Chest X Ray medical diagnosis with CNN

Import Libraries

In [2]:
```
import os
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns

from keras.preprocessing.image import ImageDataGenerator
from keras.models import Sequential, Model
from keras.layers import (
    Dense, Conv2D, MaxPool2D, Dropout, Flatten,
    BatchNormalization, GlobalAveragePooling2D
)

from keras.applications.densenet import DenseNet121
from keras import backend as K

from sklearn.metrics import confusion_matrix, classification_report

os.listdir("../input/chest-xray-pneumonia/chest_xray")
```

```
/opt/conda/lib/python3.10/site-packages/scipy/__init__.py:146: UserWarning: A NumPy version >=1.16.5 and <1.23.0 is required for this version of SciPy (detected version 1.23.5
  warnings.warn(f"A NumPy version >={np_minversion} and <{np_maxversion}"
```

Out[2]:
```
['chest_xray', '__MACOSX', 'val', 'test', 'train']
```

In [3]:
```
len(os.listdir("../input/chest-xray-pneumonia/chest_xray/train/PNEUMONIA"))
```

Out[3]:
```
3875
```

The dataset is divided into three sets

1. Train set
2. Validation set
3. Test set.

Data Visualization

In [4]:
```
train_dir = "../input/chest-xray-pneumonia/chest_xray/train"
test_dir = "../input/chest-xray-pneumonia/chest_xray/test"
val_dir = "../input/chest-xray-pneumonia/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')))}")

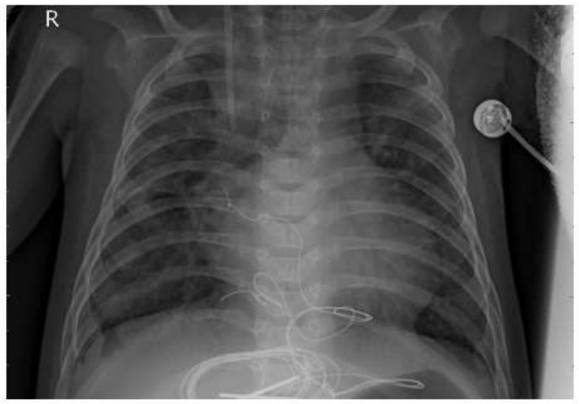
pneumonia = os.listdir("../input/chest-xray-pneumonia/chest_xray/train/PNEUMONIA")
pneumonia_dir = "../input/chest-xray-pneumonia/chest_xray/train/PNEUMONIA"

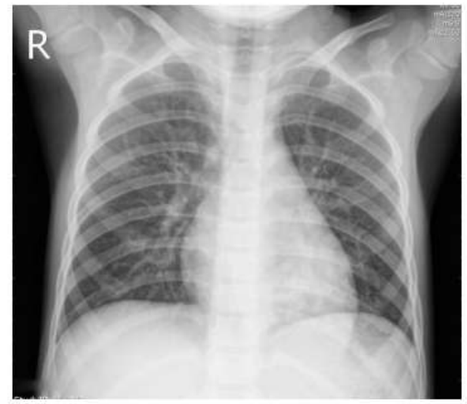
plt.figure(figsize=(20, 10))

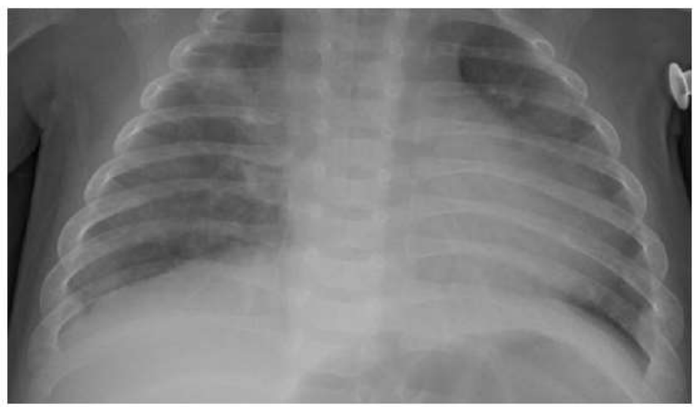
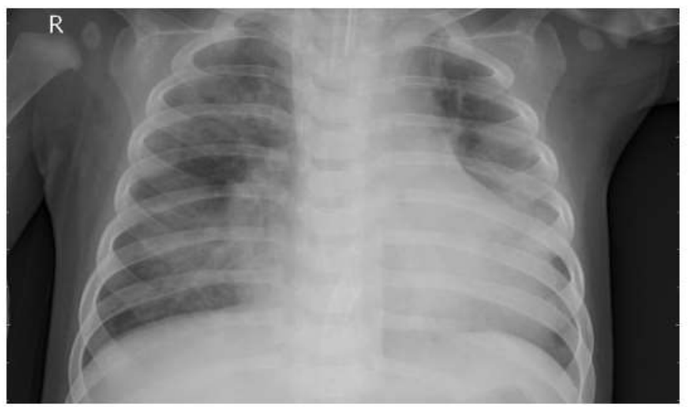
for i in range(9):
    plt.subplot(3, 3, i + 1)
    img = plt.imread(os.path.join(pneumonia_dir, pneumonia[i]))
    plt.imshow(img, cmap='gray')
    plt.axis('off')

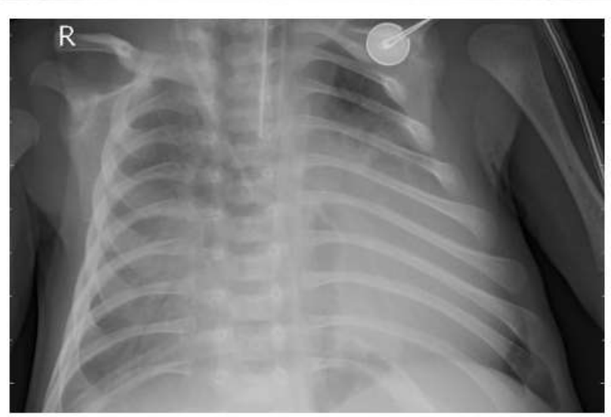
plt.tight_layout()
```

