AI for Medical Diagnosis

Computer Vision (CV) has a lot of applications in medical diagnosis:

- Dermatology
- Ophthakmology
- Histopathology.

X-rays images are critical for the detection of lung cancer, pneumenia ... In this notebook you will learn:

- Data pre-processing
- Preprocess images properly for the train, validation and test sets.
- Set-up a pre-trained neural network to make disease predictions on chest X-rays.

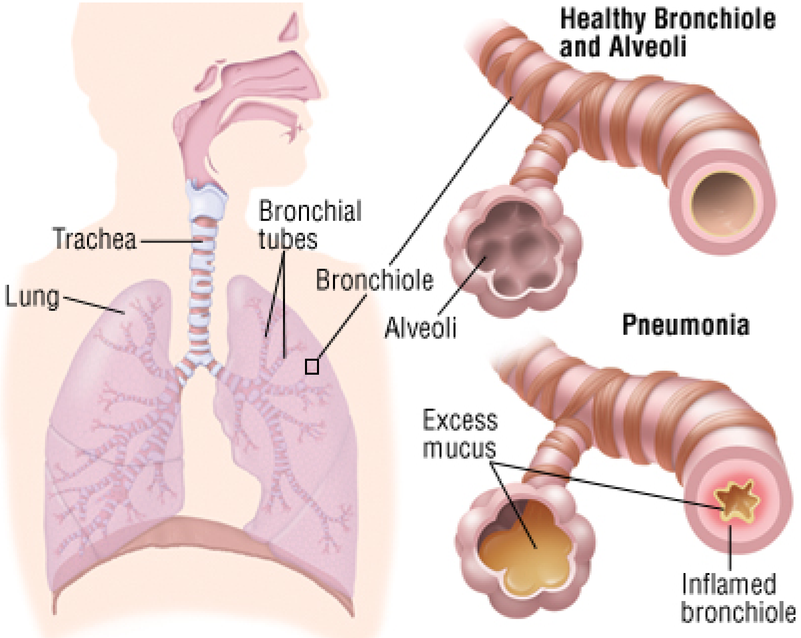
In this notebook you will work with chest X-ray images taken from the public ChestX-ray8 dataset.

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.



Computer Vision

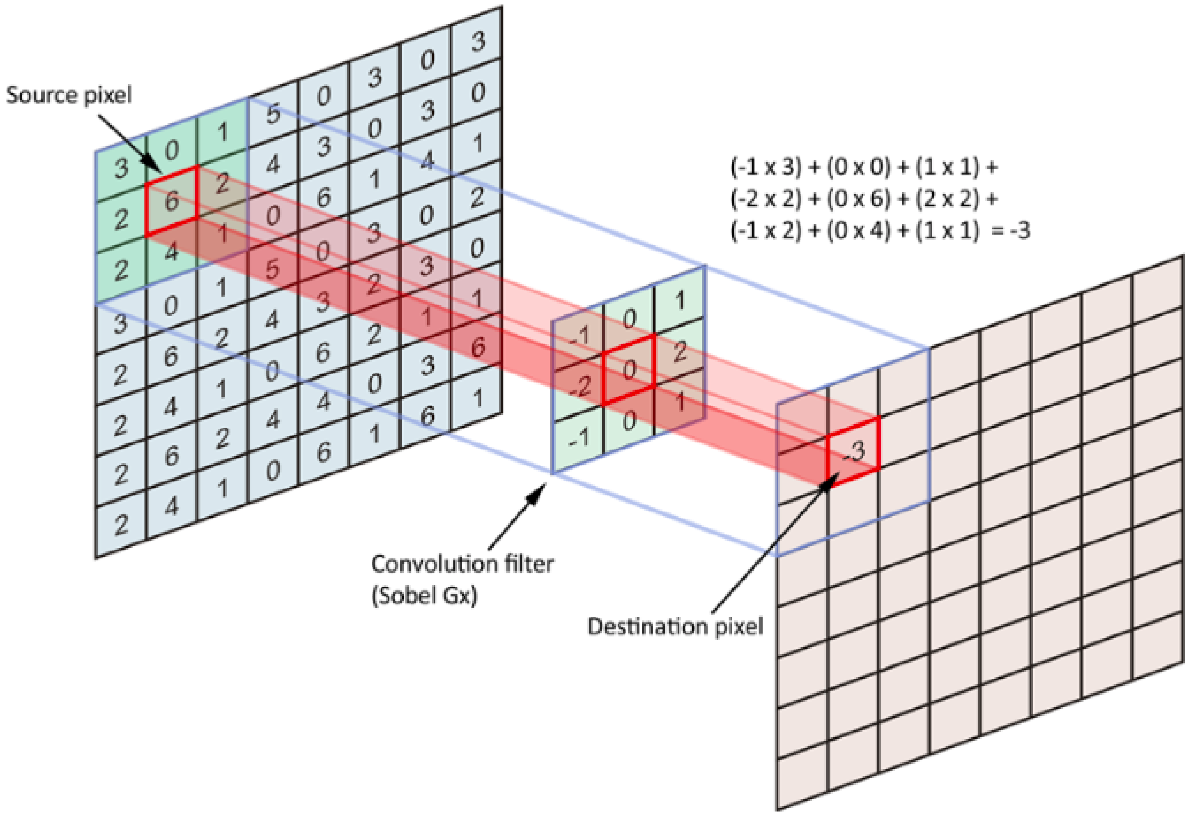
Computer vision is an interdisciplinary scientific field that deals with how computers can gain a high-level understanding from digital images or videos. From the perspective of engineering, it seeks to understand and automate tasks that the human visual system can do. We can use Computer Vision to determine whether a person is affected by pneumonia or not.

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:

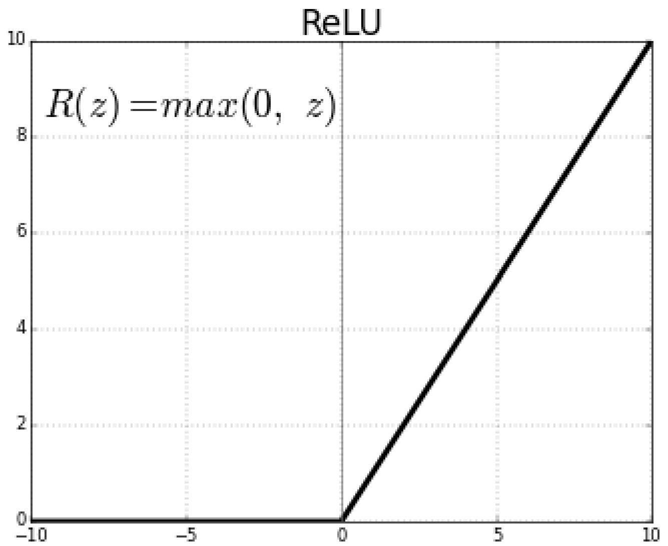
- Filter an image for a particular feature (convolution)
- Detect that feature within the filtered image (using the ReLU activation)
- Condense the image to enhance the features (maximum pooling)

The convolution process is illustrated below

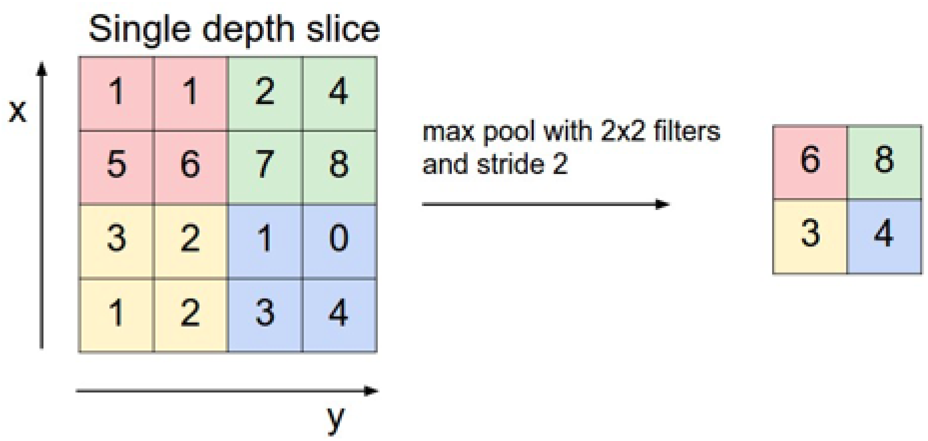


Using convolution filters with different dimensions or values results in differents features extracted

