None, 22, 22, 192)  0           conv3_block3_0_bn[0][0]
__________________________________________________________________________________________________
conv3_block3_1_conv (Conv2D)    (None, 22, 22, 128)  24576       conv3_block3_0_relu[0][0]
__________________________________________________________________________________________________
conv3_block3_1_bn (BatchNormali (None, 22, 22, 128)  512         conv3_block3_1_conv[0][0]
__________________________________________________________________________________________________
conv3_block3_1_relu (Activation (None, 22, 22, 128)  0           conv3_block3_1_bn[0][0]
__________________________________________________________________________________________________
conv3_block3_2_conv (Conv2D)    (None, 22, 22, 32)   36864       conv3_block3_1_relu[0][0]
__________________________________________________________________________________________________
conv3_block3_concat (Concatenat (None, 22, 22, 224)  0           conv3_block2_concat[0][0]
                                                                 conv3_block3_2_conv[0][0]
__________________________________________________________________________________________________
conv3_block4_0_bn (BatchNormali (None, 22, 22, 224)  896         conv3_block3_concat[0][0]
__________________________________________________________________________________________________
conv3_block4_0_relu (Activation (None, 22, 22, 224)  0           conv3_block4_0_bn[0][0]
__________________________________________________________________________________________________
conv3_block4_1_conv (Conv2D)    (None, 22, 22, 128)  28672       conv3_block4_0_relu[0][0]
__________________________________________________________________________________________________
conv3_block4_1_bn (BatchNormali (None, 22, 22, 128)  512         conv3_block4_1_conv[0][0]
__________________________________________________________________________________________________
conv3_block4_1_relu (Activation (None, 22, 22, 128)  0           conv3_block4_1_bn[0][0]
__________________________________________________________________________________________________
conv3_block4_2_conv (Conv2D)    (None, 22, 22, 32)   36864       conv3_block4_1_relu
```

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[0][0]
__________________________________________________________________________________________________
conv3_block4_concat (Concatenat (None, 22, 22, 256)  0           conv3_block3_concat[0][0]
                                                                 conv3_block4_2_conv[0][0]
__________________________________________________________________________________________________
conv3_block5_0_bn (BatchNormali (None, 22, 22, 256)  1024        conv3_block4_concat[0][0]
__________________________________________________________________________________________________
conv3_block5_0_relu (Activation (None, 22, 22, 256)  0           conv3_block5_0_bn[0][0]
__________________________________________________________________________________________________
conv3_block5_1_conv (Conv2D)    (None, 22, 22, 128)  32768       conv3_block5_0_relu[0][0]
__________________________________________________________________________________________________
conv3_block5_1_bn (BatchNormali (None, 22, 22, 128)  512         conv3_block5_1_conv[0][0]
__________________________________________________________________________________________________
conv3_block5_1_relu (Activation (None, 22, 22, 128)  0           conv3_block5_1_bn[0][0]
__________________________________________________________________________________________________
conv3_block5_2_conv (Conv2D)    (None, 22, 22, 32)   36864       conv3_block5_1_relu[0][0]
__________________________________________________________________________________________________
conv3_block5_concat (Concatenat (None, 22, 22, 288)  0           conv3_block4_concat[0][0]
                                                                 conv3_block5_2_conv[0][0]
__________________________________________________________________________________________________
conv3_block6_0_bn (BatchNormali (None, 22, 22, 288)  1152        conv3_block5_concat[0][0]
__________________________________________________________________________________________________
conv3_block6_0_relu (Activation (None, 22, 22, 288)  0           conv3_block6_0_bn[0][0]
__________________________________________________________________________________________________
conv3_block6_1_conv (Conv2D)    (None, 22, 22, 128)  36864       conv3_block6_0_relu[0][0]
__________________________________________________________________________________________________
conv3_block6_1_bn (BatchNormali (None, 22, 22, 128)  512         conv3_block6_1_conv[0][0]
__________________________________________________________________________________________________
conv3_block6_1_relu (Activation (None, 22, 22, 128)  0           conv3_block6_1_bn[0][0]
__________________________________________________________________________________________________
conv3_block6_2_conv (Conv2D)    (None, 22, 22, 32)   36864       conv3_block6_1_relu[0][0]
__________________________________________________________________________________________________
conv3_block6_concat (Concatenat (None, 22, 22, 320)  0           conv3_block5_concat
```

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[0][0]
                                                                  conv3_block6_2_conv
[0][0]
__________________________________________________________________________________________________
conv3_block7_0_bn (BatchNormali (None, 22, 22, 320)  1280        conv3_block6_concat
[0][0]
__________________________________________________________________________________________________
conv3_block7_0_relu (Activation (None, 22, 22, 320)  0           conv3_block7_0_bn
[0][0]
__________________________________________________________________________________________________
conv3_block7_1_conv (Conv2D)    (None, 22, 22, 128)  40960       conv3_block7_0_relu
[0][0]
__________________________________________________________________________________________________
conv3_block7_1_bn (BatchNormali (None, 22, 22, 128)  512         conv3_block7_1_conv
[0][0]
__________________________________________________________________________________________________
conv3_block7_1_relu (Activation (None, 22, 22, 128)  0           conv3_block7_1_bn
[0][0]
__________________________________________________________________________________________________
conv3_block7_2_conv (Conv2D)    (None, 22, 22, 32)   36864       conv3_block7_1_relu
[0][0]
__________________________________________________________________________________________________
conv3_block7_concat (Concatenat (None, 22, 22, 352)  0           conv3_block6_concat
[0][0]
                                                                  conv3_block7_2_conv
[0][0]
__________________________________________________________________________________________________
conv3_block8_0_bn (BatchNormali (None, 22, 22, 352)  1408        conv3_block7_concat
[0][0]
__________________________________________________________________________________________________
conv3_block8_0_relu (Activation (None, 22, 22, 352)  0           conv3_block8_0_bn
[0][0]
__________________________________________________________________________________________________
conv3_block8_1_conv (Conv2D)    (None, 22, 22, 128)  45056       conv3_block8_0_relu
[0][0]
__________________________________________________________________________________________________
conv3_block8_1_bn (BatchNormali (None, 22, 22, 128)  512         conv3_block8_1_conv
[0][0]
__________________________________________________________________________________________________
conv3_block8_1_relu (Activation (None, 22, 22, 128)  0           conv3_block8_1_bn
[0][0]
__________________________________________________________________________________________________
conv3_block8_2_conv (Conv2D)    (None, 22, 22, 32)   36864       conv3_block8_1_relu
[0][0]
__________________________________________________________________________________________________
conv3_block8_concat (Concatenat (None, 22, 22, 384)  0           conv3_block7_concat
[0][0]
                                                                  conv3_block8_2_conv
[0][0]
__________________________________________________________________________________________________
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__________________________________________________________________________________________________
conv3_block9_0_bn (BatchNormali (None, 22, 22, 384)  1536        conv3_block8_concat[0][0]
__________________________________________________________________________________________________
conv3_block9_0_relu (Activation (None, 22, 22, 384)  0           conv3_block9_0_bn[0][0]
__________________________________________________________________________________________________
conv3_block9_1_conv (Conv2D)    (None, 22, 22, 128)  49152       conv3_block9_0_relu[0][0]
__________________________________________________________________________________________________
conv3_block9_1_bn (BatchNormali (None, 22, 22, 128)  512         conv3_block9_1_conv[0][0]
__________________________________________________________________________________________________
conv3_block9_1_relu (Activation (None, 22, 22, 128)  0           conv3_block9_1_bn[0][0]
__________________________________________________________________________________________________
conv3_block9_2_conv (Conv2D)    (None, 22, 22, 32)   36864       conv3_block9_1_relu[0][0]
__________________________________________________________________________________________________
conv3_block9_concat (Concatenat (None, 22, 22, 416)  0           conv3_block8_concat[0][0]
                                                                 conv3_block9_2_conv[0][0]
__________________________________________________________________________________________________
conv3_block10_0_bn (BatchNormal (None, 22, 22, 416)  1664        conv3_block9_concat[0][0]
__________________________________________________________________________________________________
conv3_block10_0_relu (Activatio (None, 22, 22, 416)  0           conv3_block10_0_bn[0][0]
__________________________________________________________________________________________________
conv3_block10_1_conv (Conv2D)   (None, 22, 22, 128)  53248       conv3_block10_0_relu[0][0]
__________________________________________________________________________________________________
conv3_block10_1_bn (BatchNormal (None, 22, 22, 128)  512         conv3_block10_1_conv[0][0]
__________________________________________________________________________________________________
conv3_block10_1_relu (Activatio (None, 22, 22, 128)  0           conv3_block10_1_bn[0][0]
__________________________________________________________________________________________________
conv3_block10_2_conv (Conv2D)   (None, 22, 22, 32)   36864       conv3_block10_1_relu[0][0]
__________________________________________________________________________________________________
conv3_block10_concat (Concatena (None, 22, 22, 448)  0           conv3_block9_concat[0][0]
                                                                 conv3_block10_2_conv[0][0]
__________________________________________________________________________________________________
conv3_block11_0_bn (BatchNormal (None, 22, 22, 448)  1792        conv3_block10_concat[0][0]
__________________________________________________________________________________________________
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______________
conv3_block11_0_relu (Activatio (None, 22, 22, 448)  0           conv3_block11_0_bn
[0][0]
__________________________________________________________________________________
______________
conv3_block11_1_conv (Conv2D)   (None, 22, 22, 128)  57344       conv3_block11_0_rel
u[0][0]
__________________________________________________________________________________
______________
conv3_block11_1_bn (BatchNormal (None, 22, 22, 128)  512         conv3_block11_1_con
v[0][0]
__________________________________________________________________________________
______________
conv3_block11_1_relu (Activatio (None, 22, 22, 128)  0           conv3_block11_1_bn
[0][0]
__________________________________________________________________________________
______________
conv3_block11_2_conv (Conv2D)   (None, 22, 22, 32)   36864       conv3_block11_1_rel
u[0][0]
__________________________________________________________________________________
______________
conv3_block11_concat (Concatena (None, 22, 22, 480)  0           conv3_block10_conca
t[0][0]
                                                                 conv3_block11_2_con
v[0][0]
__________________________________________________________________________________
______________
conv3_block12_0_bn (BatchNormal (None, 22, 22, 480)  1920        conv3_block11_conca
t[0][0]
__________________________________________________________________________________
______________
conv3_block12_0_relu (Activatio (None, 22, 22, 480)  0           conv3_block12_0_bn
[0][0]
__________________________________________________________________________________
______________
conv3_block12_1_conv (Conv2D)   (None, 22, 22, 128)  61440       conv3_block12_0_rel
u[0][0]
__________________________________________________________________________________
______________
conv3_block12_1_bn (BatchNormal (None, 22, 22, 128)  512         conv3_block12_1_con
v[0][0]
__________________________________________________________________________________
______________
conv3_block12_1_relu (Activatio (None, 22, 22, 128)  0           conv3_block12_1_bn
[0][0]
__________________________________________________________________________________
______________
conv3_block12_2_conv (Conv2D)   (None, 22, 22, 32)   36864       conv3_block12_1_rel
u[0][0]
__________________________________________________________________________________
______________
conv3_block12_concat (Concatena (None, 22, 22, 512)  0           conv3_block11_conca
t[0][0]
                                                                 conv3_block12_2_con
v[0][0]
__________________________________________________________________________________
______________
pool3_bn (BatchNormalization)   (None, 22, 22, 512)  2048        conv3_block12_conca
t[0][0]
__________________________________________________________________________________
______________
pool3_relu (Activation)         (None, 22, 22, 512)  0           pool3_bn[0][0]
__________________________________________________________________________________
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pool3_conv (Conv2D)            (None, 22, 22, 256)  131072      pool3_relu[0][0]
__________________________________________________________________________________
______________
pool3_pool (AveragePooling2D)  (None, 11, 11, 256)  0           pool3_conv[0][0]
__________________________________________________________________________________
______________
conv4_block1_0_bn (BatchNormali (None, 11, 11, 256)  1024       pool3_pool[0][0]
__________________________________________________________________________________
______________
conv4_block1_0_relu (Activation (None, 11, 11, 256)  0          conv4_block1_0_bn
[0][0]
__________________________________________________________________________________
______________
conv4_block1_1_conv (Conv2D)    (None, 11, 11, 128)  32768      conv4_block1_0_relu
[0][0]
__________________________________________________________________________________
______________
conv4_block1_1_bn (BatchNormali (None, 11, 11, 128)  512        conv4_block1_1_conv
[0][0]
__________________________________________________________________________________
______________
conv4_block1_1_relu (Activation (None, 11, 11, 128)  0          conv4_block1_1_bn
[0][0]
__________________________________________________________________________________
______________
conv4_block1_2_conv (Conv2D)    (None, 11, 11, 32)   36864      conv4_block1_1_relu
[0][0]
__________________________________________________________________________________
______________
conv4_block1_concat (Concatenat (None, 11, 11, 288)  0          pool3_pool[0][0]
                                                                conv4_block1_2_conv
[0][0]
__________________________________________________________________________________
______________
conv4_block2_0_bn (BatchNormali (None, 11, 11, 288)  1152       conv4_block1_concat
[0][0]
__________________________________________________________________________________
______________
conv4_block2_0_relu (Activation (None, 11, 11, 288)  0          conv4_block2_0_bn
[0][0]
__________________________________________________________________________________
______________
conv4_block2_1_conv (Conv2D)    (None, 11, 11, 128)  36864      conv4_block2_0_relu
[0][0]
__________________________________________________________________________________
______________
conv4_block2_1_bn (BatchNormali (None, 11, 11, 128)  512        conv4_block2_1_conv
[0][0]
__________________________________________________________________________________
______________
conv4_block2_1_relu (Activation (None, 11, 11, 128)  0          conv4_block2_1_bn
[0][0]
__________________________________________________________________________________
______________
conv4_block2_2_conv (Conv2D)    (None, 11, 11, 32)   36864      conv4_block2_1_relu
[0][0]
__________________________________________________________________________________
______________
conv4_block2_concat (Concatenat (None, 11, 11, 320)  0          conv4_block1_concat
[0][0]
                                                                conv4_block2_2_conv
[0][0]
__________________________________________________________________________________
______________
```

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conv4_block3_0_bn (BatchNormali (None, 11, 11, 320)  1280        conv4_block2_concat
[0][0]
__________________________________________________________________________________________________
conv4_block3_0_relu (Activation (None, 11, 11, 320)  0           conv4_block3_0_bn
[0][0]
__________________________________________________________________________________________________
conv4_block3_1_conv (Conv2D)    (None, 11, 11, 128)  40960       conv4_block3_0_relu
[0][0]
__________________________________________________________________________________________________
conv4_block3_1_bn (BatchNormali (None, 11, 11, 128)  512         conv4_block3_1_conv
[0][0]
__________________________________________________________________________________________________
conv4_block3_1_relu (Activation (None, 11, 11, 128)  0           conv4_block3_1_bn
[0][0]
__________________________________________________________________________________________________
conv4_block3_2_conv (Conv2D)    (None, 11, 11, 32)   36864       conv4_block3_1_relu
[0][0]
__________________________________________________________________________________________________
conv4_block3_concat (Concatenat (None, 11, 11, 352)  0           conv4_block2_concat
[0][0]
                                                                 conv4_block3_2_conv
[0][0]
__________________________________________________________________________________________________
conv4_block4_0_bn (BatchNormali (None, 11, 11, 352)  1408        conv4_block3_concat
[0][0]
__________________________________________________________________________________________________
conv4_block4_0_relu (Activation (None, 11, 11, 352)  0           conv4_block4_0_bn
[0][0]
__________________________________________________________________________________________________
conv4_block4_1_conv (Conv2D)    (None, 11, 11, 128)  45056       conv4_block4_0_relu
[0][0]
__________________________________________________________________________________________________
conv4_block4_1_bn (BatchNormali (None, 11, 11, 128)  512         conv4_block4_1_conv
[0][0]
__________________________________________________________________________________________________
conv4_block4_1_relu (Activation (None, 11, 11, 128)  0           conv4_block4_1_bn
[0][0]
__________________________________________________________________________________________________
conv4_block4_2_conv (Conv2D)    (None, 11, 11, 32)   36864       conv4_block4_1_relu
[0][0]
__________________________________________________________________________________________________
conv4_block4_concat (Concatenat (None, 11, 11, 384)  0           conv4_block3_concat
[0][0]
                                                                 conv4_block4_2_conv
[0][0]
__________________________________________________________________________________________________
conv4_block5_0_bn (BatchNormali (None, 11, 11, 384)  1536        conv4_block4_concat
[0][0]
__________________________________________________________________________________________________
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conv4_block5_0_relu (Activation (None, 11, 11, 384)  0           conv4_block5_0_bn
[0][0]
__________________________________________________________________________________________________
conv4_block5_1_conv (Conv2D)    (None, 11, 11, 128)  49152       conv4_block5_0_relu
[0][0]
__________________________________________________________________________________________________
conv4_block5_1_bn (BatchNormali (None, 11, 11, 128)  512         conv4_block5_1_conv
[0][0]
__________________________________________________________________________________________________
conv4_block5_1_relu (Activation (None, 11, 11, 128)  0           conv4_block5_1_bn
[0][0]
__________________________________________________________________________________________________
conv4_block5_2_conv (Conv2D)    (None, 11, 11, 32)   36864       conv4_block5_1_relu
[0][0]
__________________________________________________________________________________________________
conv4_block5_concat (Concatenat (None, 11, 11, 416)  0           conv4_block4_concat
[0][0]
                                                                 conv4_block5_2_conv
[0][0]
__________________________________________________________________________________________________
conv4_block6_0_bn (BatchNormali (None, 11, 11, 416)  1664        conv4_block5_concat
[0][0]
__________________________________________________________________________________________________
conv4_block6_0_relu (Activation (None, 11, 11, 416)  0           conv4_block6_0_bn
[0][0]
__________________________________________________________________________________________________
conv4_block6_1_conv (Conv2D)    (None, 11, 11, 128)  53248       conv4_block6_0_relu
[0][0]
__________________________________________________________________________________________________
conv4_block6_1_bn (BatchNormali (None, 11, 11, 128)  512         conv4_block6_1_conv
[0][0]
__________________________________________________________________________________________________
conv4_block6_1_relu (Activation (None, 11, 11, 128)  0           conv4_block6_1_bn
[0][0]
__________________________________________________________________________________________________
conv4_block6_2_conv (Conv2D)    (None, 11, 11, 32)   36864       conv4_block6_1_relu
[0][0]
__________________________________________________________________________________________________
conv4_block6_concat (Concatenat (None, 11, 11, 448)  0           conv4_block5_concat
[0][0]
                                                                 conv4_block6_2_conv
[0][0]
__________________________________________________________________________________________________
conv4_block7_0_bn (BatchNormali (None, 11, 11, 448)  1792        conv4_block6_concat
[0][0]
__________________________________________________________________________________________________
conv4_block7_0_relu (Activation (None, 11, 11, 448)  0           conv4_block7_0_bn
[0][0]
__________________________________________________________________________________________________
```