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



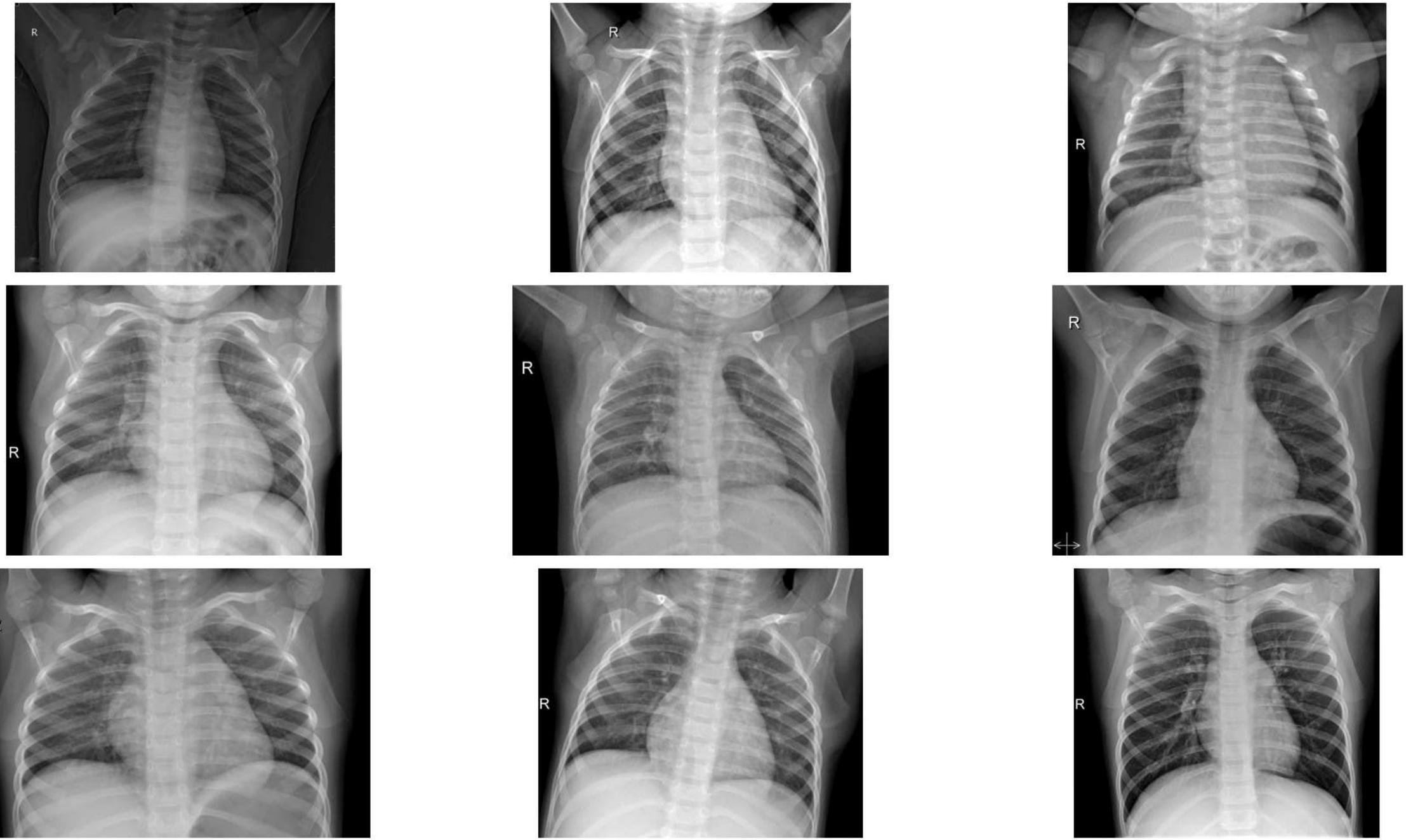



In [5]:
```
normal = os.listdir("../input/chest-xray-pneumonia/chest_xray/train/NORMAL")
normal_dir = "../input/chest-xray-pneumonia/chest_xray/train/NORMAL"

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()
```



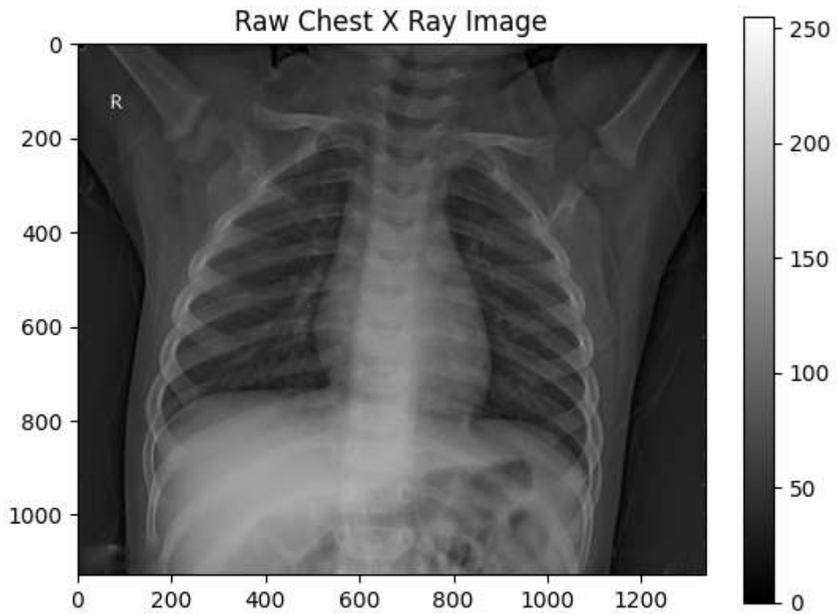
Investigate a single image

In [6]:
```
normal_img = os.listdir("../input/chest-xray-pneumonia/chest_xray/train/NORMAL")[0]
normal_dir = "../input/chest-xray-pneumonia/chest_xray/train/NORMAL"

sample_img = plt.imread(os.path.join(normal_dir, normal_img))
plt.imshow(sample_img, cmap='gray')
plt.colorbar()
plt.title('Raw Chest X Ray Image')

print(f"The dimensions of the image are {sample_img.shape[0]} pixels width and {sample_img.shape[1]} pixels height, one single color channel.")
print(f"The maximum pixel value is {sample_img.max():.4f} and the minimum is {sample_img.min():.4f}")
print(f"The mean value of the pixels is {sample_img.mean():.4f} and the standard deviation is {sample_img.std():.4f}")
```

```
The dimensions of the image are 1128 pixels width and 1336 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 73.2978 and the standard deviation is 38.1653
```