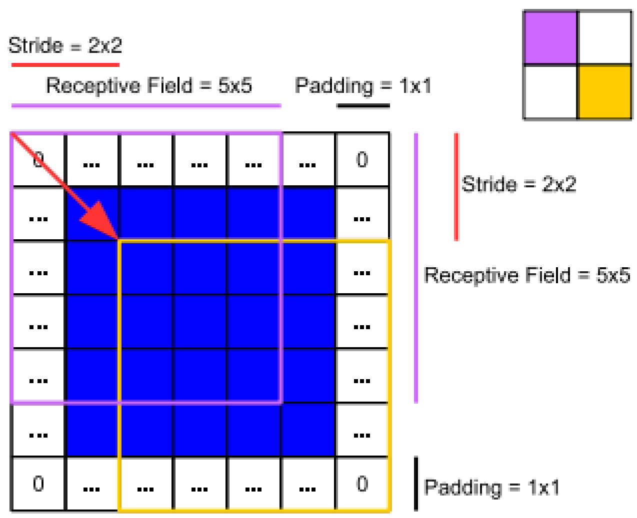
Features are then detected using the reLu activation on each destination pixel.



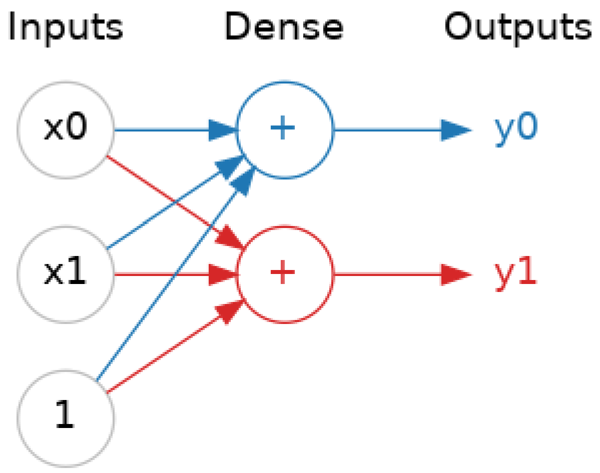
Features are the enhanced with MaxPool layers



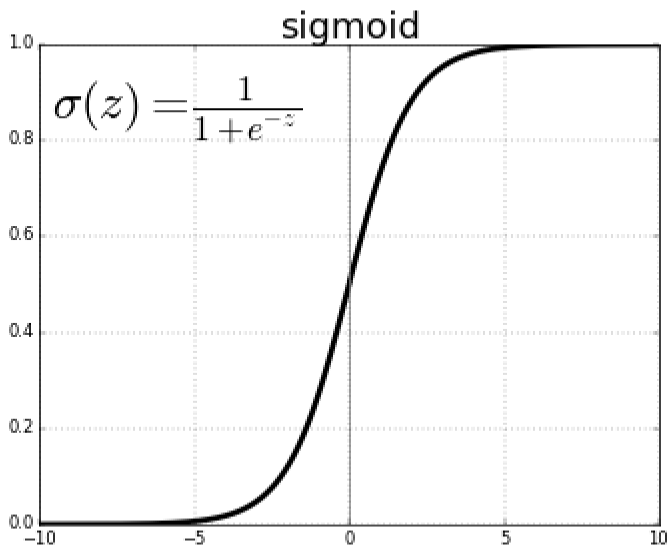
The stride parameters determines the distance between each filters. The padding one determines if we ignore the borderline pixels or not (adding zeros helps the neural network to get information on the border)



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]: ['.DS_Store', 'test', 'chest_xray', '__MACOSX', 'train', 'val']

In [2]:

```
len(os.listdir("./chest_xray/train/PNEUMONIA"))
```

Out[2]: 3875

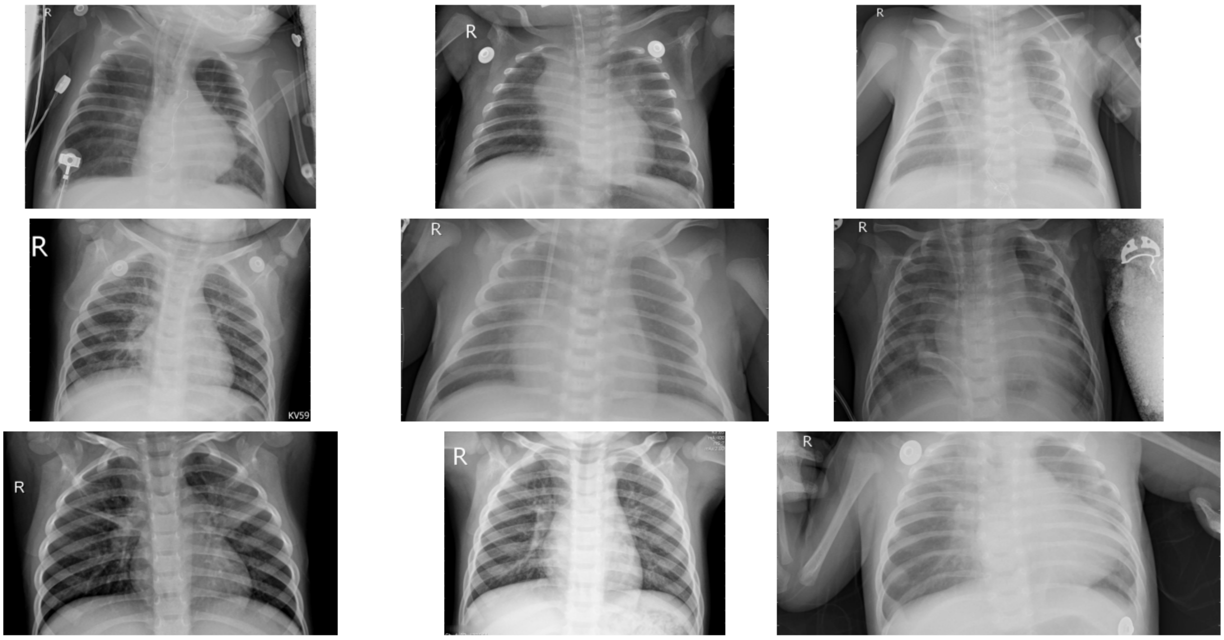
The dataset is divided into three sets: 1) Train set 2) Validation set and 3) Test set.

Data Visualization

In [3]:

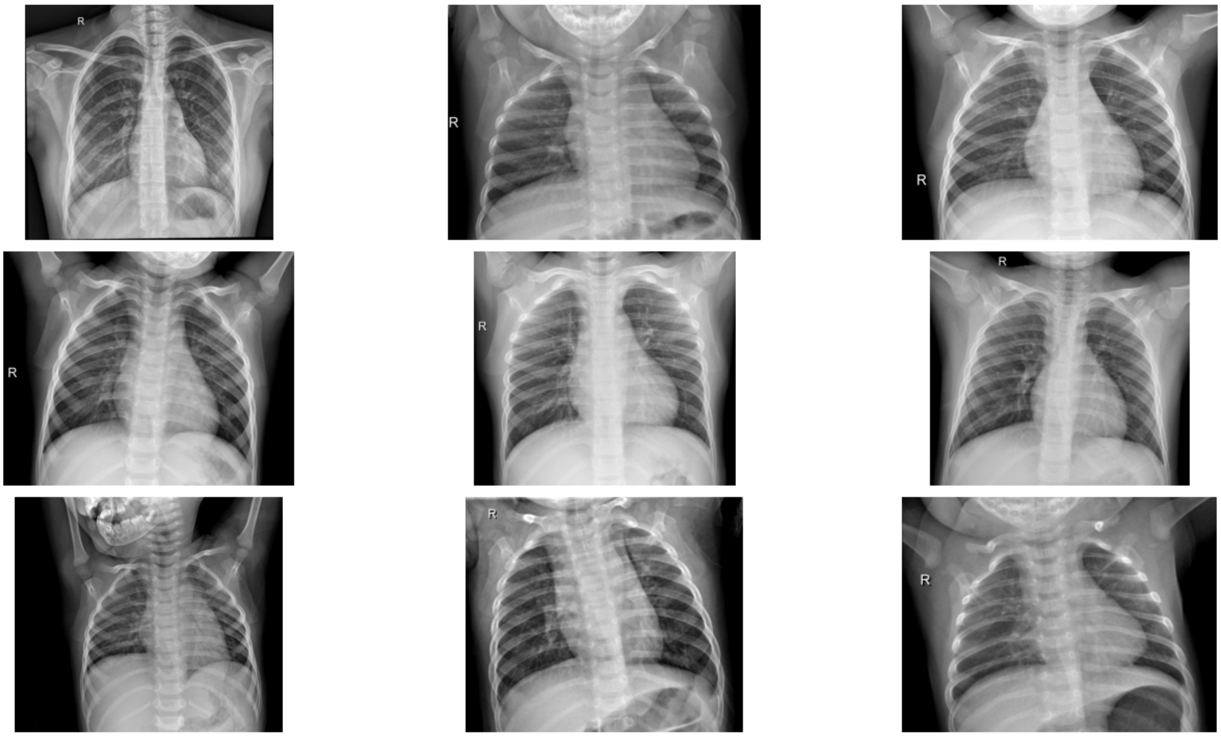
```
train_dir = "./chest_xray/train"
test_dir = "./chest_xray/test"
val_dir = "./chest_xray/val"

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()
```

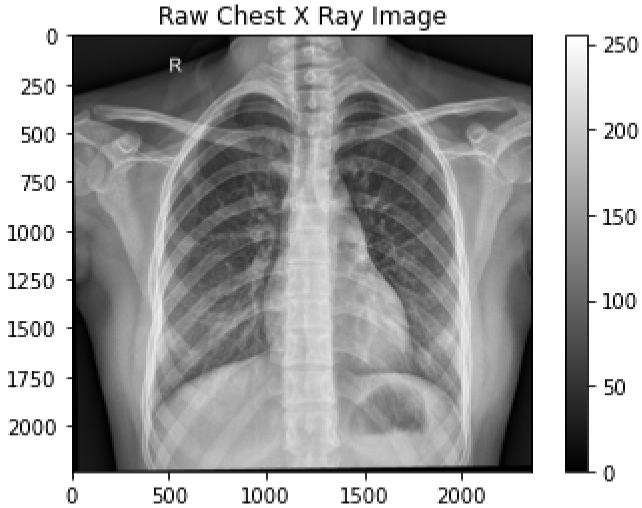


In [5]:

```
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 an
print(f"The maximum pixel value is {sample_img.max():.4f} and the minimum is
print(f"The mean value of the pixels is {sample_img.mean():.4f} and the stand
```

```
The dimensions of the image are 2234 pixels width and 2359 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 124.3910 and the standard deviation is 56.3308
```



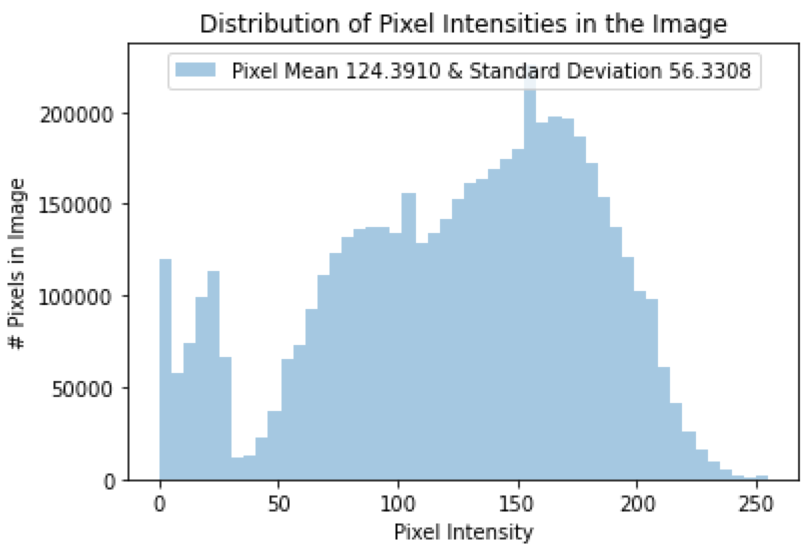
Ivestigate pixel value distribution

In [6]:

```
sns.distplot(sample_img.ravel(),
             label=f"Pixel Mean {np.mean(sample_img):.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')
```

```
/Users/wangshicong/opt/anaconda3/lib/python3.8/site-packages/seaborn/distribut
ions.py:2557: FutureWarning: `distplot` is a deprecated function and will be r
emoved in a future version. Please adapt your code to use either `displot` (a
figure-level function with similar flexibility) or `histplot` (an axes-level f
unction 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 for valid and test sets

Now we need to build a new generator for validation and testing 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 that it 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))
```

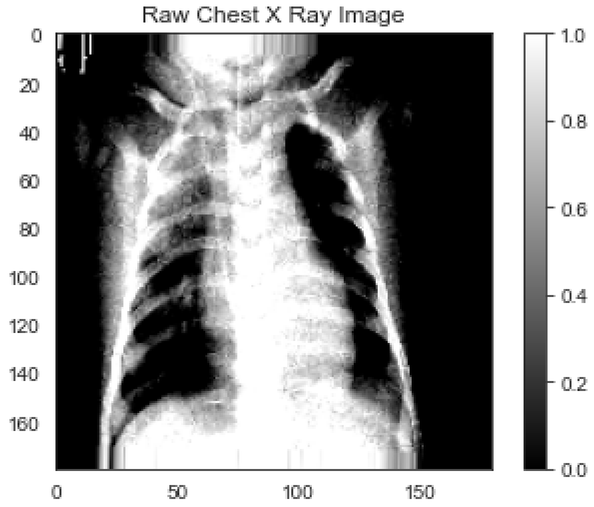
```
test = image_generator.flow_from_directory(test_dir,
                                            batch_size=1,
                                            shuffle=False,
                                            class_mode='binary',
                                            target_size=(180, 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 wid
print(f"The maximum pixel value is {generated_image.max():.4f} and the minimu
print(f"The mean value of the pixels is {generated_image.mean():.4f} and the 
```

```
Clipping input data to the valid range for imshow with RGB data ([0..1] for fl
oats or [0..255] for integers).
The dimensions of the image are 180 pixels width and 180 pixels height, one si
ngle color channel.
The maximum pixel value is 2.5148 and the minimum is -2.8703
The mean value of the pixels is 0.0000 and the standard deviation is 1.0000
```

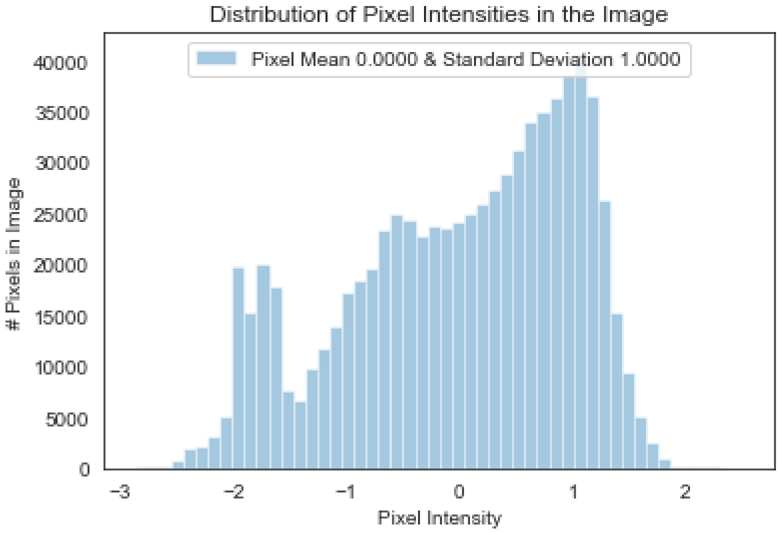


In [10]:

```
sns.distplot(generated_image.ravel(),
             label=f"Pixel Mean {np.mean(generated_image):.4f} & Standard Devi
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, BatchNor


model = Sequential()
```

```
model.add(Conv2D(filters=32, kernel_size=(3, 3), input_shape=(180, 180, 3), a
model.add(BatchNormalization())
model.add(Conv2D(filters=32, kernel_size=(3, 3), input_shape=(180, 180, 3), a
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,
)
```