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conv4_block7_1_conv (Conv2D)    (None, 11, 11, 128)  57344       conv4_block7_0_relu
[0][0]
__________________________________________________________________________________
______________
conv4_block7_1_bn (BatchNormali (None, 11, 11, 128)  512         conv4_block7_1_conv
[0][0]
__________________________________________________________________________________
______________
conv4_block7_1_relu (Activation (None, 11, 11, 128)  0           conv4_block7_1_bn
[0][0]
__________________________________________________________________________________
______________
conv4_block7_2_conv (Conv2D)    (None, 11, 11, 32)   36864       conv4_block7_1_relu
[0][0]
__________________________________________________________________________________
______________
conv4_block7_concat (Concatenat (None, 11, 11, 480)  0           conv4_block6_concat
[0][0]
                                                                 conv4_block7_2_conv
[0][0]
__________________________________________________________________________________
______________
conv4_block8_0_bn (BatchNormali (None, 11, 11, 480)  1920        conv4_block7_concat
[0][0]
__________________________________________________________________________________
______________
conv4_block8_0_relu (Activation (None, 11, 11, 480)  0           conv4_block8_0_bn
[0][0]
__________________________________________________________________________________
______________
conv4_block8_1_conv (Conv2D)    (None, 11, 11, 128)  61440       conv4_block8_0_relu
[0][0]
__________________________________________________________________________________
______________
conv4_block8_1_bn (BatchNormali (None, 11, 11, 128)  512         conv4_block8_1_conv
[0][0]
__________________________________________________________________________________
______________
conv4_block8_1_relu (Activation (None, 11, 11, 128)  0           conv4_block8_1_bn
[0][0]
__________________________________________________________________________________
______________
conv4_block8_2_conv (Conv2D)    (None, 11, 11, 32)   36864       conv4_block8_1_relu
[0][0]
__________________________________________________________________________________
______________
conv4_block8_concat (Concatenat (None, 11, 11, 512)  0           conv4_block7_concat
[0][0]
                                                                 conv4_block8_2_conv
[0][0]
__________________________________________________________________________________
______________
conv4_block9_0_bn (BatchNormali (None, 11, 11, 512)  2048        conv4_block8_concat
[0][0]
__________________________________________________________________________________
______________
conv4_block9_0_relu (Activation (None, 11, 11, 512)  0           conv4_block9_0_bn
[0][0]
__________________________________________________________________________________
______________
conv4_block9_1_conv (Conv2D)    (None, 11, 11, 128)  65536       conv4_block9_0_relu
[0][0]
__________________________________________________________________________________
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conv4_block9_1_bn (BatchNormali (None, 11, 11, 128)  512         conv4_block9_1_conv
[0][0]
__________________________________________________________________________________
______________
conv4_block9_1_relu (Activation (None, 11, 11, 128)  0           conv4_block9_1_bn
[0][0]
__________________________________________________________________________________
______________
conv4_block9_2_conv (Conv2D)    (None, 11, 11, 32)   36864       conv4_block9_1_relu
[0][0]
__________________________________________________________________________________
______________
conv4_block9_concat (Concatenat (None, 11, 11, 544)  0           conv4_block8_concat
[0][0]
                                                                 conv4_block9_2_conv
[0][0]
__________________________________________________________________________________
______________
conv4_block10_0_bn (BatchNormal (None, 11, 11, 544)  2176        conv4_block9_concat
[0][0]
__________________________________________________________________________________
______________
conv4_block10_0_relu (Activatio (None, 11, 11, 544)  0           conv4_block10_0_bn
[0][0]
__________________________________________________________________________________
______________
conv4_block10_1_conv (Conv2D)   (None, 11, 11, 128)  69632       conv4_block10_0_rel
u[0][0]
__________________________________________________________________________________
______________
conv4_block10_1_bn (BatchNormal (None, 11, 11, 128)  512         conv4_block10_1_con
v[0][0]
__________________________________________________________________________________
______________
conv4_block10_1_relu (Activatio (None, 11, 11, 128)  0           conv4_block10_1_bn
[0][0]
__________________________________________________________________________________
______________
conv4_block10_2_conv (Conv2D)   (None, 11, 11, 32)   36864       conv4_block10_1_rel
u[0][0]
__________________________________________________________________________________
______________
conv4_block10_concat (Concatena (None, 11, 11, 576)  0           conv4_block9_concat
[0][0]
                                                                 conv4_block10_2_con
v[0][0]
__________________________________________________________________________________
______________
conv4_block11_0_bn (BatchNormal (None, 11, 11, 576)  2304        conv4_block10_conca
t[0][0]
__________________________________________________________________________________
______________
conv4_block11_0_relu (Activatio (None, 11, 11, 576)  0           conv4_block11_0_bn
[0][0]
__________________________________________________________________________________
______________
conv4_block11_1_conv (Conv2D)   (None, 11, 11, 128)  73728       conv4_block11_0_rel
u[0][0]
__________________________________________________________________________________
______________
conv4_block11_1_bn (BatchNormal (None, 11, 11, 128)  512         conv4_block11_1_con
v[0][0]
__________________________________________________________________________________
______________
```

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conv4_block11_1_relu (Activatio (None, 11, 11, 128)  0           conv4_block11_1_bn
[0][0]
__________________________________________________________________________________________________
conv4_block11_2_conv (Conv2D)   (None, 11, 11, 32)   36864       conv4_block11_1_rel
u[0][0]
__________________________________________________________________________________________________
conv4_block11_concat (Concatena (None, 11, 11, 608)  0           conv4_block10_conca
t[0][0]
                                                                 conv4_block11_2_con
v[0][0]
__________________________________________________________________________________________________
conv4_block12_0_bn (BatchNormal (None, 11, 11, 608)  2432        conv4_block11_conca
t[0][0]
__________________________________________________________________________________________________
conv4_block12_0_relu (Activatio (None, 11, 11, 608)  0           conv4_block12_0_bn
[0][0]
__________________________________________________________________________________________________
conv4_block12_1_conv (Conv2D)   (None, 11, 11, 128)  77824       conv4_block12_0_rel
u[0][0]
__________________________________________________________________________________________________
conv4_block12_1_bn (BatchNormal (None, 11, 11, 128)  512         conv4_block12_1_con
v[0][0]
__________________________________________________________________________________________________
conv4_block12_1_relu (Activatio (None, 11, 11, 128)  0           conv4_block12_1_bn
[0][0]
__________________________________________________________________________________________________
conv4_block12_2_conv (Conv2D)   (None, 11, 11, 32)   36864       conv4_block12_1_rel
u[0][0]
__________________________________________________________________________________________________
conv4_block12_concat (Concatena (None, 11, 11, 640)  0           conv4_block11_conca
t[0][0]
                                                                 conv4_block12_2_con
v[0][0]
__________________________________________________________________________________________________
conv4_block13_0_bn (BatchNormal (None, 11, 11, 640)  2560        conv4_block12_conca
t[0][0]
__________________________________________________________________________________________________
conv4_block13_0_relu (Activatio (None, 11, 11, 640)  0           conv4_block13_0_bn
[0][0]
__________________________________________________________________________________________________
conv4_block13_1_conv (Conv2D)   (None, 11, 11, 128)  81920       conv4_block13_0_rel
u[0][0]
__________________________________________________________________________________________________
conv4_block13_1_bn (BatchNormal (None, 11, 11, 128)  512         conv4_block13_1_con
v[0][0]
__________________________________________________________________________________________________
conv4_block13_1_relu (Activatio (None, 11, 11, 128)  0           conv4_block13_1_bn
[0][0]
__________________________________________________________________________________________________
```