Investigate pixel value distribution

In [7]:
```
sns.distplot(sample_img.ravel(),
             label=f"Pixel Mean {np.mean(sample_img):.4f} & Standard Deviation {np.std(sample_img):.4f}",
             kde=False)
plt.legend(loc='upper right')
plt.title('Distribution of Pixel Intensities in the Image')
plt.xlabel('Pixel Intensity')
plt.ylabel('# Pixels in Image')
```

```
/tmp/ipykernel_28/296820011.py:1: UserWarning:

`distplot` is a deprecated function and will be removed in seaborn v0.14.0.

Please adapt your code to use either `displot` (a figure-level function with
similar flexibility) or `histplot` (an axes-level function for histograms).

For a guide to updating your code to use the new functions, please see
https://gist.github.com/mwaskom/de44147ed2974457ad6372750bbe5751

  sns.distplot(sample_img.ravel(),
```

Out[7]: Text(0, 0.5, '# Pixels in Image')

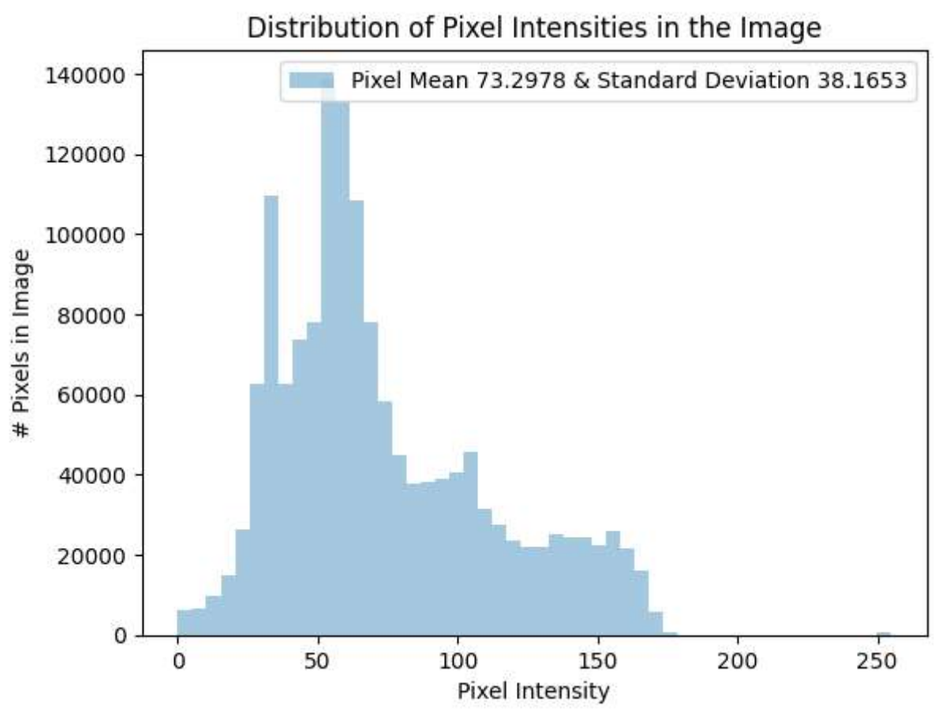


Image Preprocessing

Before commencing training, the initial step involves modifying your images to better suit the training of a convolutional neural network. To achieve this, you'll utilize the Keras ImageDataGenerator function for both data preprocessing and augmentation.

This class also supports fundamental data augmentation techniques, such as randomly flipping images horizontally. Additionally, we employ the generator to standardize the values within each batch, ensuring a mean of 0 and a standard deviation of 1. This standardization significantly aids model training by normalizing the input distribution. The generator also performs the conversion of our single-channel X-ray images (grayscale) into a three-channel format by replicating the image values across all channels. This conversion is essential because the pre-trained model we intend to use necessitates three-channel inputs.

In [8]:
```
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

It's time to create a new generator specifically designed for handling validation and testing data.

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

Revisiting the generator designed for training data:

The normalization process within this generator occurs per batch, utilizing batch-specific statistics.

However, it's crucial not to apply this approach to test and validation data, given that real-world scenarios typically involve processing individual images, not batches.

Using batch-specific statistics for test data could unintentionally bias the model, providing it with information about the test data it shouldn't possess.

What we should aim for is normalizing incoming test data using the statistical metrics computed from the training set.

In [9]:
```
train = image_generator.flow_from_directory(train_dir,
                                            batch_size=8,
                                            shuffle=True,
                                            class_mode='binary',
                                            target_size=(320, 320))

validation = image_generator.flow_from_directory(val_dir,
                                                 batch_size=1,
                                                 shuffle=False,
                                                 class_mode='binary',
                                                 target_size=(320, 320))

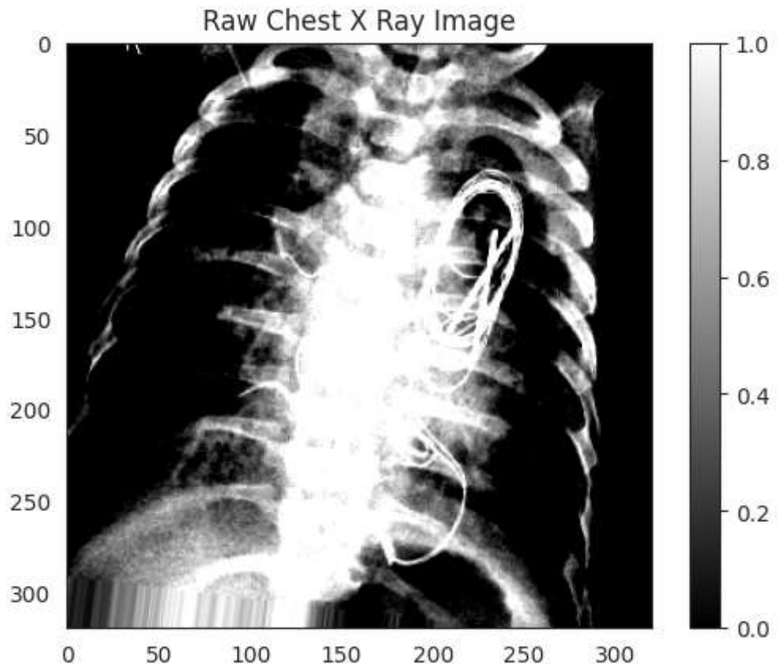
test = image_generator.flow_from_directory(test_dir,
                                           batch_size=1,
                                           shuffle=False,
                                           class_mode='binary',
                                           target_size=(320, 320))
```

```
Found 5216 images belonging to 2 classes.
Found 16 images belonging to 2 classes.
Found 624 images belonging to 2 classes.
```

In [10]:
```
sns.set_style('white')
generated_image, label = train.__getitem__(0)
plt.imshow(generated_image[0], cmap='gray')
plt.colorbar()
plt.title('Raw Chest X Ray Image')

print(f"The dimensions of the image are {generated_image.shape[1]} pixels width and {generated_image.shape[2]} pixels height, one single color channel.")
print(f"The maximum pixel value is {generated_image.max():.4f} and the minimum is {generated_image.min():.4f}")
print(f"The mean value of the pixels is {generated_image.mean():.4f} and the standard deviation is {generated_image.std():.4f}")
```