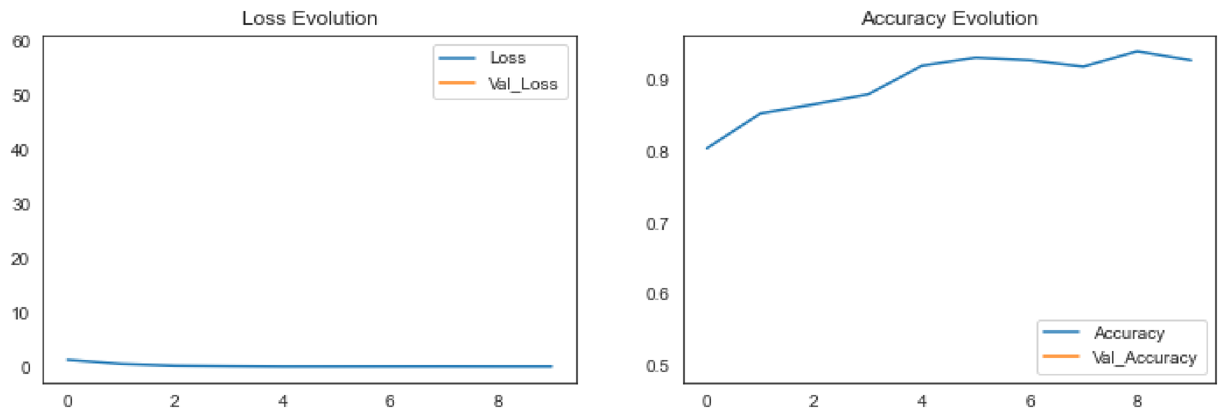
```
Epoch 1/10
100/100 [==============================] - ETA: 0s - loss: 1.3081 - accuracy: 0.8037WARNING:tensorflow:Your input ran out of data; interrupting training. Make sure that your dataset or generator can generate at least `steps_per_epoch * epochs` batches (in this case, 25 batches). You may need to use the repeat() function when building your dataset.
100/100 [==============================] - 53s 518ms/step - loss: 1.3081 - accuracy: 0.8037 - val_loss: 58.2382 - val_accuracy: 0.5000
Epoch 2/10
100/100 [==============================] - 50s 503ms/step - loss: 0.5672 - accuracy: 0.8525
Epoch 3/10
100/100 [==============================] - 50s 500ms/step - loss: 0.2279 - accuracy: 0.8650
Epoch 4/10
100/100 [==============================] - 50s 499ms/step - loss: 0.1383 - accuracy: 0.8788
Epoch 5/10
100/100 [==============================] - 50s 498ms/step - loss: 0.0726 - accuracy: 0.9187
Epoch 6/10
100/100 [==============================] - 50s 497ms/step - loss: 0.0771 - accuracy: 0.9300
Epoch 7/10
100/100 [==============================] - 50s 498ms/step - loss: 0.0860 - accuracy: 0.9262
Epoch 8/10
100/100 [==============================] - 50s 496ms/step - loss: 0.0951 - accuracy: 0.9175
Epoch 9/10
100/100 [==============================] - 50s 498ms/step - loss: 0.0803 - accuracy: 0.9388
Epoch 10/10
100/100 [==============================] - 50s 498ms/step - loss: 0.0799 - accuracy: 0.9262
```

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)
```

```python
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]:

```python
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 [==============================] - 17s 26ms/step - loss: 0.9774 - accu
racy: 0.7933
Test Accuracy: 79.33%
652/652 [==============================] - 128s 196ms/step - loss: 0.1926 - ac
curacy: 0.9411
Train Accuracy: 94.11%
```

In [17]:

```python
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
```

```
[[110 124]
 [  4 386]]
```

Out[17]:

	0	1	accuracy	macro avg	weighted avg
precision	0.964912	0.756863	0.794872	0.860888	0.834881
recall	0.470085	0.989744	0.794872	0.729915	0.794872
f1-score	0.632184	0.857778	0.794872	0.744981	0.773180
support	234.000000	390.000000	0.794872	624.000000	624.000000

In [18]:

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

```
[[134 100]
 [  8 382]]
```

Out[18]:

	0	1	accuracy	macro avg	weighted avg
precision	0.943662	0.792531	0.826923	0.868097	0.849205

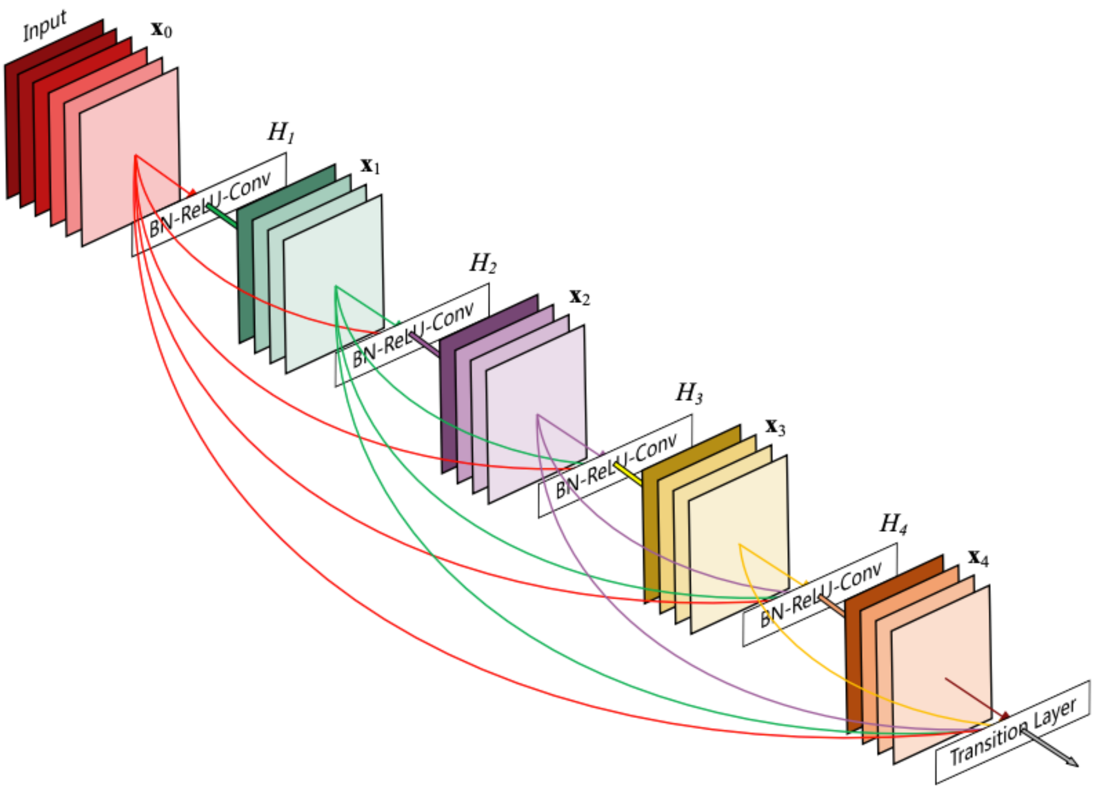
	0	1	accuracy	macro avg	weighted avg
recall	0.572650	0.979487	0.826923	0.776068	0.826923
f1-score	0.712766	0.876147	0.826923	0.794456	0.814879
support	234.000000	390.000000	0.826923	624.000000	624.000000