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conv4_block13_2_conv (Conv2D)   (None, 11, 11, 32)   36864       conv4_block13_1_rel
u[0][0]
__________________________________________________________________________________
______________
conv4_block13_concat (Concatena (None, 11, 11, 672)  0           conv4_block12_conca
t[0][0]
                                                                 conv4_block13_2_con
v[0][0]
__________________________________________________________________________________
______________
conv4_block14_0_bn (BatchNormal (None, 11, 11, 672)  2688        conv4_block13_conca
t[0][0]
__________________________________________________________________________________
______________
conv4_block14_0_relu (Activatio (None, 11, 11, 672)  0           conv4_block14_0_bn
[0][0]
__________________________________________________________________________________
______________
conv4_block14_1_conv (Conv2D)   (None, 11, 11, 128)  86016       conv4_block14_0_rel
u[0][0]
__________________________________________________________________________________
______________
conv4_block14_1_bn (BatchNormal (None, 11, 11, 128)  512         conv4_block14_1_con
v[0][0]
__________________________________________________________________________________
______________
conv4_block14_1_relu (Activatio (None, 11, 11, 128)  0           conv4_block14_1_bn
[0][0]
__________________________________________________________________________________
______________
conv4_block14_2_conv (Conv2D)   (None, 11, 11, 32)   36864       conv4_block14_1_rel
u[0][0]
__________________________________________________________________________________
______________
conv4_block14_concat (Concatena (None, 11, 11, 704)  0           conv4_block13_conca
t[0][0]
                                                                 conv4_block14_2_con
v[0][0]
__________________________________________________________________________________
______________
conv4_block15_0_bn (BatchNormal (None, 11, 11, 704)  2816        conv4_block14_conca
t[0][0]
__________________________________________________________________________________
______________
conv4_block15_0_relu (Activatio (None, 11, 11, 704)  0           conv4_block15_0_bn
[0][0]
__________________________________________________________________________________
______________
conv4_block15_1_conv (Conv2D)   (None, 11, 11, 128)  90112       conv4_block15_0_rel
u[0][0]
__________________________________________________________________________________
______________
conv4_block15_1_bn (BatchNormal (None, 11, 11, 128)  512         conv4_block15_1_con
v[0][0]
__________________________________________________________________________________
______________
conv4_block15_1_relu (Activatio (None, 11, 11, 128)  0           conv4_block15_1_bn
[0][0]
__________________________________________________________________________________
______________
conv4_block15_2_conv (Conv2D)   (None, 11, 11, 32)   36864       conv4_block15_1_rel
u[0][0]
__________________________________________________________________________________
______________
```

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conv4_block15_concat (Concatena (None, 11, 11, 736)  0           conv4_block14_conca
t[0][0]
                                                                 conv4_block15_2_con
v[0][0]
__________________________________________________________________________________________________
conv4_block16_0_bn (BatchNormal (None, 11, 11, 736)  2944        conv4_block15_conca
t[0][0]
__________________________________________________________________________________________________
conv4_block16_0_relu (Activatio (None, 11, 11, 736)  0           conv4_block16_0_bn
[0][0]
__________________________________________________________________________________________________
conv4_block16_1_conv (Conv2D)   (None, 11, 11, 128)  94208       conv4_block16_0_rel
u[0][0]
__________________________________________________________________________________________________
conv4_block16_1_bn (BatchNormal (None, 11, 11, 128)  512         conv4_block16_1_con
v[0][0]
__________________________________________________________________________________________________
conv4_block16_1_relu (Activatio (None, 11, 11, 128)  0           conv4_block16_1_bn
[0][0]
__________________________________________________________________________________________________
conv4_block16_2_conv (Conv2D)   (None, 11, 11, 32)   36864       conv4_block16_1_rel
u[0][0]
__________________________________________________________________________________________________
conv4_block16_concat (Concatena (None, 11, 11, 768)  0           conv4_block15_conca
t[0][0]
                                                                 conv4_block16_2_con
v[0][0]
__________________________________________________________________________________________________
conv4_block17_0_bn (BatchNormal (None, 11, 11, 768)  3072        conv4_block16_conca
t[0][0]
__________________________________________________________________________________________________
conv4_block17_0_relu (Activatio (None, 11, 11, 768)  0           conv4_block17_0_bn
[0][0]
__________________________________________________________________________________________________
conv4_block17_1_conv (Conv2D)   (None, 11, 11, 128)  98304       conv4_block17_0_rel
u[0][0]
__________________________________________________________________________________________________
conv4_block17_1_bn (BatchNormal (None, 11, 11, 128)  512         conv4_block17_1_con
v[0][0]
__________________________________________________________________________________________________
conv4_block17_1_relu (Activatio (None, 11, 11, 128)  0           conv4_block17_1_bn
[0][0]
__________________________________________________________________________________________________
conv4_block17_2_conv (Conv2D)   (None, 11, 11, 32)   36864       conv4_block17_1_rel
u[0][0]
__________________________________________________________________________________________________
conv4_block17_concat (Concatena (None, 11, 11, 800)  0           conv4_block16_conca
t[0][0]
                                                                 conv4_block17_2_con
v[0][0]
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__________________________________________________________________________________________________
conv4_block18_0_bn (BatchNormal (None, 11, 11, 800)  3200        conv4_block17_concat[0][0]
__________________________________________________________________________________________________
conv4_block18_0_relu (Activatio (None, 11, 11, 800)  0           conv4_block18_0_bn[0][0]
__________________________________________________________________________________________________
conv4_block18_1_conv (Conv2D)   (None, 11, 11, 128)  102400      conv4_block18_0_relu[0][0]
__________________________________________________________________________________________________
conv4_block18_1_bn (BatchNormal (None, 11, 11, 128)  512         conv4_block18_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block18_1_relu (Activatio (None, 11, 11, 128)  0           conv4_block18_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block18_2_conv (Conv2D)   (None, 11, 11, 32)   36864       conv4_block18_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block18_concat (Concatena (None, 11, 11, 832)  0           conv4_block17_concat[0][0]
                                                                 conv4_block18_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block19_0_bn (BatchNormal (None, 11, 11, 832)  3328        conv4_block18_concat[0][0]
__________________________________________________________________________________________________
conv4_block19_0_relu (Activatio (None, 11, 11, 832)  0           conv4_block19_0_bn[0][0]
__________________________________________________________________________________________________
conv4_block19_1_conv (Conv2D)   (None, 11, 11, 128)  106496      conv4_block19_0_relu[0][0]
__________________________________________________________________________________________________
conv4_block19_1_bn (BatchNormal (None, 11, 11, 128)  512         conv4_block19_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block19_1_relu (Activatio (None, 11, 11, 128)  0           conv4_block19_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block19_2_conv (Conv2D)   (None, 11, 11, 32)   36864       conv4_block19_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block19_concat (Concatena (None, 11, 11, 864)  0           conv4_block18_concat[0][0]
                                                                 conv4_block19_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block20_0_bn (BatchNormal (None, 11, 11, 864)  3456        conv4_block19_concat[0][0]
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________________________________________________________________________________________
______________
conv4_block20_0_relu (Activatio (None, 11, 11, 864)  0           conv4_block20_0_bn
[0][0]
________________________________________________________________________________________
______________
conv4_block20_1_conv (Conv2D)   (None, 11, 11, 128)  110592      conv4_block20_0_rel
u[0][0]
________________________________________________________________________________________
______________
conv4_block20_1_bn (BatchNormal (None, 11, 11, 128)  512         conv4_block20_1_con
v[0][0]
________________________________________________________________________________________
______________
conv4_block20_1_relu (Activatio (None, 11, 11, 128)  0           conv4_block20_1_bn
[0][0]
________________________________________________________________________________________
______________
conv4_block20_2_conv (Conv2D)   (None, 11, 11, 32)   36864       conv4_block20_1_rel
u[0][0]
________________________________________________________________________________________
______________
conv4_block20_concat (Concatena (None, 11, 11, 896)  0           conv4_block19_conca
t[0][0]
                                                                 conv4_block20_2_con
v[0][0]
________________________________________________________________________________________
______________
conv4_block21_0_bn (BatchNormal (None, 11, 11, 896)  3584        conv4_block20_conca
t[0][0]
________________________________________________________________________________________
______________
conv4_block21_0_relu (Activatio (None, 11, 11, 896)  0           conv4_block21_0_bn
[0][0]
________________________________________________________________________________________
______________
conv4_block21_1_conv (Conv2D)   (None, 11, 11, 128)  114688      conv4_block21_0_rel
u[0][0]
________________________________________________________________________________________
______________
conv4_block21_1_bn (BatchNormal (None, 11, 11, 128)  512         conv4_block21_1_con
v[0][0]
________________________________________________________________________________________
______________
conv4_block21_1_relu (Activatio (None, 11, 11, 128)  0           conv4_block21_1_bn
[0][0]
________________________________________________________________________________________
______________
conv4_block21_2_conv (Conv2D)   (None, 11, 11, 32)   36864       conv4_block21_1_rel
u[0][0]
________________________________________________________________________________________
______________
conv4_block21_concat (Concatena (None, 11, 11, 928)  0           conv4_block20_conca
t[0][0]
                                                                 conv4_block21_2_con
v[0][0]
________________________________________________________________________________________
______________
conv4_block22_0_bn (BatchNormal (None, 11, 11, 928)  3712        conv4_block21_conca
t[0][0]
________________________________________________________________________________________
______________
conv4_block22_0_relu (Activatio (None, 11, 11, 928)  0           conv4_block22_0_bn
[0][0]
```

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__________________________________________________________________________________________________
conv4_block22_1_conv (Conv2D)   (None, 11, 11, 128)  118784      conv4_block22_0_rel
u[0][0]
__________________________________________________________________________________________________
conv4_block22_1_bn (BatchNormal (None, 11, 11, 128)  512         conv4_block22_1_con
v[0][0]
__________________________________________________________________________________________________
conv4_block22_1_relu (Activatio (None, 11, 11, 128)  0           conv4_block22_1_bn
[0][0]
__________________________________________________________________________________________________
conv4_block22_2_conv (Conv2D)   (None, 11, 11, 32)   36864       conv4_block22_1_rel
u[0][0]
__________________________________________________________________________________________________
conv4_block22_concat (Concatena (None, 11, 11, 960)  0           conv4_block21_conca
t[0][0]
                                                                 conv4_block22_2_con
v[0][0]
__________________________________________________________________________________________________
conv4_block23_0_bn (BatchNormal (None, 11, 11, 960)  3840        conv4_block22_conca
t[0][0]
__________________________________________________________________________________________________
conv4_block23_0_relu (Activatio (None, 11, 11, 960)  0           conv4_block23_0_bn
[0][0]
__________________________________________________________________________________________________
conv4_block23_1_conv (Conv2D)   (None, 11, 11, 128)  122880      conv4_block23_0_rel
u[0][0]
__________________________________________________________________________________________________
conv4_block23_1_bn (BatchNormal (None, 11, 11, 128)  512         conv4_block23_1_con
v[0][0]
__________________________________________________________________________________________________
conv4_block23_1_relu (Activatio (None, 11, 11, 128)  0           conv4_block23_1_bn
[0][0]
__________________________________________________________________________________________________
conv4_block23_2_conv (Conv2D)   (None, 11, 11, 32)   36864       conv4_block23_1_rel
u[0][0]
__________________________________________________________________________________________________
conv4_block23_concat (Concatena (None, 11, 11, 992)  0           conv4_block22_conca
t[0][0]
                                                                 conv4_block23_2_con
v[0][0]
__________________________________________________________________________________________________
conv4_block24_0_bn (BatchNormal (None, 11, 11, 992)  3968        conv4_block23_conca
t[0][0]
__________________________________________________________________________________________________
conv4_block24_0_relu (Activatio (None, 11, 11, 992)  0           conv4_block24_0_bn
[0][0]
__________________________________________________________________________________________________
conv4_block24_1_conv (Conv2D)   (None, 11, 11, 128)  126976      conv4_block24_0_rel
u[0][0]
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__________________________________________________________________________________________________
conv4_block24_1_bn (BatchNormal (None, 11, 11, 128)  512         conv4_block24_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block24_1_relu (Activatio (None, 11, 11, 128)  0           conv4_block24_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block24_2_conv (Conv2D)   (None, 11, 11, 32)   36864       conv4_block24_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block24_concat (Concatena (None, 11, 11, 1024) 0           conv4_block23_concat[0][0]
                                                                 conv4_block24_2_conv[0][0]
__________________________________________________________________________________________________
pool4_bn (BatchNormalization)   (None, 11, 11, 1024) 4096        conv4_block24_concat[0][0]
__________________________________________________________________________________________________
pool4_relu (Activation)         (None, 11, 11, 1024) 0           pool4_bn[0][0]
__________________________________________________________________________________________________
pool4_conv (Conv2D)             (None, 11, 11, 512)  524288      pool4_relu[0][0]
__________________________________________________________________________________________________
pool4_pool (AveragePooling2D)   (None, 5, 5, 512)    0           pool4_conv[0][0]
__________________________________________________________________________________________________
conv5_block1_0_bn (BatchNormali (None, 5, 5, 512)    2048        pool4_pool[0][0]
__________________________________________________________________________________________________
conv5_block1_0_relu (Activation (None, 5, 5, 512)    0           conv5_block1_0_bn[0][0]
__________________________________________________________________________________________________
conv5_block1_1_conv (Conv2D)    (None, 5, 5, 128)    65536       conv5_block1_0_relu[0][0]
__________________________________________________________________________________________________
conv5_block1_1_bn (BatchNormali (None, 5, 5, 128)    512         conv5_block1_1_conv[0][0]
__________________________________________________________________________________________________
conv5_block1_1_relu (Activation (None, 5, 5, 128)    0           conv5_block1_1_bn[0][0]
__________________________________________________________________________________________________
conv5_block1_2_conv (Conv2D)    (None, 5, 5, 32)     36864       conv5_block1_1_relu[0][0]
__________________________________________________________________________________________________
conv5_block1_concat (Concatenat (None, 5, 5, 544)    0           pool4_pool[0][0]
                                                                 conv5_block1_2_conv[0][0]
__________________________________________________________________________________________________
conv5_block2_0_bn (BatchNormali (None, 5, 5, 544)    2176        conv5_block1_concat[0][0]
__________________________________________________________________________________________________
```

```
______________
conv5_block2_0_relu (Activation (None, 5, 5, 544)    0           conv5_block2_0_bn
[0][0]
__________________________________________________________________________________________________
______________
conv5_block2_1_conv (Conv2D)    (None, 5, 5, 128)    69632       conv5_block2_0_relu
[0][0]
__________________________________________________________________________________________________
______________
conv5_block2_1_bn (BatchNormali (None, 5, 5, 128)    512         conv5_block2_1_conv
[0][0]
__________________________________________________________________________________________________
______________
conv5_block2_1_relu (Activation (None, 5, 5, 128)    0           conv5_block2_1_bn
[0][0]
__________________________________________________________________________________________________
______________
conv5_block2_2_conv (Conv2D)    (None, 5, 5, 32)     36864       conv5_block2_1_relu
[0][0]
__________________________________________________________________________________________________
______________
conv5_block2_concat (Concatenat (None, 5, 5, 576)    0           conv5_block1_concat
[0][0]
                                                                 conv5_block2_2_conv
[0][0]
__________________________________________________________________________________________________
______________
conv5_block3_0_bn (BatchNormali (None, 5, 5, 576)    2304        conv5_block2_concat
[0][0]
__________________________________________________________________________________________________
______________
conv5_block3_0_relu (Activation (None, 5, 5, 576)    0           conv5_block3_0_bn
[0][0]
__________________________________________________________________________________________________
______________
conv5_block3_1_conv (Conv2D)    (None, 5, 5, 128)    73728       conv5_block3_0_relu
[0][0]
__________________________________________________________________________________________________
______________
conv5_block3_1_bn (BatchNormali (None, 5, 5, 128)    512         conv5_block3_1_conv
[0][0]
__________________________________________________________________________________________________
______________
conv5_block3_1_relu (Activation (None, 5, 5, 128)    0           conv5_block3_1_bn
[0][0]
__________________________________________________________________________________________________
______________
conv5_block3_2_conv (Conv2D)    (None, 5, 5, 32)     36864       conv5_block3_1_relu
[0][0]
__________________________________________________________________________________________________
______________
conv5_block3_concat (Concatenat (None, 5, 5, 608)    0           conv5_block2_concat
[0][0]
                                                                 conv5_block3_2_conv
[0][0]
__________________________________________________________________________________________________
______________
conv5_block4_0_bn (BatchNormali (None, 5, 5, 608)    2432        conv5_block3_concat
[0][0]
__________________________________________________________________________________________________
______________
conv5_block4_0_relu (Activation (None, 5, 5, 608)    0           conv5_block4_0_bn
[0][0]
__________________________________________________________________________________________________
```

```
__________________________________________________________________________________________________
conv5_block4_1_conv (Conv2D)    (None, 5, 5, 128)    77824       conv5_block4_0_relu[0][0]
__________________________________________________________________________________________________
conv5_block4_1_bn (BatchNormali (None, 5, 5, 128)    512         conv5_block4_1_conv[0][0]
__________________________________________________________________________________________________
conv5_block4_1_relu (Activation (None, 5, 5, 128)    0           conv5_block4_1_bn[0][0]
__________________________________________________________________________________________________
conv5_block4_2_conv (Conv2D)    (None, 5, 5, 32)     36864       conv5_block4_1_relu[0][0]
__________________________________________________________________________________________________
conv5_block4_concat (Concatenat (None, 5, 5, 640)    0           conv5_block3_concat[0][0]
                                                                 conv5_block4_2_conv[0][0]
__________________________________________________________________________________________________
conv5_block5_0_bn (BatchNormali (None, 5, 5, 640)    2560        conv5_block4_concat[0][0]
__________________________________________________________________________________________________
conv5_block5_0_relu (Activation (None, 5, 5, 640)    0           conv5_block5_0_bn[0][0]
__________________________________________________________________________________________________
conv5_block5_1_conv (Conv2D)    (None, 5, 5, 128)    81920       conv5_block5_0_relu[0][0]
__________________________________________________________________________________________________
conv5_block5_1_bn (BatchNormali (None, 5, 5, 128)    512         conv5_block5_1_conv[0][0]
__________________________________________________________________________________________________
conv5_block5_1_relu (Activation (None, 5, 5, 128)    0           conv5_block5_1_bn[0][0]
__________________________________________________________________________________________________
conv5_block5_2_conv (Conv2D)    (None, 5, 5, 32)     36864       conv5_block5_1_relu[0][0]
__________________________________________________________________________________________________
conv5_block5_concat (Concatenat (None, 5, 5, 672)    0           conv5_block4_concat[0][0]
                                                                 conv5_block5_2_conv[0][0]
__________________________________________________________________________________________________
conv5_block6_0_bn (BatchNormali (None, 5, 5, 672)    2688        conv5_block5_concat[0][0]
__________________________________________________________________________________________________
conv5_block6_0_relu (Activation (None, 5, 5, 672)    0           conv5_block6_0_bn[0][0]
__________________________________________________________________________________________________
conv5_block6_1_conv (Conv2D)    (None, 5, 5, 128)    86016       conv5_block6_0_relu[0][0]
__________________________________________________________________________________________________
```