```
The dimensions of the image are 320 pixels width and 320 pixels height, one single color channel.
The maximum pixel value is 2.8604 and the minimum is -3.7079
The mean value of the pixels is -0.0000 and the standard deviation is 1.0000
```



In [11]:
```
sns.distplot(generated_image.ravel(),
             label=f"Pixel Mean {np.mean(generated_image):.4f} & Standard Deviation {np.std(generated_image):.4f}",
             kde=False)
plt.legend(loc='upper center')
plt.title('Distribution of Pixel Intensities in the Image')
plt.xlabel('Pixel Intensity')
plt.ylabel('# Pixels in Image')
```

```
/tmp/ipykernel_28/4033312467.py:1: UserWarning:

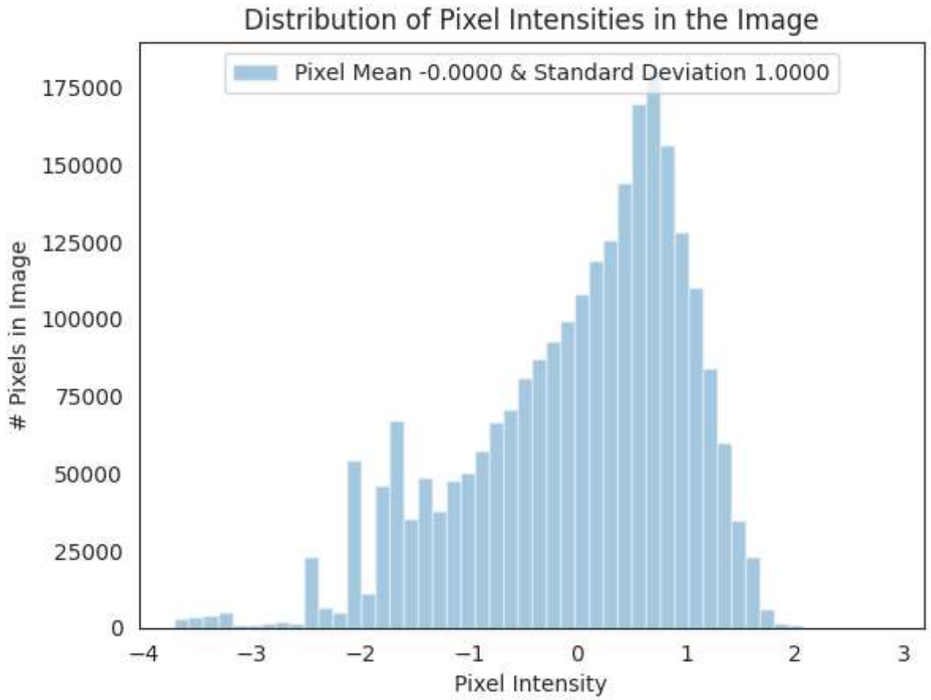
`distplot` is a deprecated function and will be removed in seaborn v0.14.0.

Please adapt your code to use either `displot` (a figure-level function with
similar flexibility) or `histplot` (an axes-level function for histograms).

For a guide to updating your code to use the new functions, please see
https://gist.github.com/mwaskom/de44147ed2974457ad6372750bbe5751

  sns.distplot(generated_image.ravel(),
```

Out[11]:
```
Text(0, 0.5, '# Pixels in Image')
```



Model Building

An inherent challenge in handling medical diagnostic datasets is the substantial class imbalance that often exists within such data.

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 express the 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 imbalanced data, using a standard loss function will result in a model that is biased toward the dominating class. One solution is to use a weighted loss function. Implementing a weighted loss function balances the contributions within the loss function.

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

In [12]:
```
# 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 [13]:
```
model = Sequential()

model.add(Conv2D(filters=32, kernel_size=(3, 3), input_shape=(320, 320, 3), activation='relu'))
model.add(BatchNormalization())
model.add(Conv2D(filters=32, kernel_size=(3, 3), input_shape=(320, 320, 3), activation='relu'))
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 [14]:
```
model.summary()
```

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)             (None, 318, 318, 32)      896

 batch_normalization (BatchN  (None, 318, 318, 32)     128
 ormalization)

 conv2d_1 (Conv2D)           (None, 316, 316, 32)      9248

 batch_normalization_1 (Batc  (None, 316, 316, 32)     128
 hNormalization)

 max_pooling2d (MaxPooling2D  (None, 158, 158, 32)     0
 )

 conv2d_2 (Conv2D)           (None, 156, 156, 64)      18496

 batch_normalization_2 (Batc  (None, 156, 156, 64)     256
 hNormalization)

 conv2d_3 (Conv2D)           (None, 154, 154, 64)      36928

 batch_normalization_3 (Batc  (None, 154, 154, 64)     256
 hNormalization)

 max_pooling2d_1 (MaxPooling  (None, 77, 77, 64)       0
 2D)

 conv2d_4 (Conv2D)           (None, 75, 75, 128)       73856

 batch_normalization_4 (Batc  (None, 75, 75, 128)      512
 hNormalization)

 conv2d_5 (Conv2D)           (None, 73, 73, 128)       147584

 batch_normalization_5 (Batc  (None, 73, 73, 128)      512
 hNormalization)

 max_pooling2d_2 (MaxPooling  (None, 36, 36, 128)      0
 2D)

 flatten (Flatten)           (None, 165888)            0

 dense (Dense)               (None, 128)               21233792

 dropout (Dropout)           (None, 128)               0

 dense_1 (Dense)             (None, 1)                 129

=================================================================
Total params: 21,522,721
Trainable params: 21,521,825
Non-trainable params: 896
_________________________________________________________________
```

In [15]:

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

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

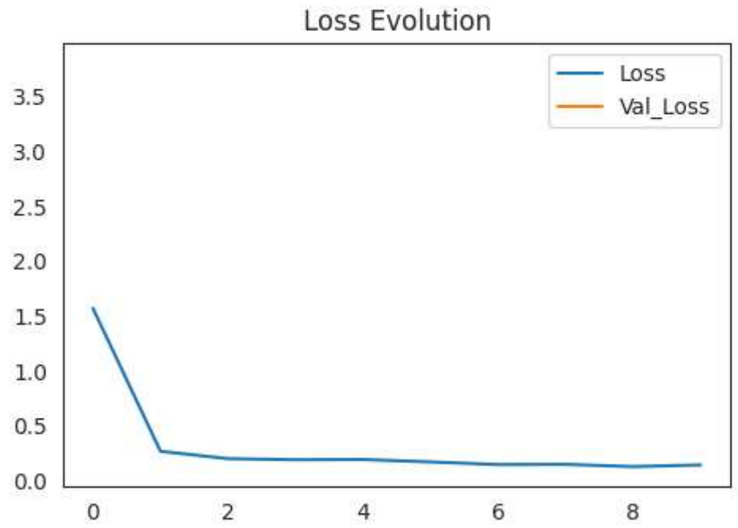
```
Epoch 1/10
100/100 [==============================] - 47s 329ms/step - loss: 1.5680 - accuracy: 0.6988 - val_loss: 3.7970 - val_accuracy: 0.5000
Epoch 2/10
100/100 [==============================] - 30s 303ms/step - loss: 0.2670 - accuracy: 0.6175
Epoch 3/10
100/100 [==============================] - 30s 300ms/step - loss: 0.1998 - accuracy: 0.6775
Epoch 4/10
100/100 [==============================] - 29s 287ms/step - loss: 0.1901 - accuracy: 0.6637
Epoch 5/10
100/100 [==============================] - 28s 281ms/step - loss: 0.1922 - accuracy: 0.7050
Epoch 6/10
100/100 [==============================] - 28s 277ms/step - loss: 0.1700 - accuracy: 0.6963
Epoch 7/10
100/100 [==============================] - 28s 279ms/step - loss: 0.1460 - accuracy: 0.7738
Epoch 8/10
100/100 [==============================] - 28s 277ms/step - loss: 0.1479 - accuracy: 0.7437
Epoch 9/10
100/100 [==============================] - 27s 267ms/step - loss: 0.1272 - accuracy: 0.7912
Epoch 10/10
100/100 [==============================] - 27s 273ms/step - loss: 0.1424 - accuracy: 0.7650
```

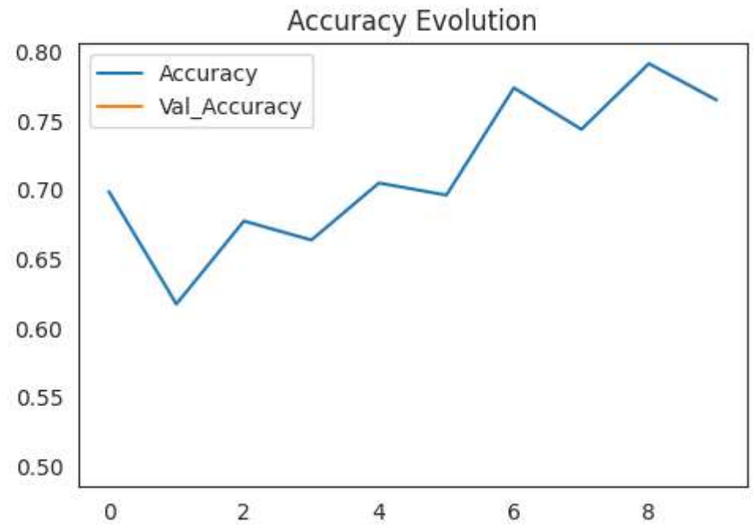
In [16]:
```
plt.figure(figsize=(12, 8))

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[16]:
```
Text(0.5, 1.0, 'Accuracy Evolution')
```





In [17]:
```
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 [==============================] - 23s 36ms/step - loss: 0.5897 - accuracy: 0.7484
Test Accuracy: 74.84%
652/652 [==============================] - 166s 255ms/step - loss: 0.3048 - accuracy: 0.8844
Train Accuracy: 88.44%
```

In [18]:
```
pred = model.predict(test)

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

```
624/624 [==============================] - 19s 31ms/step
[[ 92 142]
 [ 11 379]]
```

Out[18]:

	0	1	accuracy	macro avg	weighted avg
precision	0.893204	0.727447	0.754808	0.810326	0.789606
recall	0.393162	0.971795	0.754808	0.682479	0.754808
f1-score	0.545994	0.832053	0.754808	0.689023	0.724781
support	234.000000	390.000000	0.754808	624.000000	624.000000

In [19]:
```
print(confusion_matrix(test.classes, pred > 0.7))
pd.DataFrame(classification_report(test.classes, pred > 0.7, output_dict=True))
```

```
[[148  86]
 [ 29 361]]
```

Out[19]:

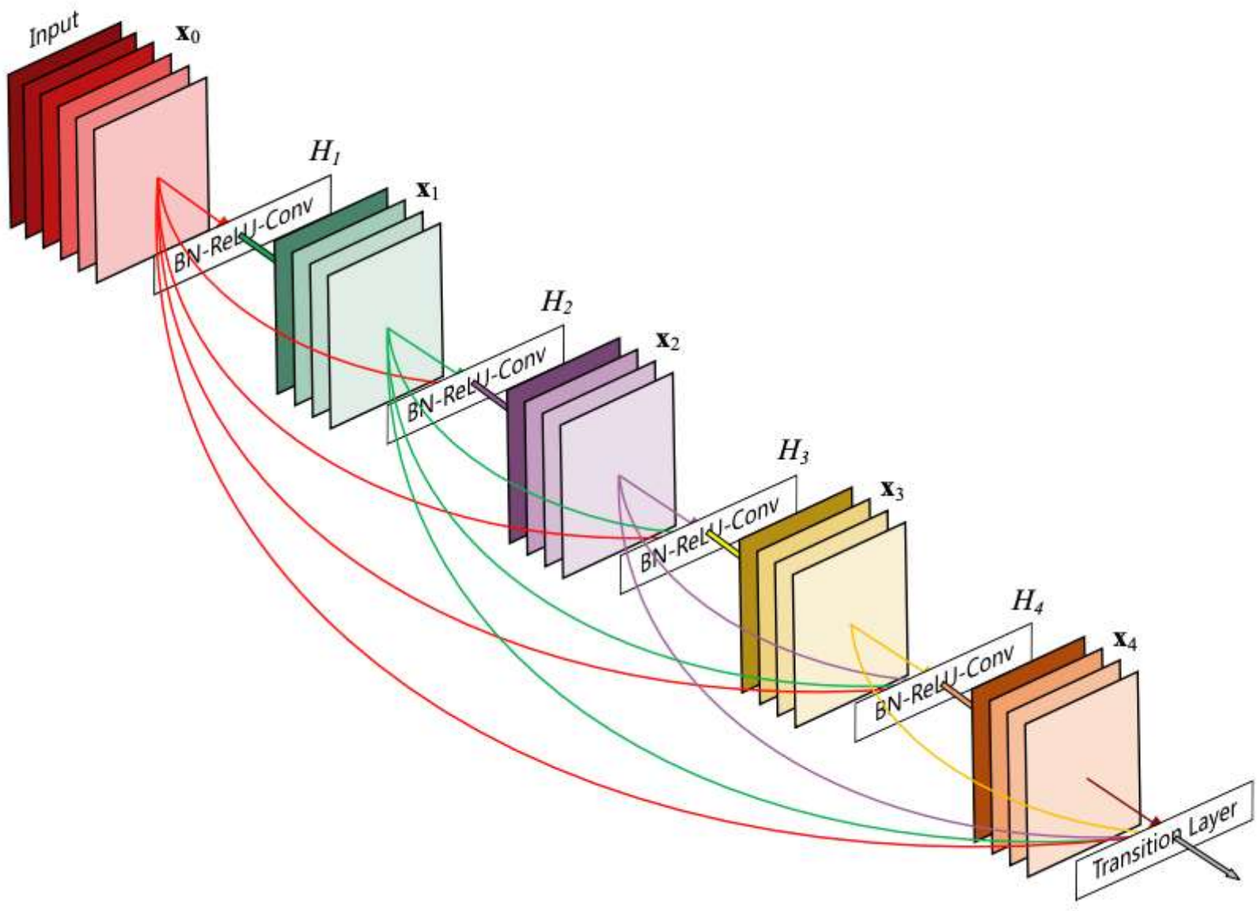
	0	1	accuracy	macro avg	weighted avg
precision	0.836158	0.807606	0.815705	0.821882	0.818313
recall	0.632479	0.925641	0.815705	0.779060	0.815705
f1-score	0.720195	0.862605	0.815705	0.791400	0.809201
support	234.000000	390.000000	0.815705	624.000000	624.000000