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, weight:

base_model.summary()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applicat
ions/densenet/densenet121_weights_tf_dim_ordering_tf_kernels_notop.h5
29089792/29084464 [==============================] - 1s 0us/step
29097984/29084464 [==============================] - 1s 0us/step
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_padding2
d[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_padding2
d_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]
__________________________________________________________________________________________________
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[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[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]
__________________________________________________________________________________________________
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]
__________________________________________________________________________________________________
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_relu[0][0]
__________________________________________________________________________________________________
conv3_block11_1_bn (BatchNormal (None, 22, 22, 128)  512         conv3_block11
_1_conv[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_relu[0][0]
```

```
__________________________________________________________________________________________________
conv3_block11_concat (Concatena (None, 22, 22, 480)  0           conv3_block10_concat[0][0]
                                                                 conv3_block11_2_conv[0][0]
__________________________________________________________________________________________________
conv3_block12_0_bn (BatchNormal (None, 22, 22, 480)  1920        conv3_block11_concat[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_relu[0][0]
__________________________________________________________________________________________________
conv3_block12_1_bn (BatchNormal (None, 22, 22, 128)  512         conv3_block12_1_conv[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_relu[0][0]
__________________________________________________________________________________________________
conv3_block12_concat (Concatena (None, 22, 22, 512)  0           conv3_block11_concat[0][0]
                                                                 conv3_block12_2_conv[0][0]
__________________________________________________________________________________________________
pool3_bn (BatchNormalization)   (None, 22, 22, 512)  2048        conv3_block12_concat[0][0]
__________________________________________________________________________________________________
pool3_relu (Activation)         (None, 22, 22, 512)  0           pool3_bn[0][0]
__________________________________________________________________________________________________
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]
__________________________________________________________________________________________________
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]
__________________________________________________________________________________________________
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]
__________________________________________________________________________________________________
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]
__________________________________________________________________________________
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_relu[0][0]
__________________________________________________________________________________
conv4_block10_1_bn (BatchNormal (None, 11, 11, 128)  512         conv4_block10
_1_conv[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_relu[0][0]
__________________________________________________________________________________________________
conv4_block10_concat (Concatena (None, 11, 11, 576)  0           conv4_block9_concat[0][0]
                                                                 conv4_block10_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block11_0_bn (BatchNormal (None, 11, 11, 576)  2304        conv4_block10_concat[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_relu[0][0]
__________________________________________________________________________________________________
conv4_block11_1_bn (BatchNormal (None, 11, 11, 128)  512         conv4_block11_1_conv[0][0]
__________________________________________________________________________________________________
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_relu[0][0]
__________________________________________________________________________________________________
conv4_block11_concat (Concatena (None, 11, 11, 608)  0           conv4_block10_concat[0][0]
                                                                 conv4_block11_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block12_0_bn (BatchNormal (None, 11, 11, 608)  2432        conv4_block11_concat[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_relu[0][0]
__________________________________________________________________________________________________
conv4_block12_1_bn (BatchNormal (None, 11, 11, 128)  512         conv4_block12_1_conv[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_relu[0][0]
__________________________________________________________________________________________________
conv4_block12_concat (Concatena (None, 11, 11, 640)  0           conv4_block11_concat[0][0]
                                                                 conv4_block12_2_conv[0][0]
__________________________________________________________________________________________________
```

```
conv4_block13_0_bn (BatchNormal (None, 11, 11, 640)  2560        conv4_block12
_concat[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_relu[0][0]
__________________________________________________________________________________________________
conv4_block13_1_bn (BatchNormal (None, 11, 11, 128)  512         conv4_block13
_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block13_1_relu (Activatio (None, 11, 11, 128)  0           conv4_block13
_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block13_2_conv (Conv2D)   (None, 11, 11, 32)   36864       conv4_block13
_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block13_concat (Concatena (None, 11, 11, 672)  0           conv4_block12
_concat[0][0]
                                                                 conv4_block13
_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block14_0_bn (BatchNormal (None, 11, 11, 672)  2688        conv4_block13
_concat[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_relu[0][0]
__________________________________________________________________________________________________
conv4_block14_1_bn (BatchNormal (None, 11, 11, 128)  512         conv4_block14
_1_conv[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_relu[0][0]
__________________________________________________________________________________________________
conv4_block14_concat (Concatena (None, 11, 11, 704)  0           conv4_block13
_concat[0][0]
                                                                 conv4_block14
_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block15_0_bn (BatchNormal (None, 11, 11, 704)  2816        conv4_block14
_concat[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_relu[0][0]
__________________________________________________________________________________________________
conv4_block15_1_bn (BatchNormal (None, 11, 11, 128)  512         conv4_block15
_1_conv[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_relu[0][0]
__________________________________________________________________________________________________
conv4_block15_concat (Concatena (None, 11, 11, 736)  0           conv4_block14
_concat[0][0]
                                                                 conv4_block15
_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block16_0_bn (BatchNormal (None, 11, 11, 736)  2944        conv4_block15
_concat[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_relu[0][0]
__________________________________________________________________________________________________
conv4_block16_1_bn (BatchNormal (None, 11, 11, 128)  512         conv4_block16
_1_conv[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_relu[0][0]
__________________________________________________________________________________________________
conv4_block16_concat (Concatena (None, 11, 11, 768)  0           conv4_block15
_concat[0][0]
                                                                 conv4_block16
_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block17_0_bn (BatchNormal (None, 11, 11, 768)  3072        conv4_block16
_concat[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_relu[0][0]
__________________________________________________________________________________________________
conv4_block17_1_bn (BatchNormal (None, 11, 11, 128)  512         conv4_block17
_1_conv[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_relu[0][0]
__________________________________________________________________________________________________
conv4_block17_concat (Concatena (None, 11, 11, 800)  0           conv4_block16_concat[0][0]
                                                                 conv4_block17_2_conv[0][0]
__________________________________________________________________________________________________
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]
__________________________________________________________________________________________________
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_relu[0][0]
__________________________________________________________________________________________________
conv4_block20_1_bn (BatchNormal (None, 11, 11, 128)  512         conv4_block20_1_conv[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_relu[0][0]
__________________________________________________________________________________________________
conv4_block20_concat (Concatena (None, 11, 11, 896)  0           conv4_block19_concat[0][0]
                                                                 conv4_block20_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block21_0_bn (BatchNormal (None, 11, 11, 896)  3584        conv4_block20_concat[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_relu[0][0]
__________________________________________________________________________________________________
conv4_block21_1_bn (BatchNormal (None, 11, 11, 128)  512         conv4_block21_1_conv[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_relu[0][0]
__________________________________________________________________________________________________
conv4_block21_concat (Concatena (None, 11, 11, 928)  0           conv4_block20_concat[0][0]
                                                                 conv4_block21_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block22_0_bn (BatchNormal (None, 11, 11, 928)  3712        conv4_block21_concat[0][0]
__________________________________________________________________________________________________
conv4_block22_0_relu (Activatio (None, 11, 11, 928)  0           conv4_block22_0_bn[0][0]
```