```
__________________
conv5_block6_1_bn (BatchNormali (None, 5, 5, 128)    512         conv5_block6_1_conv
[0][0]
__________________________________________________________________________________________________
__________________
conv5_block6_1_relu (Activation (None, 5, 5, 128)    0           conv5_block6_1_bn
[0][0]
__________________________________________________________________________________________________
__________________
conv5_block6_2_conv (Conv2D)    (None, 5, 5, 32)     36864       conv5_block6_1_relu
[0][0]
__________________________________________________________________________________________________
__________________
conv5_block6_concat (Concatenat (None, 5, 5, 704)    0           conv5_block5_concat
[0][0]
                                                                 conv5_block6_2_conv
[0][0]
__________________________________________________________________________________________________
__________________
conv5_block7_0_bn (BatchNormali (None, 5, 5, 704)    2816        conv5_block6_concat
[0][0]
__________________________________________________________________________________________________
__________________
conv5_block7_0_relu (Activation (None, 5, 5, 704)    0           conv5_block7_0_bn
[0][0]
__________________________________________________________________________________________________
__________________
conv5_block7_1_conv (Conv2D)    (None, 5, 5, 128)    90112       conv5_block7_0_relu
[0][0]
__________________________________________________________________________________________________
__________________
conv5_block7_1_bn (BatchNormali (None, 5, 5, 128)    512         conv5_block7_1_conv
[0][0]
__________________________________________________________________________________________________
__________________
conv5_block7_1_relu (Activation (None, 5, 5, 128)    0           conv5_block7_1_bn
[0][0]
__________________________________________________________________________________________________
__________________
conv5_block7_2_conv (Conv2D)    (None, 5, 5, 32)     36864       conv5_block7_1_relu
[0][0]
__________________________________________________________________________________________________
__________________
conv5_block7_concat (Concatenat (None, 5, 5, 736)    0           conv5_block6_concat
[0][0]
                                                                 conv5_block7_2_conv
[0][0]
__________________________________________________________________________________________________
__________________
conv5_block8_0_bn (BatchNormali (None, 5, 5, 736)    2944        conv5_block7_concat
[0][0]
__________________________________________________________________________________________________
__________________
conv5_block8_0_relu (Activation (None, 5, 5, 736)    0           conv5_block8_0_bn
[0][0]
__________________________________________________________________________________________________
__________________
conv5_block8_1_conv (Conv2D)    (None, 5, 5, 128)    94208       conv5_block8_0_relu
[0][0]
__________________________________________________________________________________________________
__________________
conv5_block8_1_bn (BatchNormali (None, 5, 5, 128)    512         conv5_block8_1_conv
[0][0]
__________________________________________________________________________________________________
```

```
________________
conv5_block8_1_relu (Activation (None, 5, 5, 128)    0           conv5_block8_1_bn
[0][0]
__________________________________________________________________________________________________
conv5_block8_2_conv (Conv2D)    (None, 5, 5, 32)     36864       conv5_block8_1_relu
[0][0]
__________________________________________________________________________________________________
conv5_block8_concat (Concatenat (None, 5, 5, 768)    0           conv5_block7_concat
[0][0]
                                                                 conv5_block8_2_conv
[0][0]
__________________________________________________________________________________________________
conv5_block9_0_bn (BatchNormali (None, 5, 5, 768)    3072        conv5_block8_concat
[0][0]
__________________________________________________________________________________________________
conv5_block9_0_relu (Activation (None, 5, 5, 768)    0           conv5_block9_0_bn
[0][0]
__________________________________________________________________________________________________
conv5_block9_1_conv (Conv2D)    (None, 5, 5, 128)    98304       conv5_block9_0_relu
[0][0]
__________________________________________________________________________________________________
conv5_block9_1_bn (BatchNormali (None, 5, 5, 128)    512         conv5_block9_1_conv
[0][0]
__________________________________________________________________________________________________
conv5_block9_1_relu (Activation (None, 5, 5, 128)    0           conv5_block9_1_bn
[0][0]
__________________________________________________________________________________________________
conv5_block9_2_conv (Conv2D)    (None, 5, 5, 32)     36864       conv5_block9_1_relu
[0][0]
__________________________________________________________________________________________________
conv5_block9_concat (Concatenat (None, 5, 5, 800)    0           conv5_block8_concat
[0][0]
                                                                 conv5_block9_2_conv
[0][0]
__________________________________________________________________________________________________
conv5_block10_0_bn (BatchNormal (None, 5, 5, 800)    3200        conv5_block9_concat
[0][0]
__________________________________________________________________________________________________
conv5_block10_0_relu (Activatio (None, 5, 5, 800)    0           conv5_block10_0_bn
[0][0]
__________________________________________________________________________________________________
conv5_block10_1_conv (Conv2D)   (None, 5, 5, 128)    102400      conv5_block10_0_rel
u[0][0]
__________________________________________________________________________________________________
conv5_block10_1_bn (BatchNormal (None, 5, 5, 128)    512         conv5_block10_1_con
v[0][0]
__________________________________________________________________________________________________
conv5_block10_1_relu (Activatio (None, 5, 5, 128)    0           conv5_block10_1_bn
[0][0]
__________________________________________________________________________________________________
```

```
________________
conv5_block10_2_conv (Conv2D)   (None, 5, 5, 32)     36864       conv5_block10_1_rel
u[0][0]
__________________________________________________________________________________
________________
conv5_block10_concat (Concatena (None, 5, 5, 832)    0           conv5_block9_concat
[0][0]
                                                                 conv5_block10_2_con
v[0][0]
__________________________________________________________________________________
________________
conv5_block11_0_bn (BatchNormal (None, 5, 5, 832)    3328        conv5_block10_conca
t[0][0]
__________________________________________________________________________________
________________
conv5_block11_0_relu (Activatio (None, 5, 5, 832)    0           conv5_block11_0_bn
[0][0]
__________________________________________________________________________________
________________
conv5_block11_1_conv (Conv2D)   (None, 5, 5, 128)    106496      conv5_block11_0_rel
u[0][0]
__________________________________________________________________________________
________________
conv5_block11_1_bn (BatchNormal (None, 5, 5, 128)    512         conv5_block11_1_con
v[0][0]
__________________________________________________________________________________
________________
conv5_block11_1_relu (Activatio (None, 5, 5, 128)    0           conv5_block11_1_bn
[0][0]
__________________________________________________________________________________
________________
conv5_block11_2_conv (Conv2D)   (None, 5, 5, 32)     36864       conv5_block11_1_rel
u[0][0]
__________________________________________________________________________________
________________
conv5_block11_concat (Concatena (None, 5, 5, 864)    0           conv5_block10_conca
t[0][0]
                                                                 conv5_block11_2_con
v[0][0]
__________________________________________________________________________________
________________
conv5_block12_0_bn (BatchNormal (None, 5, 5, 864)    3456        conv5_block11_conca
t[0][0]
__________________________________________________________________________________
________________
conv5_block12_0_relu (Activatio (None, 5, 5, 864)    0           conv5_block12_0_bn
[0][0]
__________________________________________________________________________________
________________
conv5_block12_1_conv (Conv2D)   (None, 5, 5, 128)    110592      conv5_block12_0_rel
u[0][0]
__________________________________________________________________________________
________________
conv5_block12_1_bn (BatchNormal (None, 5, 5, 128)    512         conv5_block12_1_con
v[0][0]
__________________________________________________________________________________
________________
conv5_block12_1_relu (Activatio (None, 5, 5, 128)    0           conv5_block12_1_bn
[0][0]
__________________________________________________________________________________
________________
conv5_block12_2_conv (Conv2D)   (None, 5, 5, 32)     36864       conv5_block12_1_rel
u[0][0]
__________________________________________________________________________________
```

```
_______________
conv5_block12_concat (Concatena (None, 5, 5, 896)    0           conv5_block11_conca
t[0][0]
                                                                 conv5_block12_2_con
v[0][0]
__________________________________________________________________________________________________
_______________
conv5_block13_0_bn (BatchNormal (None, 5, 5, 896)    3584        conv5_block12_conca
t[0][0]
__________________________________________________________________________________________________
_______________
conv5_block13_0_relu (Activatio (None, 5, 5, 896)    0           conv5_block13_0_bn
[0][0]
__________________________________________________________________________________________________
_______________
conv5_block13_1_conv (Conv2D)   (None, 5, 5, 128)    114688      conv5_block13_0_rel
u[0][0]
__________________________________________________________________________________________________
_______________
conv5_block13_1_bn (BatchNormal (None, 5, 5, 128)    512         conv5_block13_1_con
v[0][0]
__________________________________________________________________________________________________
_______________
conv5_block13_1_relu (Activatio (None, 5, 5, 128)    0           conv5_block13_1_bn
[0][0]
__________________________________________________________________________________________________
_______________
conv5_block13_2_conv (Conv2D)   (None, 5, 5, 32)     36864       conv5_block13_1_rel
u[0][0]
__________________________________________________________________________________________________
_______________
conv5_block13_concat (Concatena (None, 5, 5, 928)    0           conv5_block12_conca
t[0][0]
                                                                 conv5_block13_2_con
v[0][0]
__________________________________________________________________________________________________
_______________
conv5_block14_0_bn (BatchNormal (None, 5, 5, 928)    3712        conv5_block13_conca
t[0][0]
__________________________________________________________________________________________________
_______________
conv5_block14_0_relu (Activatio (None, 5, 5, 928)    0           conv5_block14_0_bn
[0][0]
__________________________________________________________________________________________________
_______________
conv5_block14_1_conv (Conv2D)   (None, 5, 5, 128)    118784      conv5_block14_0_rel
u[0][0]
__________________________________________________________________________________________________
_______________
conv5_block14_1_bn (BatchNormal (None, 5, 5, 128)    512         conv5_block14_1_con
v[0][0]
__________________________________________________________________________________________________
_______________
conv5_block14_1_relu (Activatio (None, 5, 5, 128)    0           conv5_block14_1_bn
[0][0]
__________________________________________________________________________________________________
_______________
conv5_block14_2_conv (Conv2D)   (None, 5, 5, 32)     36864       conv5_block14_1_rel
u[0][0]
__________________________________________________________________________________________________
_______________
conv5_block14_concat (Concatena (None, 5, 5, 960)    0           conv5_block13_conca
t[0][0]
                                                                 conv5_block14_2_con
```

```
v[0][0]
__________________________________________________________________________________________________
conv5_block15_0_bn (BatchNormal (None, 5, 5, 960)    3840        conv5_block14_conca
t[0][0]
__________________________________________________________________________________________________
conv5_block15_0_relu (Activatio (None, 5, 5, 960)    0           conv5_block15_0_bn
[0][0]
__________________________________________________________________________________________________
conv5_block15_1_conv (Conv2D)   (None, 5, 5, 128)    122880      conv5_block15_0_rel
u[0][0]
__________________________________________________________________________________________________
conv5_block15_1_bn (BatchNormal (None, 5, 5, 128)    512         conv5_block15_1_con
v[0][0]
__________________________________________________________________________________________________
conv5_block15_1_relu (Activatio (None, 5, 5, 128)    0           conv5_block15_1_bn
[0][0]
__________________________________________________________________________________________________
conv5_block15_2_conv (Conv2D)   (None, 5, 5, 32)     36864       conv5_block15_1_rel
u[0][0]
__________________________________________________________________________________________________
conv5_block15_concat (Concatena (None, 5, 5, 992)    0           conv5_block14_conca
t[0][0]
                                                                 conv5_block15_2_con
v[0][0]
__________________________________________________________________________________________________
conv5_block16_0_bn (BatchNormal (None, 5, 5, 992)    3968        conv5_block15_conca
t[0][0]
__________________________________________________________________________________________________
conv5_block16_0_relu (Activatio (None, 5, 5, 992)    0           conv5_block16_0_bn
[0][0]
__________________________________________________________________________________________________
conv5_block16_1_conv (Conv2D)   (None, 5, 5, 128)    126976      conv5_block16_0_rel
u[0][0]
__________________________________________________________________________________________________
conv5_block16_1_bn (BatchNormal (None, 5, 5, 128)    512         conv5_block16_1_con
v[0][0]
__________________________________________________________________________________________________
conv5_block16_1_relu (Activatio (None, 5, 5, 128)    0           conv5_block16_1_bn
[0][0]
__________________________________________________________________________________________________
conv5_block16_2_conv (Conv2D)   (None, 5, 5, 32)     36864       conv5_block16_1_rel
u[0][0]
__________________________________________________________________________________________________
conv5_block16_concat (Concatena (None, 5, 5, 1024)   0           conv5_block15_conca
t[0][0]
                                                                 conv5_block16_2_con
v[0][0]
__________________________________________________________________________________________________
bn (BatchNormalization)         (None, 5, 5, 1024)   4096        conv5_block16_conca
```

```
t[0][0]
__________________________________________________________________________________________
______________
relu (Activation)                (None, 5, 5, 1024)   0           bn[0][0]
__________________________________________________________________________________________
______________
avg_pool (GlobalAveragePooling2 (None, 1024)          0           relu[0][0]
==========================================================================================
==============
Total params: 7,037,504
Trainable params: 6,953,856
Non-trainable params: 83,648
__________________________________________________________________________________________
______________
```

In [20]:

```
layers = base_model.layers
print(f"The model has {len(layers)} layers")
```

```
The model has 428 layers
```

In [21]:

```
print(f"The input shape {base_model.input}")
print(f"The output shape {base_model.output}")
```

```
The input shape Tensor("input_1:0", shape=(None, 180, 180, 3), dtype=float32)
The output shape Tensor("avg_pool/Mean:0", shape=(None, 1024), dtype=float32)
```

In [22]:

```
#model = Sequential()
base_model = DenseNet121(include_top=False, weights='imagenet')
x = base_model.output

x = GlobalAveragePooling2D()(x)

predictions = Dense(1, activation="sigmoid")(x)

model = Model(inputs=base_model.input, outputs=predictions)
#model.add(base_model)
#model.add(GlobalAveragePooling2D())
#model.add(Dense(1, activation='sigmoid'))

model.compile(loss='binary_crossentropy',
              optimizer='adam',
              metrics=['accuracy'])
```

In [23]:

```
r = model.fit(
    train,
    epochs=10,
    validation_data=validation,
    class_weight=class_weight,
    steps_per_epoch=100,
    validation_steps=25,
)
```