DenseNet

Densenet is a type of convolutional network in which each layer is connected to all subsequent layers within the network:

The first layer is connected to the 2nd, 3rd, 4th, and so forth.

Subsequently, the second layer is connected to the 3rd, 4th, 5th, and so on



In [20]:
```
base_model = DenseNet121(input_shape=(320, 320, 3), include_top=False, weights='imagenet', pooling='avg')

base_model.summary()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/densenet/densenet121_weights_tf_dim_ordering_tf_kernels_notop.h5
29084464/29084464 [==============================] - 0s 0us/step
Model: "densenet121"
```

Layer (type)	Output Shape	Param #	Connected to
input_1 (InputLayer)	[(None, 320, 320, 3)]	0	[]
zero_padding2d (ZeroPadding2D)	(None, 326, 326, 3)	0	['input_1[0][0]']
conv1/conv (Conv2D)	(None, 160, 160, 64)	9408	['zero_padding2d[0][0]']
conv1/bn (BatchNormalization)	(None, 160, 160, 64)	256	['conv1/conv[0][0]']
conv1/relu (Activation)	(None, 160, 160, 64)	0	['conv1/bn[0][0]']
zero_padding2d_1 (ZeroPadding2D)	(None, 162, 162, 64)	0	['conv1/relu[0][0]']
pool1 (MaxPooling2D)	(None, 80, 80, 64)	0	['zero_padding2d_1[0][0]']
conv2_block1_0_bn (BatchNormalization)	(None, 80, 80, 64)	256	['pool1[0][0]']
conv2_block1_0_relu (Activation)	(None, 80, 80, 64)	0	['conv2_block1_0_bn[0][0]']
conv2_block1_1_conv (Conv2D)	(None, 80, 80, 128)	8192	['conv2_block1_0_relu[0][0]']
conv2_block1_1_bn (BatchNormalization)	(None, 80, 80, 128)	512	['conv2_block1_1_conv[0][0]']
conv2_block1_1_relu (Activation)	(None, 80, 80, 128)	0	['conv2_block1_1_bn[0][0]']
conv2_block1_2_conv (Conv2D)	(None, 80, 80, 32)	36864	['conv2_block1_1_relu[0][0]']
conv2_block1_concat (Concatenate)	(None, 80, 80, 96)	0	['pool1[0][0]', 'conv2_block1_2_conv[0][0]']
conv2_block2_0_bn (BatchNormalization)	(None, 80, 80, 96)	384	['conv2_block1_concat[0][0]']
conv2_block2_0_relu (Activation)	(None, 80, 80, 96)	0	['conv2_block2_0_bn[0][0]']
conv2_block2_1_conv (Conv2D)	(None, 80, 80, 128)	12288	['conv2_block2_0_relu[0][0]']
conv2_block2_1_bn (BatchNormalization)	(None, 80, 80, 128)	512	['conv2_block2_1_conv[0][0]']
conv2_block2_1_relu (Activation)	(None, 80, 80, 128)	0	['conv2_block2_1_bn[0][0]']
conv2_block2_2_conv (Conv2D)	(None, 80, 80, 32)	36864	['conv2_block2_1_relu[0][0]']

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conv2_block2_concat (Concatena  (None, 80, 80, 128)  0          ['conv2_block1_concat[0][0]',
te)                                                              'conv2_block2_2_conv[0][0]']

conv2_block3_0_bn (BatchNormal  (None, 80, 80, 128)  512        ['conv2_block2_concat[0][0]']
ization)

conv2_block3_0_relu (Activatio  (None, 80, 80, 128)  0          ['conv2_block3_0_bn[0][0]']
n)

conv2_block3_1_conv (Conv2D)   (None, 80, 80, 128)  16384      ['conv2_block3_0_relu[0][0]']

conv2_block3_1_bn (BatchNormal  (None, 80, 80, 128)  512        ['conv2_block3_1_conv[0][0]']
ization)

conv2_block3_1_relu (Activatio  (None, 80, 80, 128)  0          ['conv2_block3_1_bn[0][0]']
n)

conv2_block3_2_conv (Conv2D)   (None, 80, 80, 32)   36864      ['conv2_block3_1_relu[0][0]']

conv2_block3_concat (Concatena  (None, 80, 80, 160)  0          ['conv2_block2_concat[0][0]',
te)                                                              'conv2_block3_2_conv[0][0]']

conv2_block4_0_bn (BatchNormal  (None, 80, 80, 160)  640        ['conv2_block3_concat[0][0]']
ization)

conv2_block4_0_relu (Activatio  (None, 80, 80, 160)  0          ['conv2_block4_0_bn[0][0]']
n)