```
__________________________________________________________________________________________________
conv4_block22_1_conv (Conv2D)   (None, 11, 11, 128)  118784      conv4_block22_0_relu[0][0]
__________________________________________________________________________________________________
conv4_block22_1_bn (BatchNormal (None, 11, 11, 128)  512         conv4_block22_1_conv[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_relu[0][0]
__________________________________________________________________________________________________
conv4_block22_concat (Concatena (None, 11, 11, 960)  0           conv4_block21_concat[0][0]
                                                                 conv4_block22_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block23_0_bn (BatchNormal (None, 11, 11, 960)  3840        conv4_block22_concat[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_relu[0][0]
__________________________________________________________________________________________________
conv4_block23_1_bn (BatchNormal (None, 11, 11, 128)  512         conv4_block23_1_conv[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_relu[0][0]
__________________________________________________________________________________________________
conv4_block23_concat (Concatena (None, 11, 11, 992)  0           conv4_block22_concat[0][0]
                                                                 conv4_block23_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block24_0_bn (BatchNormal (None, 11, 11, 992)  3968        conv4_block23_concat[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_relu[0][0]
__________________________________________________________________________________________________
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_relu[0][0]
__________________________________________________________________________________________________
conv5_block10_1_bn (BatchNormal (None, 5, 5, 128)    512         conv5_block10_1_conv[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_relu[0][0]
__________________________________________________________________________________________________
conv5_block10_concat (Concatena (None, 5, 5, 832)    0           conv5_block9_concat[0][0]
                                                                 conv5_block10_2_conv[0][0]
__________________________________________________________________________________________________
conv5_block11_0_bn (BatchNormal (None, 5, 5, 832)    3328        conv5_block10_concat[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_relu[0][0]
__________________________________________________________________________________________________
conv5_block11_1_bn (BatchNormal (None, 5, 5, 128)    512         conv5_block11_1_conv[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_relu[0][0]
__________________________________________________________________________________________________
conv5_block11_concat (Concatena (None, 5, 5, 864)    0           conv5_block10
_concat[0][0]
                                                                 conv5_block11
_2_conv[0][0]
__________________________________________________________________________________________________
conv5_block12_0_bn (BatchNormal (None, 5, 5, 864)    3456        conv5_block11
_concat[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_relu[0][0]
__________________________________________________________________________________________________
conv5_block12_1_bn (BatchNormal (None, 5, 5, 128)    512         conv5_block12
_1_conv[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_relu[0][0]
__________________________________________________________________________________________________
conv5_block12_concat (Concatena (None, 5, 5, 896)    0           conv5_block11
_concat[0][0]
                                                                 conv5_block12
_2_conv[0][0]
__________________________________________________________________________________________________
conv5_block13_0_bn (BatchNormal (None, 5, 5, 896)    3584        conv5_block12
_concat[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_relu[0][0]
__________________________________________________________________________________________________
conv5_block13_1_bn (BatchNormal (None, 5, 5, 128)    512         conv5_block13
_1_conv[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_relu[0][0]
__________________________________________________________________________________________________
```

```
____________________
conv5_block13_concat (Concatena (None, 5, 5, 928)    0           conv5_block12
_concat[0][0]
                                                                 conv5_block13
_2_conv[0][0]
__________________________________________________________________________________
____________________
conv5_block14_0_bn (BatchNormal (None, 5, 5, 928)    3712        conv5_block13
_concat[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_relu[0][0]
__________________________________________________________________________________
____________________
conv5_block14_1_bn (BatchNormal (None, 5, 5, 128)    512         conv5_block14
_1_conv[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_relu[0][0]
__________________________________________________________________________________
____________________
conv5_block14_concat (Concatena (None, 5, 5, 960)    0           conv5_block13
_concat[0][0]
                                                                 conv5_block14
_2_conv[0][0]
__________________________________________________________________________________
____________________
conv5_block15_0_bn (BatchNormal (None, 5, 5, 960)    3840        conv5_block14
_concat[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_relu[0][0]
__________________________________________________________________________________
____________________
conv5_block15_1_bn (BatchNormal (None, 5, 5, 128)    512         conv5_block15
_1_conv[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_relu[0][0]
__________________________________________________________________________________
____________________
conv5_block15_concat (Concatena (None, 5, 5, 992)    0           conv5_block14
_concat[0][0]
                                                                 conv5_block15
_2_conv[0][0]
__________________________________________________________________________________
____________________
conv5_block16_0_bn (BatchNormal (None, 5, 5, 992)    3968        conv5_block15
_concat[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_relu[0][0]
__________________________________________________________________________________
conv5_block16_1_bn (BatchNormal (None, 5, 5, 128)    512         conv5_block16
_1_conv[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_relu[0][0]
__________________________________________________________________________________
conv5_block16_concat (Concatena (None, 5, 5, 1024)   0           conv5_block15
_concat[0][0]
                                                                 conv5_block16
_2_conv[0][0]
__________________________________________________________________________________
bn (BatchNormalization)         (None, 5, 5, 1024)   4096        conv5_block16
_concat[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 KerasTensor(type_spec=TensorSpec(shape=(None, 180, 180, 3), dt
ype=tf.float32, name='input_1'), name='input_1', description="created by layer
'input_1'")
The output shape KerasTensor(type_spec=TensorSpec(shape=(None, 1024), dtype=t
f.float32, name=None), name='avg_pool/Mean:0', description="created by layer
'avg_pool'")
```

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,
)
```

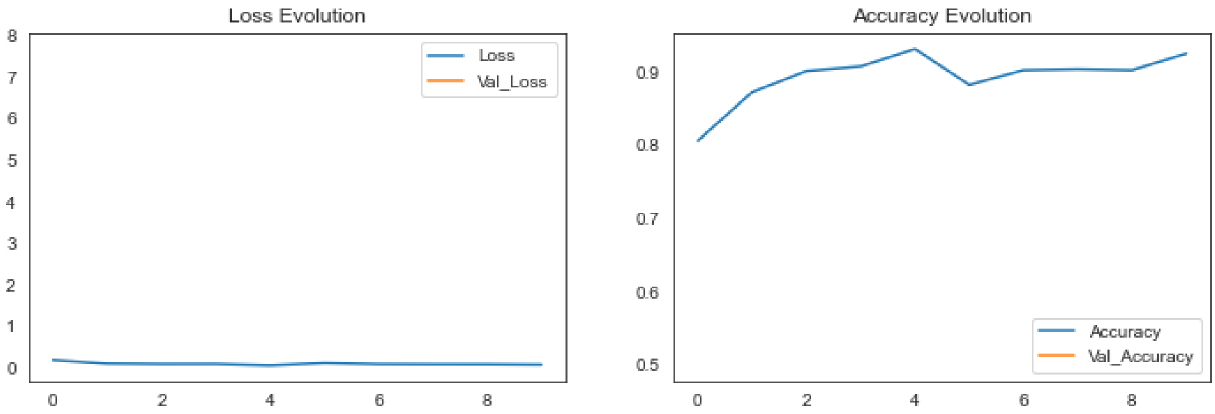
```
Epoch 1/10
100/100 [==============================] - ETA: 0s - loss: 0.1880 - accuracy:
0.8062WARNING:tensorflow:Your input ran out of data; interrupting training. Ma
ke sure that your dataset or generator can generate at least `steps_per_epoch
* epochs` batches (in this case, 25 batches). You may need to use the repeat()
function when building your dataset.
100/100 [==============================] - 151s 1s/step - loss: 0.1880 - accur
acy: 0.8062 - val_loss: 7.6849 - val_accuracy: 0.5000
Epoch 2/10
100/100 [==============================] - 141s 1s/step - loss: 0.1025 - accur
acy: 0.8725
Epoch 3/10
100/100 [==============================] - 142s 1s/step - loss: 0.0920 - accur
acy: 0.9013
Epoch 4/10
100/100 [==============================] - 141s 1s/step - loss: 0.0928 - accur
acy: 0.9075
Epoch 5/10
100/100 [==============================] - 141s 1s/step - loss: 0.0602 - accur
acy: 0.9312
Epoch 6/10
100/100 [==============================] - 141s 1s/step - loss: 0.1165 - accur
acy: 0.8825
Epoch 7/10
100/100 [==============================] - 146s 1s/step - loss: 0.0896 - accur
acy: 0.9025
Epoch 8/10
100/100 [==============================] - 145s 1s/step - loss: 0.0859 - accur
acy: 0.9038
Epoch 9/10
100/100 [==============================] - 141s 1s/step - loss: 0.0844 - accur
acy: 0.9025
Epoch 10/10
100/100 [==============================] - 142s 1s/step - loss: 0.0769 - accur
acy: 0.9250
```

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 [==============================] - 39s 63ms/step - loss: 0.5829 - accu
racy: 0.8077
Test Accuracy: 80.77%
652/652 [==============================] - 218s 334ms/step - loss: 0.2211 - ac
curacy: 0.9132
Train Accuracy: 91.32%
```

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_
```