```
Epoch 1/10
100/100 [==============================] - ETA: 0s - loss: 0.1463 - accuracy: 0.8438
WARNING:tensorflow:Your input ran out of data; interrupting training. Make sure that
your dataset or generator can generate at least `steps_per_epoch * epochs` batches
(in this case, 25 batches). You may need to use the repeat() function when building
your dataset.
100/100 [==============================] - 700s 7s/step - loss: 0.1463 - accuracy:
```

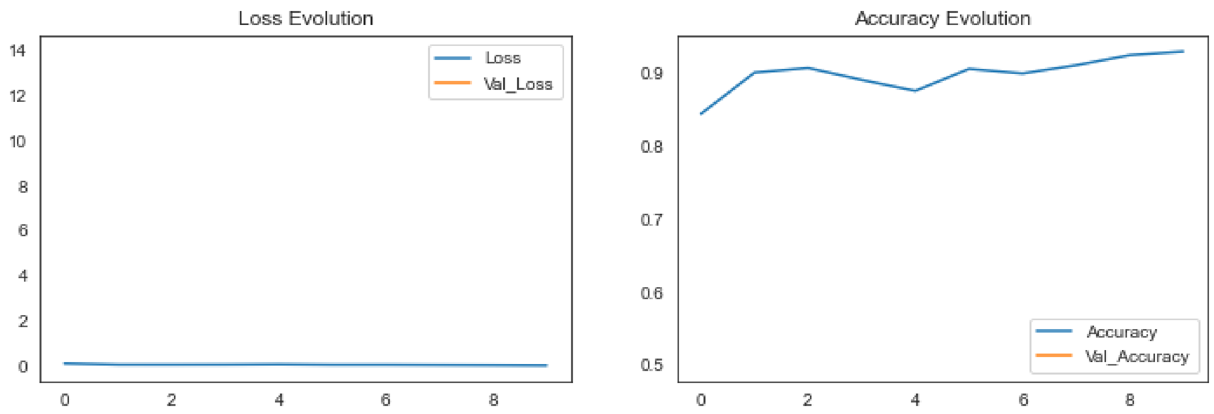
```
0.8438 - val_loss: 13.9214 - val_accuracy: 0.5000
Epoch 2/10
100/100 [==============================] - 692s 7s/step - loss: 0.0960 - accuracy:
0.9000
Epoch 3/10
100/100 [==============================] - 694s 7s/step - loss: 0.0955 - accuracy:
0.9062
Epoch 4/10
100/100 [==============================] - 698s 7s/step - loss: 0.0981 - accuracy:
0.8900
Epoch 5/10
100/100 [==============================] - 692s 7s/step - loss: 0.1079 - accuracy:
0.8750
Epoch 6/10
100/100 [==============================] - 687s 7s/step - loss: 0.0918 - accuracy:
0.9050
Epoch 7/10
100/100 [==============================] - 677s 7s/step - loss: 0.0919 - accuracy:
0.8988
Epoch 8/10
100/100 [==============================] - 682s 7s/step - loss: 0.0836 - accuracy:
0.9100
Epoch 9/10
100/100 [==============================] - 678s 7s/step - loss: 0.0768 - accuracy:
0.9237
Epoch 10/10
100/100 [==============================] - 684s 7s/step - loss: 0.0664 - accuracy:
0.9287
```

In [24]:

```
plt.figure(figsize=(12, 8))

plt.subplot(2, 2, 1)
plt.plot(r.history['loss'], label='Loss')
plt.plot(r.history['val_loss'], label='Val_Loss')
plt.legend()
plt.title('Loss Evolution')

plt.subplot(2, 2, 2)
plt.plot(r.history['accuracy'], label='Accuracy')
plt.plot(r.history['val_accuracy'], label='Val_Accuracy')
plt.legend()
plt.title('Accuracy Evolution')
```

Out[24]:

```
Text(0.5, 1.0, 'Accuracy Evolution')
```



In [25]:

```
evaluation = model.evaluate(test)
print(f"Test Accuracy: {evaluation[1] * 100:.2f}%")
```

```
evaluation = model.evaluate(train)
print(f"Train Accuracy: {evaluation[1] * 100:.2f}%")
```

```
624/624 [==============================] - 140s 224ms/step - loss: 0.5100 - accurac
y: 0.7676
Test Accuracy: 76.76%
652/652 [==============================] - 937s 1s/step - loss: 0.6964 - accuracy:
0.6848
Train Accuracy: 68.48%
```

Evaluation

In [26]:

```
predicted_vals = model.predict(test, steps=len(test))
```

In [27]:

```
print(confusion_matrix(test.classes, predicted_vals > 0.5))
pd.DataFrame(classification_report(test.classes, predicted_vals > 0.5, output_dict=T
```

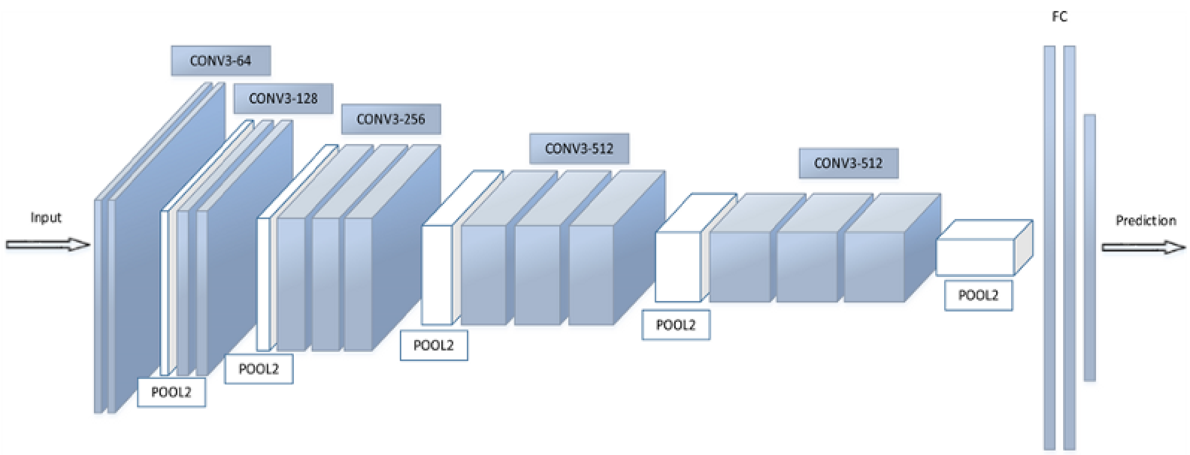
```
[[227   7]
 [150 240]]
```

Out[27]:

	0	1	accuracy	macro avg	weighted avg
precision	0.602122	0.971660	0.748397	0.786891	0.833083
recall	0.970085	0.615385	0.748397	0.792735	0.748397
f1-score	0.743044	0.753532	0.748397	0.748288	0.749599
support	234.000000	390.000000	0.748397	624.000000	624.000000

VGG16

Presented in 2014, VGG16 has a very simple and classical architecture, with blocks of 2 or 3 convolutional layers followed by a pooling layer, plus a final dense network composed of 2 hidden layers (of 4096 nodes each) and one output layer (of 1000 nodes). Only 3x3 filters are used.



In [28]:

```
from keras.models import Sequential
from keras.layers import GlobalAveragePooling2D
from keras.applications import VGG16
```

```
vgg16_base_model = VGG16(input_shape=(180,180,3),include_top=False,weights='imagenet
```

In [29]:

```
vgg16_base_model.summary()
```

```
Model: "vgg16"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
input_3 (InputLayer)         [(None, 180, 180, 3)]     0         
_________________________________________________________________
block1_conv1 (Conv2D)        (None, 180, 180, 64)      1792      
_________________________________________________________________
block1_conv2 (Conv2D)        (None, 180, 180, 64)      36928     
_________________________________________________________________
block1_pool (MaxPooling2D)   (None, 90, 90, 64)        0         
_________________________________________________________________
block2_conv1 (Conv2D)        (None, 90, 90, 128)       73856     
_________________________________________________________________
block2_conv2 (Conv2D)        (None, 90, 90, 128)       147584    
_________________________________________________________________
block2_pool (MaxPooling2D)   (None, 45, 45, 128)       0         
_________________________________________________________________
block3_conv1 (Conv2D)        (None, 45, 45, 256)       295168    
_________________________________________________________________
block3_conv2 (Conv2D)        (None, 45, 45, 256)       590080    
_________________________________________________________________
block3_conv3 (Conv2D)        (None, 45, 45, 256)       590080    
_________________________________________________________________
block3_pool (MaxPooling2D)   (None, 22, 22, 256)       0         
_________________________________________________________________
block4_conv1 (Conv2D)        (None, 22, 22, 512)       1180160   
_________________________________________________________________
block4_conv2 (Conv2D)        (None, 22, 22, 512)       2359808   
_________________________________________________________________
block4_conv3 (Conv2D)        (None, 22, 22, 512)       2359808   
_________________________________________________________________
block4_pool (MaxPooling2D)   (None, 11, 11, 512)       0         
_________________________________________________________________
block5_conv1 (Conv2D)        (None, 11, 11, 512)       2359808   
_________________________________________________________________
block5_conv2 (Conv2D)        (None, 11, 11, 512)       2359808   
_________________________________________________________________
block5_conv3 (Conv2D)        (None, 11, 11, 512)       2359808   
_________________________________________________________________
block5_pool (MaxPooling2D)   (None, 5, 5, 512)         0         
=================================================================
Total params: 14,714,688
Trainable params: 14,714,688
Non-trainable params: 0
_________________________________________________________________
```

In [30]:

```
    vgg16_model = Sequential([
        vgg16_base_model,
        GlobalAveragePooling2D(),
        Dense(512, activation="relu"),
        BatchNormalization(),
        Dropout(0.6),
        Dense(128, activation="relu"),
        BatchNormalization(),
        Dropout(0.4),
```

```
        Dense(64,activation="relu"),
        BatchNormalization(),
        Dropout(0.3),
        Dense(1,activation="sigmoid")
    ])

model = Sequential()
model.add(vgg16_model.layers[0])
```

In [31]:

```
    opt = tf.keras.optimizers.Adam(learning_rate=0.001)
    METRICS = [
        'accuracy',
        tf.keras.metrics.Precision(name='precision'),
        tf.keras.metrics.Recall(name='recall')
    ]
    vgg16_model.compile(optimizer=opt,loss='binary_crossentropy',metrics=METRICS)
```

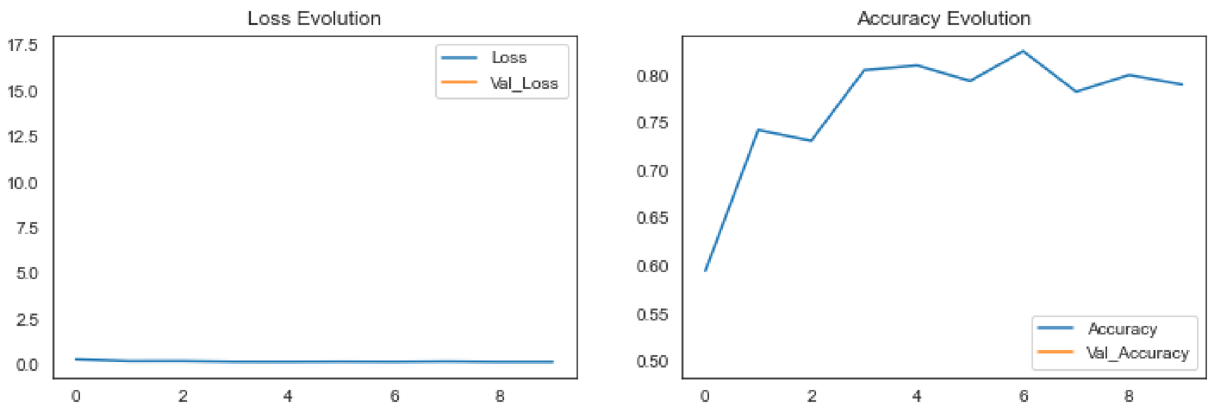
In [32]:

```
r = vgg16_model.fit(train,
          epochs=10,
          validation_data=validation,
          class_weight=class_weight,
          steps_per_epoch=100,
          validation_steps=25)
```

```
Epoch 1/10
100/100 [==============================] - ETA: 0s - loss: 0.2962 - accuracy: 0.5950
- precision: 0.8444 - recall: 0.5672 WARNING:tensorflow:Your input ran out of data;
interrupting training. Make sure that your dataset or generator can generate at leas
t `steps_per_epoch * epochs` batches (in this case, 25 batches). You may need to use
the repeat() function when building your dataset.
100/100 [==============================] - 1595s 16s/step - loss: 0.2962 - accuracy:
0.5950 - precision: 0.8444 - recall: 0.5672 - val_loss: 17.1873 - val_accuracy: 0.50
00 - val_precision: 0.0000e+00 - val_recall: 0.0000e+00
Epoch 2/10
100/100 [==============================] - 1588s 16s/step - loss: 0.1996 - accuracy:
0.7425 - precision: 0.9212 - recall: 0.7124
Epoch 3/10
100/100 [==============================] - 1993s 20s/step - loss: 0.2028 - accuracy:
0.7312 - precision: 0.9119 - recall: 0.7212
Epoch 4/10
100/100 [==============================] - 1701s 17s/step - loss: 0.1667 - accuracy:
0.8050 - precision: 0.9335 - recall: 0.7963
Epoch 5/10
100/100 [==============================] - 1620s 16s/step - loss: 0.1641 - accuracy:
0.8100 - precision: 0.9259 - recall: 0.7951
Epoch 6/10
100/100 [==============================] - 1595s 16s/step - loss: 0.1726 - accuracy:
0.7937 - precision: 0.9395 - recall: 0.7754
Epoch 7/10
100/100 [==============================] - 1593s 16s/step - loss: 0.1651 - accuracy:
0.8250 - precision: 0.9425 - recall: 0.8106
Epoch 8/10
100/100 [==============================] - 1576s 16s/step - loss: 0.1827 - accuracy:
0.7825 - precision: 0.9217 - recall: 0.7727
Epoch 9/10
100/100 [==============================] - 1789s 18s/step - loss: 0.1603 - accuracy:
0.8000 - precision: 0.9391 - recall: 0.7808
Epoch 10/10
100/100 [==============================] - 1650s 16s/step - loss: 0.1606 - accuracy:
0.7900 - precision: 0.9378 - recall: 0.7661
```

In [33]:
```
plt.figure(figsize=(12, 8))

plt.subplot(2, 2, 1)
plt.plot(r.history['loss'], label='Loss')
plt.plot(r.history['val_loss'], label='Val_Loss')
plt.legend()
plt.title('Loss Evolution')

plt.subplot(2, 2, 2)
plt.plot(r.history['accuracy'], label='Accuracy')
plt.plot(r.history['val_accuracy'], label='Val_Accuracy')
plt.legend()
plt.title('Accuracy Evolution')
```

Out[33]:
```
Text(0.5, 1.0, 'Accuracy Evolution')
```



In [34]:
```
evaluation =vgg16_model.evaluate(test)
print(f"Test Accuracy: {evaluation[1] * 100:.2f}%")

evaluation = vgg16_model.evaluate(train)
print(f"Train Accuracy: {evaluation[1] * 100:.2f}%")
```