conv2_block4_1_conv (Conv2D)   (None, 80, 80, 128)  20480      ['conv2_block4_0_relu[0][0]']

conv2_block4_1_bn (BatchNormal  (None, 80, 80, 128)  512        ['conv2_block4_1_conv[0][0]']
ization)

conv2_block4_1_relu (Activatio  (None, 80, 80, 128)  0          ['conv2_block4_1_bn[0][0]']
n)

conv2_block4_2_conv (Conv2D)   (None, 80, 80, 32)   36864      ['conv2_block4_1_relu[0][0]']

conv2_block4_concat (Concatena  (None, 80, 80, 192)  0          ['conv2_block3_concat[0][0]',
te)                                                              'conv2_block4_2_conv[0][0]']

conv2_block5_0_bn (BatchNormal  (None, 80, 80, 192)  768        ['conv2_block4_concat[0][0]']
ization)

conv2_block5_0_relu (Activatio  (None, 80, 80, 192)  0          ['conv2_block5_0_bn[0][0]']
n)

conv2_block5_1_conv (Conv2D)   (None, 80, 80, 128)  24576      ['conv2_block5_0_relu[0][0]']

conv2_block5_1_bn (BatchNormal  (None, 80, 80, 128)  512        ['conv2_block5_1_conv[0][0]']
ization)

conv2_block5_1_relu (Activatio  (None, 80, 80, 128)  0          ['conv2_block5_1_bn[0][0]']
n)

conv2_block5_2_conv (Conv2D)   (None, 80, 80, 32)   36864      ['conv2_block5_1_relu[0][0]']

conv2_block5_concat (Concatena  (None, 80, 80, 224)  0          ['conv2_block4_concat[0][0]',
te)                                                              'conv2_block5_2_conv[0][0]']
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conv2_block6_0_bn (BatchNormal  (None, 80, 80, 224)  896        ['conv2_block5_concat[0][0]']
ization)

conv2_block6_0_relu (Activatio  (None, 80, 80, 224)  0          ['conv2_block6_0_bn[0][0]']
n)

conv2_block6_1_conv (Conv2D)   (None, 80, 80, 128)  28672      ['conv2_block6_0_relu[0][0]']

conv2_block6_1_bn (BatchNormal  (None, 80, 80, 128)  512        ['conv2_block6_1_conv[0][0]']
ization)

conv2_block6_1_relu (Activatio  (None, 80, 80, 128)  0          ['conv2_block6_1_bn[0][0]']
n)

conv2_block6_2_conv (Conv2D)   (None, 80, 80, 32)   36864      ['conv2_block6_1_relu[0][0]']

conv2_block6_concat (Concatena  (None, 80, 80, 256)  0          ['conv2_block5_concat[0][0]',
te)                                                              'conv2_block6_2_conv[0][0]']

pool2_bn (BatchNormalization)  (None, 80, 80, 256)  1024       ['conv2_block6_concat[0][0]']

pool2_relu (Activation)        (None, 80, 80, 256)  0          ['pool2_bn[0][0]']

pool2_conv (Conv2D)            (None, 80, 80, 128)  32768      ['pool2_relu[0][0]']

pool2_pool (AveragePooling2D)  (None, 40, 40, 128)  0          ['pool2_conv[0][0]']

conv3_block1_0_bn (BatchNormal  (None, 40, 40, 128)  512        ['pool2_pool[0][0]']
ization)

conv3_block1_0_relu (Activatio  (None, 40, 40, 128)  0          ['conv3_block1_0_bn[0][0]']
n)

conv3_block1_1_conv (Conv2D)   (None, 40, 40, 128)  16384      ['conv3_block1_0_relu[0][0]']

conv3_block1_1_bn (BatchNormal  (None, 40, 40, 128)  512        ['conv3_block1_1_conv[0][0]']
ization)

conv3_block1_1_relu (Activatio  (None, 40, 40, 128)  0          ['conv3_block1_1_bn[0][0]']
n)

conv3_block1_2_conv (Conv2D)   (None, 40, 40, 32)   36864      ['conv3_block1_1_relu[0][0]']

conv3_block1_concat (Concatena  (None, 40, 40, 160)  0          ['pool2_pool[0][0]',
te)                                                              'conv3_block1_2_conv[0][0]']

conv3_block2_0_bn (BatchNormal  (None, 40, 40, 160)  640        ['conv3_block1_concat[0][0]']
ization)

conv3_block2_0_relu (Activatio  (None, 40, 40, 160)  0          ['conv3_block2_0_bn[0][0]']
n)

conv3_block2_1_conv (Conv2D)   (None, 40, 40, 128)  20480      ['conv3_block2_0_relu[0][0]']

conv3_block2_1_bn (BatchNormal  (None, 40, 40, 128)  512        ['conv3_block2_1_conv[0][0]']
ization)