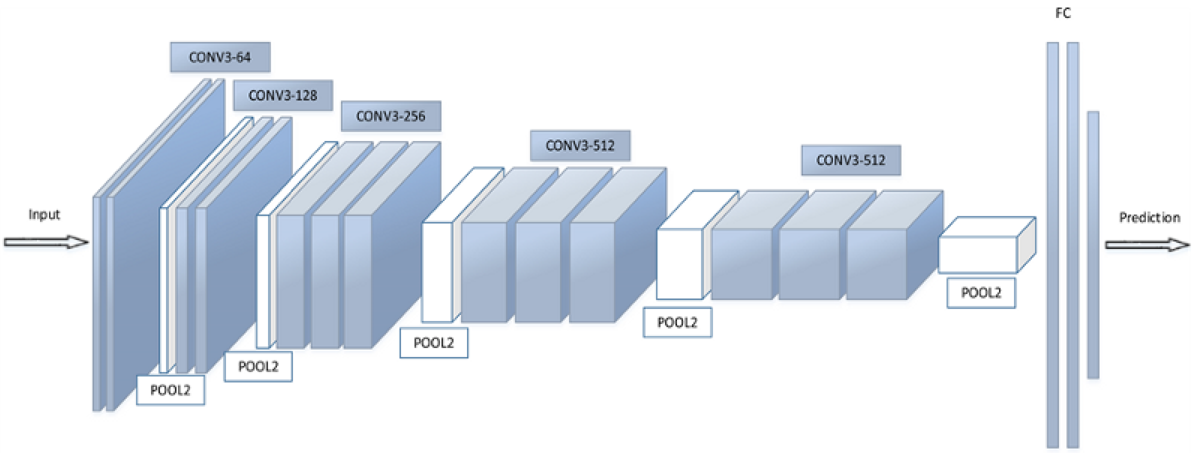
```
[[140  94]
 [ 25 365]]
```

Out[27]:

	0	1	accuracy	macro avg	weighted avg
precision	0.848485	0.795207	0.809295	0.821846	0.815186
recall	0.598291	0.935897	0.809295	0.767094	0.809295
f1-score	0.701754	0.859835	0.809295	0.780795	0.800555
support	234.000000	390.000000	0.809295	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 [29]:

```
from keras.models import Sequential
from keras.layers import GlobalAveragePooling2D
from keras.applications.vgg16 import VGG16


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

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applicat
ions/vgg16/vgg16_weights_tf_dim_ordering_tf_kernels_notop.h5
58892288/58889256 [==============================] - 1s 0us/step
58900480/58889256 [==============================] - 1s 0us/step
```

In [30]:

```
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 [31]:

```
    vgg16_model = tf.keras.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")
    ])
```

In [32]:

```
    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=METR
```

In [33]:

```
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: 0.3160 - accuracy:
0.5512 - precision: 0.8158 - recall: 0.5175WARNING:tensorflow:Your input ran o
ut of data; interrupting training. Make sure that your dataset or generator ca
n generate at least `steps_per_epoch * epochs` batches (in this case, 25 batch
es). You may need to use the repeat() function when building your dataset.
100/100 [==============================] - 224s 2s/step - loss: 0.3160 - accur
acy: 0.5512 - precision: 0.8158 - recall: 0.5175 - val_loss: 3.2663 - val_accu
racy: 0.5000 - val_precision: 0.0000e+00 - val_recall: 0.0000e+00
Epoch 2/10
100/100 [==============================] - 217s 2s/step - loss: 0.2063 - accur
acy: 0.7200 - precision: 0.9103 - recall: 0.6881
Epoch 3/10
100/100 [==============================] - 222s 2s/step - loss: 0.1919 - accur
acy: 0.7763 - precision: 0.9468 - recall: 0.7429
Epoch 4/10
```

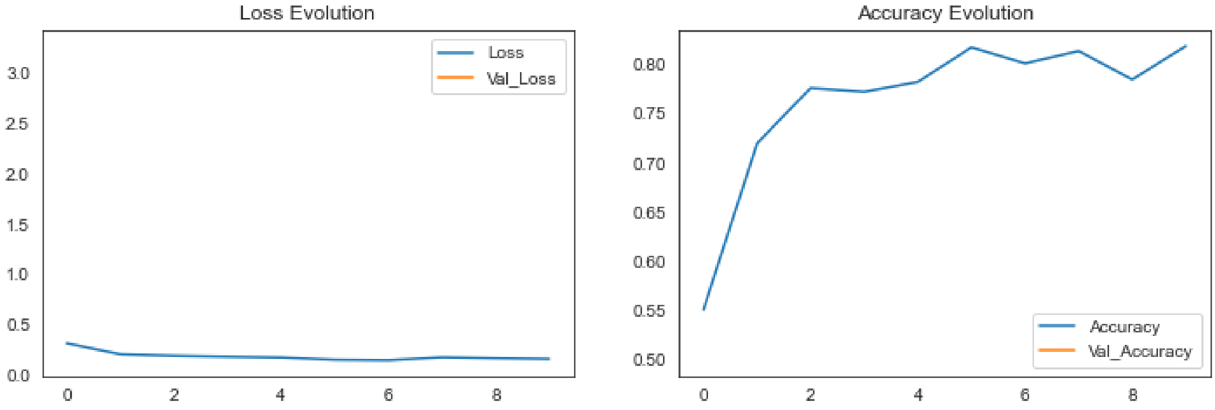
```
100/100 [==============================] - 226s 2s/step - loss: 0.1828 - accuracy: 0.7725 - precision: 0.9291 - recall: 0.7574
Epoch 5/10
100/100 [==============================] - 229s 2s/step - loss: 0.1748 - accuracy: 0.7825 - precision: 0.9293 - recall: 0.7615
Epoch 6/10
100/100 [==============================] - 235s 2s/step - loss: 0.1521 - accuracy: 0.8175 - precision: 0.9512 - recall: 0.8010
Epoch 7/10
100/100 [==============================] - 236s 2s/step - loss: 0.1475 - accuracy: 0.8012 - precision: 0.9526 - recall: 0.7726
Epoch 8/10
100/100 [==============================] - 242s 2s/step - loss: 0.1765 - accuracy: 0.8138 - precision: 0.9278 - recall: 0.8147
Epoch 9/10
100/100 [==============================] - 228s 2s/step - loss: 0.1675 - accuracy: 0.7850 - precision: 0.9340 - recall: 0.7639
Epoch 10/10
100/100 [==============================] - 229s 2s/step - loss: 0.1605 - accuracy: 0.8188 - precision: 0.9380 - recall: 0.8107
```

In [34]:

```
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[34]:

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



In [35]:

```
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 [==============================] - 61s 98ms/step - loss: 0.5405 - accuracy: 0.7228 - precision: 0.7020 - recall: 0.9667
Test Accuracy: 72.28%
652/652 [==============================] - 498s 764ms/step - loss: 0.2566 - accuracy: 0.8892 - precision: 0.9077 - recall: 0.9471
Train Accuracy: 88.92%
```

ResNet

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

In [43]:

```
from tensorflow.python.keras.applications.resnet import ResNet50

resnet_base_model = ResNet50(input_shape=(180,180,3), include_top=False, weig
```

In [44]:

```
resnet_base_model.summary()
```

```
Model: "resnet50"
______________________________________________________________________________
____________________
Layer (type)                    Output Shape         Param #     Connected to
==============================================================================
====================
input_2 (InputLayer)            [(None, 180, 180, 3) 0
______________________________________________________________________________
____________________
conv1_pad (ZeroPadding2D)       (None, 186, 186, 3)  0           input_2[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 [45]:

```
    resnet_model = tf.keras.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=MET
```

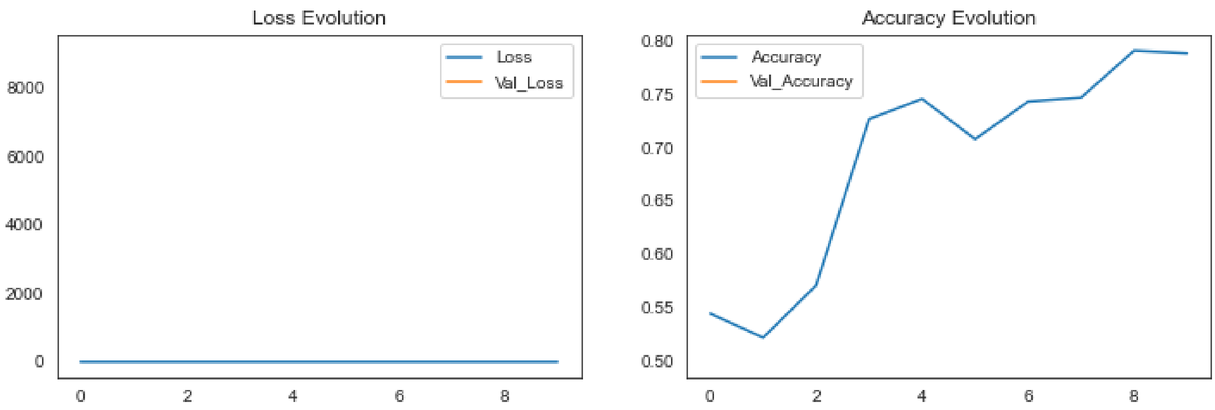
In [46]:

```
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: 0.3237 - accuracy:
0.5450 - precision: 0.7888 - recall: 0.5399WARNING:tensorflow:Your input ran o
ut of data; interrupting training. Make sure that your dataset or generator ca
n generate at least `steps_per_epoch * epochs` batches (in this case, 25 batch
es). You may need to use the repeat() function when building your dataset.
100/100 [==============================] - 144s 1s/step - loss: 0.3237 - accur
acy: 0.5450 - precision: 0.7888 - recall: 0.5399 - val_loss: 9098.6367 - val_a
ccuracy: 0.5000 - val_precision: 0.5000 - val_recall: 1.0000
Epoch 2/10
100/100 [==============================] - 133s 1s/step - loss: 0.3136 - accur
acy: 0.5225 - precision: 0.7724 - recall: 0.5255
Epoch 3/10
100/100 [==============================] - 126s 1s/step - loss: 0.2928 - accur
acy: 0.5713 - precision: 0.8072 - recall: 0.5395
Epoch 4/10
100/100 [==============================] - 129s 1s/step - loss: 0.2005 - accur
acy: 0.7262 - precision: 0.9234 - recall: 0.6964
Epoch 5/10
100/100 [==============================] - 134s 1s/step - loss: 0.2195 - accur
acy: 0.7450 - precision: 0.8921 - recall: 0.7436
Epoch 6/10
100/100 [==============================] - 153s 2s/step - loss: 0.2269 - accur
acy: 0.7075 - precision: 0.8671 - recall: 0.7150
Epoch 7/10
100/100 [==============================] - 142s 1s/step - loss: 0.2106 - accur
acy: 0.7425 - precision: 0.8834 - recall: 0.7435
Epoch 8/10
100/100 [==============================] - 135s 1s/step - loss: 0.1953 - accur
acy: 0.7462 - precision: 0.9110 - recall: 0.7333
Epoch 9/10
100/100 [==============================] - 136s 1s/step - loss: 0.1814 - accur
acy: 0.7900 - precision: 0.9160 - recall: 0.7947
Epoch 10/10
100/100 [==============================] - 132s 1s/step - loss: 0.1778 - accur
acy: 0.7875 - precision: 0.9275 - recall: 0.7805
```

In [47]:
```
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[47]:
```
Text(0.5, 1.0, 'Accuracy Evolution')
```



In [48]:
```
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 [==============================] - 42s 67ms/step - loss: 0.5661 - accu
racy: 0.7308 - precision: 0.7606 - recall: 0.8308
Test Accuracy: 73.08%
652/652 [==============================] - 245s 375ms/step - loss: 0.3449 - ac
curacy: 0.8407 - precision: 0.9666 - recall: 0.8137
Train Accuracy: 84.07%
```

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 [51]:
```
from keras.applications.inception_v3 import InceptionV3
from tensorflow.keras.applications import imagenet_utils

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

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applicat
ions/inception_v3/inception_v3_weights_tf_dim_ordering_tf_kernels_notop.h5
```

```
87916544/87910968 [==============================] - 3s 0us/step
87924736/87910968 [==============================] - 3s 0us/step
```

In [52]:

```
    inception_model = tf.keras.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=M
```

In [53]:

```
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: 0.2935 - accuracy:
0.6212 - precision: 0.8239 - recall: 0.6062WARNING:tensorflow:Your input ran o
ut of data; interrupting training. Make sure that your dataset or generator ca
n generate at least `steps_per_epoch * epochs` batches (in this case, 25 batch
es). You may need to use the repeat() function when building your dataset.
100/100 [==============================] - 91s 834ms/step - loss: 0.2935 - acc
uracy: 0.6212 - precision: 0.8239 - recall: 0.6062 - val_loss: 40.9358 - val_a
ccuracy: 0.6250 - val_precision: 0.5714 - val_recall: 1.0000
Epoch 2/10
100/100 [==============================] - 81s 813ms/step - loss: 0.1979 - acc
uracy: 0.7800 - precision: 0.9126 - recall: 0.7602
Epoch 3/10
100/100 [==============================] - 82s 815ms/step - loss: 0.1927 - acc
uracy: 0.7900 - precision: 0.9293 - recall: 0.7694
Epoch 4/10
100/100 [==============================] - 80s 797ms/step - loss: 0.1804 - acc
uracy: 0.7750 - precision: 0.9244 - recall: 0.7534
Epoch 5/10
100/100 [==============================] - 84s 837ms/step - loss: 0.1836 - acc
uracy: 0.7900 - precision: 0.9208 - recall: 0.7841
Epoch 6/10
100/100 [==============================] - 84s 833ms/step - loss: 0.1624 - acc
uracy: 0.7987 - precision: 0.9481 - recall: 0.7787
Epoch 7/10
100/100 [==============================] - 84s 842ms/step - loss: 0.1728 - acc
uracy: 0.8012 - precision: 0.9193 - recall: 0.8086
Epoch 8/10
100/100 [==============================] - 95s 947ms/step - loss: 0.1419 - acc
uracy: 0.8662 - precision: 0.9542 - recall: 0.8640
Epoch 9/10
100/100 [==============================] - 92s 920ms/step - loss: 0.1731 - acc
```

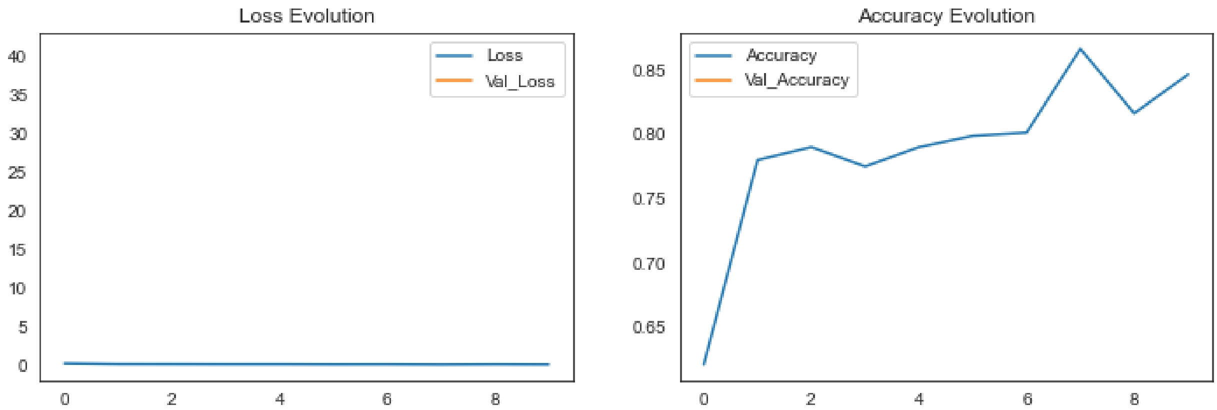
```
uracy: 0.8163 - precision: 0.9206 - recall: 0.8226
Epoch 10/10
100/100 [==============================] - 85s 845ms/step - loss: 0.1457 - acc
uracy: 0.8462 - precision: 0.9332 - recall: 0.8475
```

In [54]:

```
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[54]:

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



In [55]:

```
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 [==============================] - 24s 38ms/step - loss: 5.1198 - accu
racy: 0.6667 - precision: 0.6585 - recall: 0.9692
Test Accuracy: 66.67%
652/652 [==============================] - 140s 215ms/step - loss: 2.6478 - ac
curacy: 0.8037 - precision: 0.8106 - recall: 0.9600
Train Accuracy: 80.37%
```