```
624/624 [==============================] - 416s 666ms/step - loss: 0.6091 - accurac
y: 0.7163 - precision: 0.7036 - recall: 0.9436
Test Accuracy: 71.63%
652/652 [==============================] - 3235s 5s/step - loss: 0.3134 - accuracy:
0.8600 - precision: 0.8803 - recall: 0.9394
Train Accuracy: 86.00%
```

ResNet

See the full explanation and schemes in the Research Paper on Deep Residual Learning (https://arxiv.org/pdf/1512.03385.pdf)

In [35]:
```
from keras.applications import ResNet50

resnet_base_model = ResNet50(input_shape=(180,180,3), include_top=False, weights='im
```

In [36]:
```
resnet_base_model.summary()
```

```
Model: "resnet50"
__________________________________________________________________________________________________
Layer (type)                    Output Shape         Param #     Connected to
==================================================================================================
```

```
==============
input_4 (InputLayer)            [(None, 180, 180, 3) 0
__________________________________________________________________________________________________
conv1_pad (ZeroPadding2D)       (None, 186, 186, 3)  0           input_4[0][0]
__________________________________________________________________________________________________
conv1_conv (Conv2D)             (None, 90, 90, 64)   9472        conv1_pad[0][0]
__________________________________________________________________________________________________
conv1_bn (BatchNormalization)   (None, 90, 90, 64)   256         conv1_conv[0][0]
__________________________________________________________________________________________________
conv1_relu (Activation)         (None, 90, 90, 64)   0           conv1_bn[0][0]
__________________________________________________________________________________________________
pool1_pad (ZeroPadding2D)       (None, 92, 92, 64)   0           conv1_relu[0][0]
__________________________________________________________________________________________________
pool1_pool (MaxPooling2D)       (None, 45, 45, 64)   0           pool1_pad[0][0]
__________________________________________________________________________________________________
conv2_block1_1_conv (Conv2D)    (None, 45, 45, 64)   4160        pool1_pool[0][0]
__________________________________________________________________________________________________
conv2_block1_1_bn (BatchNormali (None, 45, 45, 64)   256         conv2_block1_1_conv
[0][0]
__________________________________________________________________________________________________
conv2_block1_1_relu (Activation (None, 45, 45, 64)   0           conv2_block1_1_bn
[0][0]
__________________________________________________________________________________________________
conv2_block1_2_conv (Conv2D)    (None, 45, 45, 64)   36928       conv2_block1_1_relu
[0][0]
__________________________________________________________________________________________________
conv2_block1_2_bn (BatchNormali (None, 45, 45, 64)   256         conv2_block1_2_conv
[0][0]
__________________________________________________________________________________________________
conv2_block1_2_relu (Activation (None, 45, 45, 64)   0           conv2_block1_2_bn
[0][0]
__________________________________________________________________________________________________
conv2_block1_0_conv (Conv2D)    (None, 45, 45, 256)  16640       pool1_pool[0][0]
__________________________________________________________________________________________________
conv2_block1_3_conv (Conv2D)    (None, 45, 45, 256)  16640       conv2_block1_2_relu
[0][0]
__________________________________________________________________________________________________
conv2_block1_0_bn (BatchNormali (None, 45, 45, 256)  1024        conv2_block1_0_conv
[0][0]
__________________________________________________________________________________________________
conv2_block1_3_bn (BatchNormali (None, 45, 45, 256)  1024        conv2_block1_3_conv
[0][0]
__________________________________________________________________________________________________
conv2_block1_add (Add)          (None, 45, 45, 256)  0           conv2_block1_0_bn
[0][0]
                                                                 conv2_block1_3_bn
[0][0]
```

```
__________________________________________________________________________________________________
conv2_block1_out (Activation)   (None, 45, 45, 256)  0           conv2_block1_add[0][0]
__________________________________________________________________________________________________
conv2_block2_1_conv (Conv2D)    (None, 45, 45, 64)   16448       conv2_block1_out[0][0]
__________________________________________________________________________________________________
conv2_block2_1_bn (BatchNormali (None, 45, 45, 64)   256         conv2_block2_1_conv[0][0]
__________________________________________________________________________________________________
conv2_block2_1_relu (Activation (None, 45, 45, 64)   0           conv2_block2_1_bn[0][0]
__________________________________________________________________________________________________
conv2_block2_2_conv (Conv2D)    (None, 45, 45, 64)   36928       conv2_block2_1_relu[0][0]
__________________________________________________________________________________________________
conv2_block2_2_bn (BatchNormali (None, 45, 45, 64)   256         conv2_block2_2_conv[0][0]
__________________________________________________________________________________________________
conv2_block2_2_relu (Activation (None, 45, 45, 64)   0           conv2_block2_2_bn[0][0]
__________________________________________________________________________________________________
conv2_block2_3_conv (Conv2D)    (None, 45, 45, 256)  16640       conv2_block2_2_relu[0][0]
__________________________________________________________________________________________________
conv2_block2_3_bn (BatchNormali (None, 45, 45, 256)  1024        conv2_block2_3_conv[0][0]
__________________________________________________________________________________________________
conv2_block2_add (Add)          (None, 45, 45, 256)  0           conv2_block1_out[0][0]
                                                                 conv2_block2_3_bn[0][0]
__________________________________________________________________________________________________
conv2_block2_out (Activation)   (None, 45, 45, 256)  0           conv2_block2_add[0][0]
__________________________________________________________________________________________________
conv2_block3_1_conv (Conv2D)    (None, 45, 45, 64)   16448       conv2_block2_out[0][0]
__________________________________________________________________________________________________
conv2_block3_1_bn (BatchNormali (None, 45, 45, 64)   256         conv2_block3_1_conv[0][0]
__________________________________________________________________________________________________
conv2_block3_1_relu (Activation (None, 45, 45, 64)   0           conv2_block3_1_bn[0][0]
__________________________________________________________________________________________________
conv2_block3_2_conv (Conv2D)    (None, 45, 45, 64)   36928       conv2_block3_1_relu[0][0]
__________________________________________________________________________________________________
```

```
conv2_block3_2_bn (BatchNormali (None, 45, 45, 64)   256         conv2_block3_2_conv
[0][0]
__________________________________________________________________________________________________
conv2_block3_2_relu (Activation (None, 45, 45, 64)   0           conv2_block3_2_bn
[0][0]
__________________________________________________________________________________________________
conv2_block3_3_conv (Conv2D)    (None, 45, 45, 256)  16640       conv2_block3_2_relu
[0][0]
__________________________________________________________________________________________________
conv2_block3_3_bn (BatchNormali (None, 45, 45, 256)  1024        conv2_block3_3_conv
[0][0]
__________________________________________________________________________________________________
conv2_block3_add (Add)          (None, 45, 45, 256)  0           conv2_block2_out[0]
[0]
                                                                 conv2_block3_3_bn
[0][0]
__________________________________________________________________________________________________
conv2_block3_out (Activation)   (None, 45, 45, 256)  0           conv2_block3_add[0]
[0]
__________________________________________________________________________________________________
conv3_block1_1_conv (Conv2D)    (None, 23, 23, 128)  32896       conv2_block3_out[0]
[0]
__________________________________________________________________________________________________
conv3_block1_1_bn (BatchNormali (None, 23, 23, 128)  512         conv3_block1_1_conv
[0][0]
__________________________________________________________________________________________________
conv3_block1_1_relu (Activation (None, 23, 23, 128)  0           conv3_block1_1_bn
[0][0]
__________________________________________________________________________________________________
conv3_block1_2_conv (Conv2D)    (None, 23, 23, 128)  147584      conv3_block1_1_relu
[0][0]
__________________________________________________________________________________________________
conv3_block1_2_bn (BatchNormali (None, 23, 23, 128)  512         conv3_block1_2_conv
[0][0]
__________________________________________________________________________________________________
conv3_block1_2_relu (Activation (None, 23, 23, 128)  0           conv3_block1_2_bn
[0][0]
__________________________________________________________________________________________________
conv3_block1_0_conv (Conv2D)    (None, 23, 23, 512)  131584      conv2_block3_out[0]
[0]
__________________________________________________________________________________________________
conv3_block1_3_conv (Conv2D)    (None, 23, 23, 512)  66048       conv3_block1_2_relu
[0][0]
__________________________________________________________________________________________________
conv3_block1_0_bn (BatchNormali (None, 23, 23, 512)  2048        conv3_block1_0_conv
[0][0]
__________________________________________________________________________________________________
conv3_block1_3_bn (BatchNormali (None, 23, 23, 512)  2048        conv3_block1_3_conv
[0][0]
```

```
__________________________________________________________________________________
________________
conv3_block1_add (Add)          (None, 23, 23, 512)  0           conv3_block1_0_bn
[0][0]
                                                                 conv3_block1_3_bn
[0][0]
__________________________________________________________________________________
________________
conv3_block1_out (Activation)   (None, 23, 23, 512)  0           conv3_block1_add[0]
[0]
__________________________________________________________________________________
________________
conv3_block2_1_conv (Conv2D)    (None, 23, 23, 128)  65664       conv3_block1_out[0]
[0]
__________________________________________________________________________________
________________
conv3_block2_1_bn (BatchNormali (None, 23, 23, 128)  512         conv3_block2_1_conv
[0][0]
__________________________________________________________________________________
________________
conv3_block2_1_relu (Activation (None, 23, 23, 128)  0           conv3_block2_1_bn
[0][0]
__________________________________________________________________________________
________________
conv3_block2_2_conv (Conv2D)    (None, 23, 23, 128)  147584      conv3_block2_1_relu
[0][0]
__________________________________________________________________________________
________________
conv3_block2_2_bn (BatchNormali (None, 23, 23, 128)  512         conv3_block2_2_conv
[0][0]
__________________________________________________________________________________
________________
conv3_block2_2_relu (Activation (None, 23, 23, 128)  0           conv3_block2_2_bn
[0][0]
__________________________________________________________________________________
________________
conv3_block2_3_conv (Conv2D)    (None, 23, 23, 512)  66048       conv3_block2_2_relu
[0][0]
__________________________________________________________________________________
________________
conv3_block2_3_bn (BatchNormali (None, 23, 23, 512)  2048        conv3_block2_3_conv
[0][0]
__________________________________________________________________________________
________________
conv3_block2_add (Add)          (None, 23, 23, 512)  0           conv3_block1_out[0]
[0]
                                                                 conv3_block2_3_bn
[0][0]
__________________________________________________________________________________
________________
conv3_block2_out (Activation)   (None, 23, 23, 512)  0           conv3_block2_add[0]
[0]
__________________________________________________________________________________
________________
conv3_block3_1_conv (Conv2D)    (None, 23, 23, 128)  65664       conv3_block2_out[0]
[0]
__________________________________________________________________________________
________________
conv3_block3_1_bn (BatchNormali (None, 23, 23, 128)  512         conv3_block3_1_conv
[0][0]
__________________________________________________________________________________
________________
conv3_block3_1_relu (Activation (None, 23, 23, 128)  0           conv3_block3_1_bn
[0][0]
```

```
__________________________________________________________________________________________________
conv3_block3_2_conv (Conv2D)    (None, 23, 23, 128)  147584      conv3_block3_1_relu[0][0]
__________________________________________________________________________________________________
conv3_block3_2_bn (BatchNormali (None, 23, 23, 128)  512         conv3_block3_2_conv[0][0]
__________________________________________________________________________________________________
conv3_block3_2_relu (Activation (None, 23, 23, 128)  0           conv3_block3_2_bn[0][0]
__________________________________________________________________________________________________
conv3_block3_3_conv (Conv2D)    (None, 23, 23, 512)  66048       conv3_block3_2_relu[0][0]
__________________________________________________________________________________________________
conv3_block3_3_bn (BatchNormali (None, 23, 23, 512)  2048        conv3_block3_3_conv[0][0]
__________________________________________________________________________________________________
conv3_block3_add (Add)          (None, 23, 23, 512)  0           conv3_block2_out[0][0]
                                                                 conv3_block3_3_bn[0][0]
__________________________________________________________________________________________________
conv3_block3_out (Activation)   (None, 23, 23, 512)  0           conv3_block3_add[0][0]
__________________________________________________________________________________________________
conv3_block4_1_conv (Conv2D)    (None, 23, 23, 128)  65664       conv3_block3_out[0][0]
__________________________________________________________________________________________________
conv3_block4_1_bn (BatchNormali (None, 23, 23, 128)  512         conv3_block4_1_conv[0][0]
__________________________________________________________________________________________________
conv3_block4_1_relu (Activation (None, 23, 23, 128)  0           conv3_block4_1_bn[0][0]
__________________________________________________________________________________________________
conv3_block4_2_conv (Conv2D)    (None, 23, 23, 128)  147584      conv3_block4_1_relu[0][0]
__________________________________________________________________________________________________
conv3_block4_2_bn (BatchNormali (None, 23, 23, 128)  512         conv3_block4_2_conv[0][0]
__________________________________________________________________________________________________
conv3_block4_2_relu (Activation (None, 23, 23, 128)  0           conv3_block4_2_bn[0][0]
__________________________________________________________________________________________________
conv3_block4_3_conv (Conv2D)    (None, 23, 23, 512)  66048       conv3_block4_2_relu[0][0]
__________________________________________________________________________________________________
conv3_block4_3_bn (BatchNormali (None, 23, 23, 512)  2048        conv3_block4_3_conv[0][0]
__________________________________________________________________________________________________
```

```
conv3_block4_add (Add)          (None, 23, 23, 512)  0           conv3_block3_out[0]
[0]
                                                                 conv3_block4_3_bn
[0][0]
__________________________________________________________________________________
________________
conv3_block4_out (Activation)   (None, 23, 23, 512)  0           conv3_block4_add[0]
[0]
__________________________________________________________________________________
________________
conv4_block1_1_conv (Conv2D)    (None, 12, 12, 256)  131328      conv3_block4_out[0]
[0]
__________________________________________________________________________________
________________
conv4_block1_1_bn (BatchNormali (None, 12, 12, 256)  1024        conv4_block1_1_conv
[0][0]
__________________________________________________________________________________
________________
conv4_block1_1_relu (Activation (None, 12, 12, 256)  0           conv4_block1_1_bn
[0][0]
__________________________________________________________________________________
________________
conv4_block1_2_conv (Conv2D)    (None, 12, 12, 256)  590080      conv4_block1_1_relu
[0][0]
__________________________________________________________________________________
________________
conv4_block1_2_bn (BatchNormali (None, 12, 12, 256)  1024        conv4_block1_2_conv
[0][0]
__________________________________________________________________________________
________________
conv4_block1_2_relu (Activation (None, 12, 12, 256)  0           conv4_block1_2_bn
[0][0]
__________________________________________________________________________________
________________
conv4_block1_0_conv (Conv2D)    (None, 12, 12, 1024) 525312      conv3_block4_out[0]
[0]
__________________________________________________________________________________
________________
conv4_block1_3_conv (Conv2D)    (None, 12, 12, 1024) 263168      conv4_block1_2_relu
[0][0]
__________________________________________________________________________________
________________
conv4_block1_0_bn (BatchNormali (None, 12, 12, 1024) 4096        conv4_block1_0_conv
[0][0]
__________________________________________________________________________________
________________
conv4_block1_3_bn (BatchNormali (None, 12, 12, 1024) 4096        conv4_block1_3_conv
[0][0]
__________________________________________________________________________________
________________
conv4_block1_add (Add)          (None, 12, 12, 1024) 0           conv4_block1_0_bn
[0][0]
                                                                 conv4_block1_3_bn
[0][0]
__________________________________________________________________________________
________________
conv4_block1_out (Activation)   (None, 12, 12, 1024) 0           conv4_block1_add[0]
[0]
__________________________________________________________________________________
________________
conv4_block2_1_conv (Conv2D)    (None, 12, 12, 256)  262400      conv4_block1_out[0]
[0]
__________________________________________________________________________________
________________
```

```
conv4_block2_1_bn (BatchNormali (None, 12, 12, 256)  1024        conv4_block2_1_conv
[0][0]
__________________________________________________________________________________
conv4_block2_1_relu (Activation (None, 12, 12, 256)  0           conv4_block2_1_bn
[0][0]
__________________________________________________________________________________
conv4_block2_2_conv (Conv2D)    (None, 12, 12, 256)  590080      conv4_block2_1_relu
[0][0]
__________________________________________________________________________________
conv4_block2_2_bn (BatchNormali (None, 12, 12, 256)  1024        conv4_block2_2_conv
[0][0]
__________________________________________________________________________________
conv4_block2_2_relu (Activation (None, 12, 12, 256)  0           conv4_block2_2_bn
[0][0]
__________________________________________________________________________________
conv4_block2_3_conv (Conv2D)    (None, 12, 12, 1024) 263168      conv4_block2_2_relu
[0][0]
__________________________________________________________________________________
conv4_block2_3_bn (BatchNormali (None, 12, 12, 1024) 4096        conv4_block2_3_conv
[0][0]
__________________________________________________________________________________
conv4_block2_add (Add)          (None, 12, 12, 1024) 0           conv4_block1_out[0]
[0]
                                                                 conv4_block2_3_bn
[0][0]
__________________________________________________________________________________
conv4_block2_out (Activation)   (None, 12, 12, 1024) 0           conv4_block2_add[0]
[0]
__________________________________________________________________________________
conv4_block3_1_conv (Conv2D)    (None, 12, 12, 256)  262400      conv4_block2_out[0]
[0]
__________________________________________________________________________________
conv4_block3_1_bn (BatchNormali (None, 12, 12, 256)  1024        conv4_block3_1_conv
[0][0]
__________________________________________________________________________________
conv4_block3_1_relu (Activation (None, 12, 12, 256)  0           conv4_block3_1_bn
[0][0]
__________________________________________________________________________________
conv4_block3_2_conv (Conv2D)    (None, 12, 12, 256)  590080      conv4_block3_1_relu
[0][0]
__________________________________________________________________________________
conv4_block3_2_bn (BatchNormali (None, 12, 12, 256)  1024        conv4_block3_2_conv
[0][0]
__________________________________________________________________________________
conv4_block3_2_relu (Activation (None, 12, 12, 256)  0           conv4_block3_2_bn
[0][0]
__________________________________________________________________________________
conv4_block3_3_conv (Conv2D)    (None, 12, 12, 1024) 263168      conv4_block3_2_relu
[0][0]
```

```
__________________________________________________________________________________________________
conv4_block3_3_bn (BatchNormali (None, 12, 12, 1024) 4096        conv4_block3_3_conv[0][0]
__________________________________________________________________________________________________
conv4_block3_add (Add)          (None, 12, 12, 1024) 0           conv4_block2_out[0][0]
                                                                 conv4_block3_3_bn[0][0]
__________________________________________________________________________________________________
conv4_block3_out (Activation)   (None, 12, 12, 1024) 0           conv4_block3_add[0][0]
__________________________________________________________________________________________________
conv4_block4_1_conv (Conv2D)    (None, 12, 12, 256)  262400      conv4_block3_out[0][0]
__________________________________________________________________________________________________
conv4_block4_1_bn (BatchNormali (None, 12, 12, 256)  1024        conv4_block4_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block4_1_relu (Activation (None, 12, 12, 256)  0           conv4_block4_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block4_2_conv (Conv2D)    (None, 12, 12, 256)  590080      conv4_block4_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block4_2_bn (BatchNormali (None, 12, 12, 256)  1024        conv4_block4_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block4_2_relu (Activation (None, 12, 12, 256)  0           conv4_block4_2_bn[0][0]
__________________________________________________________________________________________________
conv4_block4_3_conv (Conv2D)    (None, 12, 12, 1024) 263168      conv4_block4_2_relu[0][0]
__________________________________________________________________________________________________
conv4_block4_3_bn (BatchNormali (None, 12, 12, 1024) 4096        conv4_block4_3_conv[0][0]
__________________________________________________________________________________________________
conv4_block4_add (Add)          (None, 12, 12, 1024) 0           conv4_block3_out[0][0]
                                                                 conv4_block4_3_bn[0][0]
__________________________________________________________________________________________________
conv4_block4_out (Activation)   (None, 12, 12, 1024) 0           conv4_block4_add[0][0]
__________________________________________________________________________________________________
conv4_block5_1_conv (Conv2D)    (None, 12, 12, 256)  262400      conv4_block4_out[0][0]
__________________________________________________________________________________________________
conv4_block5_1_bn (BatchNormali (None, 12, 12, 256)  1024        conv4_block5_1_conv[0][0]
```

```
__________________________________________________________________________________
conv4_block5_1_relu (Activation (None, 12, 12, 256)  0           conv4_block5_1_bn
[0][0]
__________________________________________________________________________________
conv4_block5_2_conv (Conv2D)    (None, 12, 12, 256)  590080      conv4_block5_1_relu
[0][0]
__________________________________________________________________________________
conv4_block5_2_bn (BatchNormali (None, 12, 12, 256)  1024        conv4_block5_2_conv
[0][0]
__________________________________________________________________________________
conv4_block5_2_relu (Activation (None, 12, 12, 256)  0           conv4_block5_2_bn
[0][0]
__________________________________________________________________________________
conv4_block5_3_conv (Conv2D)    (None, 12, 12, 1024) 263168      conv4_block5_2_relu
[0][0]
__________________________________________________________________________________
conv4_block5_3_bn (BatchNormali (None, 12, 12, 1024) 4096        conv4_block5_3_conv
[0][0]
__________________________________________________________________________________
conv4_block5_add (Add)          (None, 12, 12, 1024) 0           conv4_block4_out[0]
[0]
                                                                 conv4_block5_3_bn
[0][0]
__________________________________________________________________________________
conv4_block5_out (Activation)   (None, 12, 12, 1024) 0           conv4_block5_add[0]
[0]
__________________________________________________________________________________
conv4_block6_1_conv (Conv2D)    (None, 12, 12, 256)  262400      conv4_block5_out[0]
[0]
__________________________________________________________________________________
conv4_block6_1_bn (BatchNormali (None, 12, 12, 256)  1024        conv4_block6_1_conv
[0][0]
__________________________________________________________________________________
conv4_block6_1_relu (Activation (None, 12, 12, 256)  0           conv4_block6_1_bn
[0][0]
__________________________________________________________________________________
conv4_block6_2_conv (Conv2D)    (None, 12, 12, 256)  590080      conv4_block6_1_relu
[0][0]
__________________________________________________________________________________
conv4_block6_2_bn (BatchNormali (None, 12, 12, 256)  1024        conv4_block6_2_conv
[0][0]
__________________________________________________________________________________
conv4_block6_2_relu (Activation (None, 12, 12, 256)  0           conv4_block6_2_bn
[0][0]
__________________________________________________________________________________
conv4_block6_3_conv (Conv2D)    (None, 12, 12, 1024) 263168      conv4_block6_2_relu
[0][0]
__________________________________________________________________________________
```

```
conv4_block6_3_bn (BatchNormali (None, 12, 12, 1024) 4096        conv4_block6_3_conv
[0][0]
__________________________________________________________________________________________________
conv4_block6_add (Add)          (None, 12, 12, 1024) 0           conv4_block5_out[0]
[0]
                                                                 conv4_block6_3_bn
[0][0]
__________________________________________________________________________________________________
conv4_block6_out (Activation)   (None, 12, 12, 1024) 0           conv4_block6_add[0]
[0]
__________________________________________________________________________________________________
conv5_block1_1_conv (Conv2D)    (None, 6, 6, 512)    524800      conv4_block6_out[0]
[0]
__________________________________________________________________________________________________
conv5_block1_1_bn (BatchNormali (None, 6, 6, 512)    2048        conv5_block1_1_conv
[0][0]
__________________________________________________________________________________________________
conv5_block1_1_relu (Activation (None, 6, 6, 512)    0           conv5_block1_1_bn
[0][0]
__________________________________________________________________________________________________
conv5_block1_2_conv (Conv2D)    (None, 6, 6, 512)    2359808     conv5_block1_1_relu
[0][0]
__________________________________________________________________________________________________
conv5_block1_2_bn (BatchNormali (None, 6, 6, 512)    2048        conv5_block1_2_conv
[0][0]
__________________________________________________________________________________________________
conv5_block1_2_relu (Activation (None, 6, 6, 512)    0           conv5_block1_2_bn
[0][0]
__________________________________________________________________________________________________
conv5_block1_0_conv (Conv2D)    (None, 6, 6, 2048)   2099200     conv4_block6_out[0]
[0]
__________________________________________________________________________________________________
conv5_block1_3_conv (Conv2D)    (None, 6, 6, 2048)   1050624     conv5_block1_2_relu
[0][0]
__________________________________________________________________________________________________
conv5_block1_0_bn (BatchNormali (None, 6, 6, 2048)   8192        conv5_block1_0_conv
[0][0]
__________________________________________________________________________________________________
conv5_block1_3_bn (BatchNormali (None, 6, 6, 2048)   8192        conv5_block1_3_conv
[0][0]
__________________________________________________________________________________________________
conv5_block1_add (Add)          (None, 6, 6, 2048)   0           conv5_block1_0_bn
[0][0]
                                                                 conv5_block1_3_bn
[0][0]
__________________________________________________________________________________________________
conv5_block1_out (Activation)   (None, 6, 6, 2048)   0           conv5_block1_add[0]
[0]
__________________________________________________________________________________________________
```

```
conv5_block2_1_conv (Conv2D)    (None, 6, 6, 512)    1049088     conv5_block1_out[0]
[0]
__________________________________________________________________________________________________
conv5_block2_1_bn (BatchNormali (None, 6, 6, 512)    2048        conv5_block2_1_conv
[0][0]
__________________________________________________________________________________________________
conv5_block2_1_relu (Activation (None, 6, 6, 512)    0           conv5_block2_1_bn
[0][0]
__________________________________________________________________________________________________
conv5_block2_2_conv (Conv2D)    (None, 6, 6, 512)    2359808     conv5_block2_1_relu
[0][0]
__________________________________________________________________________________________________
conv5_block2_2_bn (BatchNormali (None, 6, 6, 512)    2048        conv5_block2_2_conv
[0][0]
__________________________________________________________________________________________________
conv5_block2_2_relu (Activation (None, 6, 6, 512)    0           conv5_block2_2_bn
[0][0]
__________________________________________________________________________________________________
conv5_block2_3_conv (Conv2D)    (None, 6, 6, 2048)   1050624     conv5_block2_2_relu
[0][0]
__________________________________________________________________________________________________
conv5_block2_3_bn (BatchNormali (None, 6, 6, 2048)   8192        conv5_block2_3_conv
[0][0]
__________________________________________________________________________________________________
conv5_block2_add (Add)          (None, 6, 6, 2048)   0           conv5_block1_out[0]
[0]
                                                                 conv5_block2_3_bn
[0][0]
__________________________________________________________________________________________________
conv5_block2_out (Activation)   (None, 6, 6, 2048)   0           conv5_block2_add[0]
[0]
__________________________________________________________________________________________________
conv5_block3_1_conv (Conv2D)    (None, 6, 6, 512)    1049088     conv5_block2_out[0]
[0]
__________________________________________________________________________________________________
conv5_block3_1_bn (BatchNormali (None, 6, 6, 512)    2048        conv5_block3_1_conv
[0][0]
__________________________________________________________________________________________________
conv5_block3_1_relu (Activation (None, 6, 6, 512)    0           conv5_block3_1_bn
[0][0]
__________________________________________________________________________________________________
conv5_block3_2_conv (Conv2D)    (None, 6, 6, 512)    2359808     conv5_block3_1_relu
[0][0]
__________________________________________________________________________________________________
conv5_block3_2_bn (BatchNormali (None, 6, 6, 512)    2048        conv5_block3_2_conv
[0][0]
__________________________________________________________________________________________________
conv5_block3_2_relu (Activation (None, 6, 6, 512)    0           conv5_block3_2_bn
[0][0]
```

```
________________________________________________________________________________________
______________
conv5_block3_3_conv (Conv2D)    (None, 6, 6, 2048)   1050624     conv5_block3_2_relu
[0][0]
________________________________________________________________________________________
______________
conv5_block3_3_bn (BatchNormali (None, 6, 6, 2048)   8192        conv5_block3_3_conv
[0][0]
________________________________________________________________________________________
______________
conv5_block3_add (Add)          (None, 6, 6, 2048)   0           conv5_block2_out[0]
[0]
                                                                 conv5_block3_3_bn
[0][0]
________________________________________________________________________________________
______________
conv5_block3_out (Activation)   (None, 6, 6, 2048)   0           conv5_block3_add[0]
[0]
========================================================================================
==============
Total params: 23,587,712
Trainable params: 23,534,592
Non-trainable params: 53,120
________________________________________________________________________________________
______________
```

In [37]:

```
    resnet_model = Sequential([
        resnet_base_model,
        GlobalAveragePooling2D(),
        Dense(512, activation="relu"),
        BatchNormalization(),
        Dropout(0.6),
        Dense(128, activation="relu"),
        BatchNormalization(),
        Dropout(0.4),
        Dense(64,activation="relu"),
        BatchNormalization(),
        Dropout(0.3),
        Dense(1,activation="sigmoid")
    ])

    opt = tf.keras.optimizers.Adam(learning_rate=0.001)
    METRICS = [
        'accuracy',
        tf.keras.metrics.Precision(name='precision'),
        tf.keras.metrics.Recall(name='recall')
    ]
    resnet_model.compile(optimizer=opt,loss='binary_crossentropy',metrics=METRICS)
```

In [38]:

```
r = resnet_model.fit(train,
          epochs=10,
          validation_data=validation,
          class_weight=class_weight,
          steps_per_epoch=100,
          validation_steps=25)
```

```
Epoch 1/10
100/100 [==============================] - ETA: 0s - loss: 0.2354 - accuracy: 0.7200
- precision: 0.9000 - recall: 0.6993WARNING:tensorflow:Your input ran out of data; i
nterrupting training. Make sure that your dataset or generator can generate at least
`steps_per_epoch * epochs` batches (in this case, 25 batches). You may need to use t
```

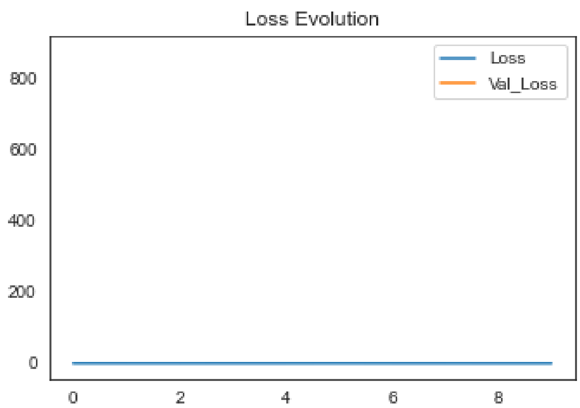
```
he repeat() function when building your dataset.
100/100 [==============================] - 383s 4s/step - loss: 0.2354 - accuracy:
0.7200 - precision: 0.9000 - recall: 0.6993 - val_loss: 874.2960 - val_accuracy: 0.5
000 - val_precision: 0.5000 - val_recall: 1.0000
Epoch 2/10
100/100 [==============================] - 658s 7s/step - loss: 0.1914 - accuracy:
0.7675 - precision: 0.9249 - recall: 0.7537
Epoch 3/10
100/100 [==============================] - 773s 8s/step - loss: 0.1763 - accuracy:
0.7975 - precision: 0.9453 - recall: 0.7832
Epoch 4/10
100/100 [==============================] - 765s 8s/step - loss: 0.2092 - accuracy:
0.7538 - precision: 0.8896 - recall: 0.7573
Epoch 5/10
100/100 [==============================] - 812s 8s/step - loss: 0.2206 - accuracy:
0.7400 - precision: 0.8942 - recall: 0.7430
Epoch 6/10
100/100 [==============================] - 786s 8s/step - loss: 0.2471 - accuracy:
0.6488 - precision: 0.8413 - recall: 0.6504
Epoch 7/10
100/100 [==============================] - 774s 8s/step - loss: 0.2119 - accuracy:
0.6825 - precision: 0.9073 - recall: 0.6597
Epoch 8/10
100/100 [==============================] - 780s 8s/step - loss: 0.2056 - accuracy:
0.7638 - precision: 0.9012 - recall: 0.7565
Epoch 9/10
100/100 [==============================] - 820s 8s/step - loss: 0.1637 - accuracy:
0.8275 - precision: 0.9399 - recall: 0.8193
Epoch 10/10
100/100 [==============================] - 801s 8s/step - loss: 0.1466 - accuracy:
0.8425 - precision: 0.9594 - recall: 0.8253
```

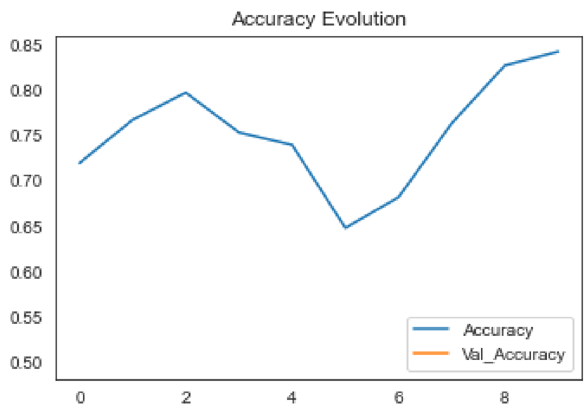
In [39]:

```
plt.figure(figsize=(12, 8))

plt.subplot(2, 2, 1)
plt.plot(r.history['loss'], label='Loss')
plt.plot(r.history['val_loss'], label='Val_Loss')
plt.legend()
plt.title('Loss Evolution')

plt.subplot(2, 2, 2)
plt.plot(r.history['accuracy'], label='Accuracy')
plt.plot(r.history['val_accuracy'], label='Val_Accuracy')
plt.legend()
plt.title('Accuracy Evolution')
```

Out[39]:

```
Text(0.5, 1.0, 'Accuracy Evolution')
```





In [40]:

```
evaluation =resnet_model.evaluate(test)
```

```
print(f"Test Accuracy: {evaluation[1] * 100:.2f}%")

evaluation = resnet_model.evaluate(train)
print(f"Train Accuracy: {evaluation[1] * 100:.2f}%")
```

```
624/624 [==============================] - 207s 332ms/step - loss: 1.0688 - accurac
y: 0.6378 - precision: 0.6336 - recall: 0.9974
Test Accuracy: 63.78%
652/652 [==============================] - 805s 1s/step - loss: 0.5094 - accuracy:
0.7789 - precision: 0.7720 - recall: 0.9969
Train Accuracy: 77.89%
```

InceptionNet

Also known as GoogleNet, this architecture presents sub-networks called inception modules, which allows fast training computing, complex patterns detection, and optimal use of parameters

for more information visit
https://static.googleusercontent.com/media/research.google.com/en//pubs/archive/43022.pdf

In [41]:
```
from keras.applications import InceptionV3

inception_base_model = InceptionV3(input_shape=(180,180,3),include_top=False,weights
```

In [42]:
```
    inception_model = Sequential([
        inception_base_model,
        GlobalAveragePooling2D(),
        Dense(512, activation="relu"),
        BatchNormalization(),
        Dropout(0.6),
        Dense(128, activation="relu"),
        BatchNormalization(),
        Dropout(0.4),
        Dense(64,activation="relu"),
        BatchNormalization(),
        Dropout(0.3),
        Dense(1,activation="sigmoid")
    ])

    opt = tf.keras.optimizers.Adam(learning_rate=0.001)
    METRICS = [
        'accuracy',
        tf.keras.metrics.Precision(name='precision'),
        tf.keras.metrics.Recall(name='recall')
    ]
    inception_model.compile(optimizer=opt,loss='binary_crossentropy',metrics=METRICS
```

In [43]:
```
r = inception_model.fit(train,
          epochs=10,
          validation_data=validation,
          class_weight=class_weight,
          steps_per_epoch=100,
          validation_steps=25)
```

```
Epoch 1/10
100/100 [==============================] - ETA: 0s - loss: 0.2088 - accuracy: 0.7300
```

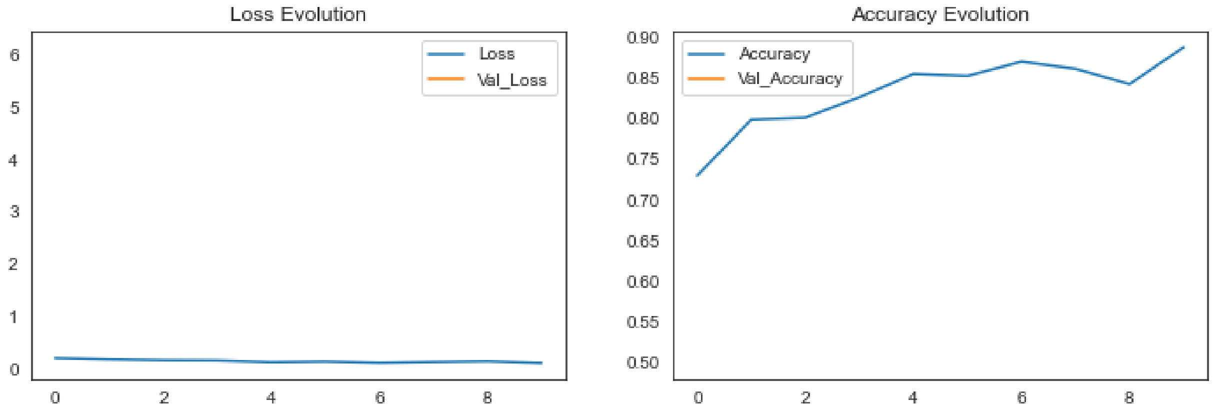
```
- precision: 0.9187 - recall: 0.7002WARNING:tensorflow:Your input ran out of data; i
nterrupting training. Make sure that your dataset or generator can generate at least
`steps_per_epoch * epochs` batches (in this case, 25 batches). You may need to use t
he repeat() function when building your dataset.
100/100 [==============================] - 225s 2s/step - loss: 0.2088 - accuracy:
0.7300 - precision: 0.9187 - recall: 0.7002 - val_loss: 6.1463 - val_accuracy: 0.500
0 - val_precision: 0.0000e+00 - val_recall: 0.0000e+00
Epoch 2/10
100/100 [==============================] - 226s 2s/step - loss: 0.1842 - accuracy:
0.7987 - precision: 0.9369 - recall: 0.7797
Epoch 3/10
100/100 [==============================] - 285s 3s/step - loss: 0.1660 - accuracy:
0.8012 - precision: 0.9499 - recall: 0.7796
Epoch 4/10
100/100 [==============================] - 443s 4s/step - loss: 0.1616 - accuracy:
0.8263 - precision: 0.9339 - recall: 0.8205
Epoch 5/10
100/100 [==============================] - 431s 4s/step - loss: 0.1290 - accuracy:
0.8550 - precision: 0.9662 - recall: 0.8399
Epoch 6/10
100/100 [==============================] - 408s 4s/step - loss: 0.1415 - accuracy:
0.8525 - precision: 0.9519 - recall: 0.8484
Epoch 7/10
100/100 [==============================] - 428s 4s/step - loss: 0.1168 - accuracy:
0.8700 - precision: 0.9643 - recall: 0.8579
Epoch 8/10
100/100 [==============================] - 446s 4s/step - loss: 0.1331 - accuracy:
0.8612 - precision: 0.9467 - recall: 0.8626
Epoch 9/10
100/100 [==============================] - 449s 4s/step - loss: 0.1471 - accuracy:
0.8425 - precision: 0.9378 - recall: 0.8479
Epoch 10/10
100/100 [==============================] - 441s 4s/step - loss: 0.1121 - accuracy:
0.8875 - precision: 0.9696 - recall: 0.8813
```

In [44]:

```python
plt.figure(figsize=(12, 8))

plt.subplot(2, 2, 1)
plt.plot(r.history['loss'], label='Loss')
plt.plot(r.history['val_loss'], label='Val_Loss')
plt.legend()
plt.title('Loss Evolution')

plt.subplot(2, 2, 2)
plt.plot(r.history['accuracy'], label='Accuracy')
plt.plot(r.history['val_accuracy'], label='Val_Accuracy')
plt.legend()
plt.title('Accuracy Evolution')
```

Out[44]:

```
Text(0.5, 1.0, 'Accuracy Evolution')
```



In [45]:
```
evaluation =inception_model.evaluate(test)
print(f"Test Accuracy: {evaluation[1] * 100:.2f}%")

evaluation = inception_model.evaluate(train)
print(f"Train Accuracy: {evaluation[1] * 100:.2f}%")
```

```
624/624 [==============================] - 119s 191ms/step - loss: 3.2893 - accurac
y: 0.7532 - precision: 0.7305 - recall: 0.9590
Test Accuracy: 75.32%
652/652 [==============================] - 743s 1s/step - loss: 1.6314 - accuracy:
0.9030 - precision: 0.9158 - recall: 0.9574
Train Accuracy: 90.30%
```

Comparing different models

In [46]:
```
model_mae_scores_dict = {'CNN': 91.98, 'CNN_2': 68.91, 'DenseNet' : 87.18, 'VGG16' :
```

In [47]:
```
model_mae_scores = pd.Series(model_mae_scores_dict)
```

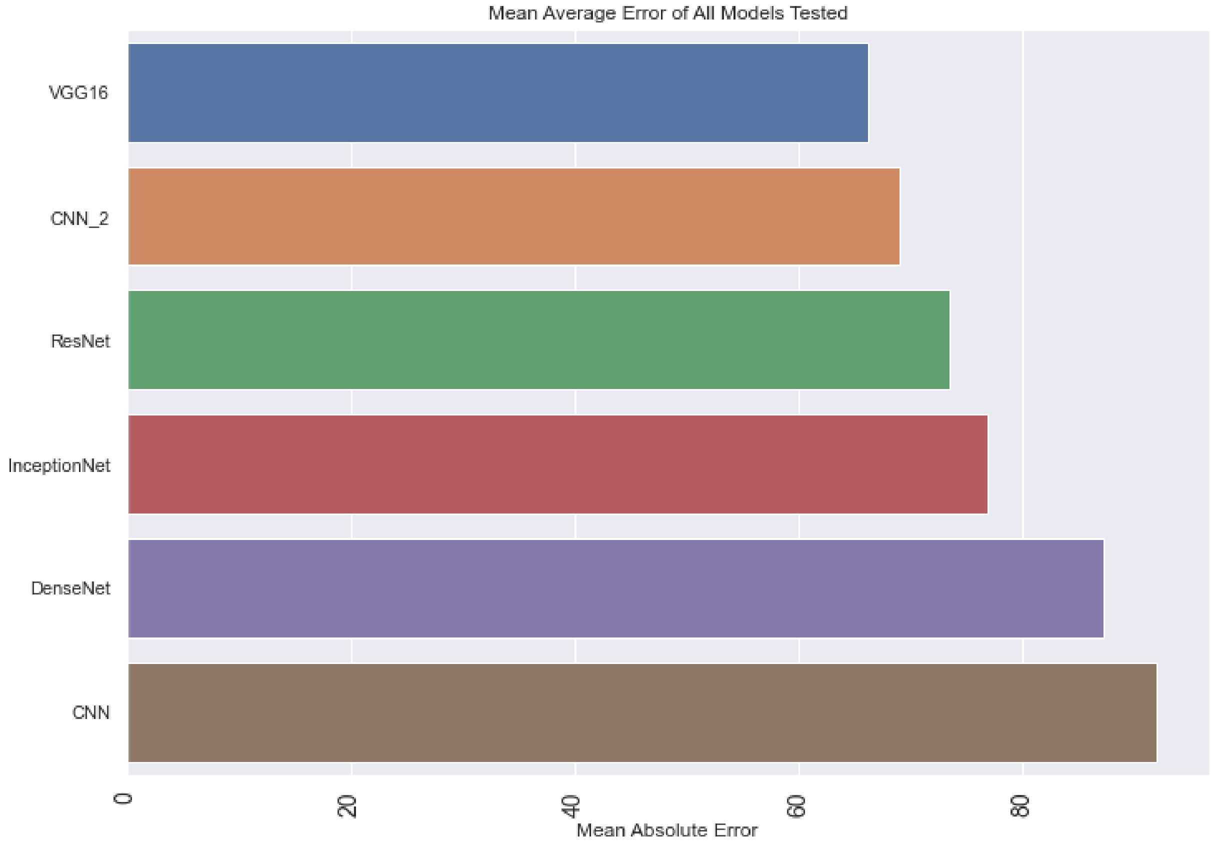
In [48]:
```
model_mae_scores
```

Out[48]:
```
CNN            91.98
CNN_2          68.91
DenseNet       87.18
VGG16          66.19
ResNet         73.40
InceptionNet   76.76
dtype: float64
```

In [49]:
```
order = model_mae_scores.sort_values()
```

In [50]:
```
from matplotlib import pyplot
import seaborn as sns

sns.set(rc={'figure.figsize':(11.7,8.27)})
sns.barplot(x=order.values, y = order.index, orient='h')

plt.xlabel('Mean Absolute Error')
plt.xticks(rotation='vertical',fontsize=14)
plt.title('Mean Average Error of All Models Tested')
```

Out[50]:
```
Text(0.5, 1.0, 'Mean Average Error of All Models Tested')
```



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