conv3_block2_1_relu (Activatio  (None, 40, 40, 128)  0          ['conv3_block2_1_bn[0][0]']
n)
```

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conv3_block2_2_conv (Conv2D)   (None, 40, 40, 32)   36864       ['conv3_block2_1_relu[0][0]']

conv3_block2_concat (Concatena  (None, 40, 40, 192)  0          ['conv3_block1_concat[0][0]',
te)                                                              'conv3_block2_2_conv[0][0]']

conv3_block3_0_bn (BatchNormal  (None, 40, 40, 192)  768        ['conv3_block2_concat[0][0]']
ization)

conv3_block3_0_relu (Activatio  (None, 40, 40, 192)  0          ['conv3_block3_0_bn[0][0]']
n)

conv3_block3_1_conv (Conv2D)   (None, 40, 40, 128)  24576       ['conv3_block3_0_relu[0][0]']

conv3_block3_1_bn (BatchNormal  (None, 40, 40, 128)  512        ['conv3_block3_1_conv[0][0]']
ization)

conv3_block3_1_relu (Activatio  (None, 40, 40, 128)  0          ['conv3_block3_1_bn[0][0]']
n)

conv3_block3_2_conv (Conv2D)   (None, 40, 40, 32)   36864       ['conv3_block3_1_relu[0][0]']

conv3_block3_concat (Concatena  (None, 40, 40, 224)  0          ['conv3_block2_concat[0][0]',
te)                                                              'conv3_block3_2_conv[0][0]']

conv3_block4_0_bn (BatchNormal  (None, 40, 40, 224)  896        ['conv3_block3_concat[0][0]']
ization)

conv3_block4_0_relu (Activatio  (None, 40, 40, 224)  0          ['conv3_block4_0_bn[0][0]']
n)

conv3_block4_1_conv (Conv2D)   (None, 40, 40, 128)  28672       ['conv3_block4_0_relu[0][0]']

conv3_block4_1_bn (BatchNormal  (None, 40, 40, 128)  512        ['conv3_block4_1_conv[0][0]']
ization)

conv3_block4_1_relu (Activatio  (None, 40, 40, 128)  0          ['conv3_block4_1_bn[0][0]']
n)

conv3_block4_2_conv (Conv2D)   (None, 40, 40, 32)   36864       ['conv3_block4_1_relu[0][0]']

conv3_block4_concat (Concatena  (None, 40, 40, 256)  0          ['conv3_block3_concat[0][0]',
te)                                                              'conv3_block4_2_conv[0][0]']

conv3_block5_0_bn (BatchNormal  (None, 40, 40, 256)  1024       ['conv3_block4_concat[0][0]']
ization)

conv3_block5_0_relu (Activatio  (None, 40, 40, 256)  0          ['conv3_block5_0_bn[0][0]']
n)

conv3_block5_1_conv (Conv2D)   (None, 40, 40, 128)  32768       ['conv3_block5_0_relu[0][0]']

conv3_block5_1_bn (BatchNormal  (None, 40, 40, 128)  512        ['conv3_block5_1_conv[0][0]']
ization)

conv3_block5_1_relu (Activatio  (None, 40, 40, 128)  0          ['conv3_block5_1_bn[0][0]']
n)

conv3_block5_2_conv (Conv2D)   (None, 40, 40, 32)   36864       ['conv3_block5_1_relu[0][0]']

conv3_block5_concat (Concatena  (None, 40, 40, 288)  0          ['conv3_block4_concat[0][0]',
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te)                                                                 'conv3_block5_2_conv[0][0]']

conv3_block6_0_bn (BatchNormal  (None, 40, 40, 288)  1152       ['conv3_block5_concat[0][0]']
ization)

conv3_block6_0_relu (Activatio  (None, 40, 40, 288)  0          ['conv3_block6_0_bn[0][0]']
n)

conv3_block6_1_conv (Conv2D)   (None, 40, 40, 128)  36864       ['conv3_block6_0_relu[0][0]']

conv3_block6_1_bn (BatchNormal  (None, 40, 40, 128)  512        ['conv3_block6_1_conv[0][0]']
ization)

conv3_block6_1_relu (Activatio  (None, 40, 40, 128)  0          ['conv3_block6_1_bn[0][0]']
n)

conv3_block6_2_conv (Conv2D)   (None, 40, 40, 32)   36864       ['conv3_block6_1_relu[0][0]']

conv3_block6_concat (Concatena  (None, 40, 40, 320)  0          ['conv3_block5_concat[0][0]',
te)                                                              'conv3_block6_2_conv[0][0]']

conv3_block7_0_bn (BatchNormal  (None, 40, 40, 320)  1280       ['conv3_block6_concat[0][0]']
ization)

conv3_block7_0_relu (Activatio  (None, 40, 40, 320)  0          ['conv3_block7_0_bn[0][0]']
n)

conv3_block7_1_conv (Conv2D)   (None, 40, 40, 128)  40960       ['conv3_block7_0_relu[0][0]']

conv3_block7_1_bn (BatchNormal  (None, 40, 40, 128)  512        ['conv3_block7_1_conv[0][0]']
ization)

conv3_block7_1_relu (Activatio  (None, 40, 40, 128)  0          ['conv3_block7_1_bn[0][0]']
n)

conv3_block7_2_conv (Conv2D)   (None, 40, 40, 32)   36864       ['conv3_block7_1_relu[0][0]']

conv3_block7_concat (Concatena  (None, 40, 40, 352)  0          ['conv3_block6_concat[0][0]',
te)                                                              'conv3_block7_2_conv[0][0]']

conv3_block8_0_bn (BatchNormal  (None, 40, 40, 352)  1408       ['conv3_block7_concat[0][0]']
ization)

conv3_block8_0_relu (Activatio  (None, 40, 40, 352)  0          ['conv3_block8_0_bn[0][0]']
n)

conv3_block8_1_conv (Conv2D)   (None, 40, 40, 128)  45056       ['conv3_block8_0_relu[0][0]']

conv3_block8_1_bn (BatchNormal  (None, 40, 40, 128)  512        ['conv3_block8_1_conv[0][0]']
ization)

conv3_block8_1_relu (Activatio  (None, 40, 40, 128)  0          ['conv3_block8_1_bn[0][0]']
n)

conv3_block8_2_conv (Conv2D)   (None, 40, 40, 32)   36864       ['conv3_block8_1_relu[0][0]']

conv3_block8_concat (Concatena  (None, 40, 40, 384)  0          ['conv3_block7_concat[0][0]',
te)                                                              'conv3_block8_2_conv[0][0]']

conv3_block9_0_bn (BatchNormal  (None, 40, 40, 384)  1536       ['conv3_block8_concat[0][0]']
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ization)

conv3_block9_0_relu (Activatio  (None, 40, 40, 384)  0          ['conv3_block9_0_bn[0][0]']
n)

conv3_block9_1_conv (Conv2D)   (None, 40, 40, 128)  49152      ['conv3_block9_0_relu[0][0]']

conv3_block9_1_bn (BatchNormal  (None, 40, 40, 128)  512        ['conv3_block9_1_conv[0][0]']
ization)

conv3_block9_1_relu (Activatio  (None, 40, 40, 128)  0          ['conv3_block9_1_bn[0][0]']
n)

conv3_block9_2_conv (Conv2D)   (None, 40, 40, 32)   36864      ['conv3_block9_1_relu[0][0]']

conv3_block9_concat (Concatena  (None, 40, 40, 416)  0          ['conv3_block8_concat[0][0]',
te)                                                              'conv3_block9_2_conv[0][0]']

conv3_block10_0_bn (BatchNorma  (None, 40, 40, 416)  1664       ['conv3_block9_concat[0][0]']
lization)

conv3_block10_0_relu (Activati  (None, 40, 40, 416)  0          ['conv3_block10_0_bn[0][0]']
on)

conv3_block10_1_conv (Conv2D)  (None, 40, 40, 128)  53248      ['conv3_block10_0_relu[0][0]']

conv3_block10_1_bn (BatchNorma  (None, 40, 40, 128)  512        ['conv3_block10_1_conv[0][0]']
lization)

conv3_block10_1_relu (Activati  (None, 40, 40, 128)  0          ['conv3_block10_1_bn[0][0]']
on)

conv3_block10_2_conv (Conv2D)  (None, 40, 40, 32)   36864      ['conv3_block10_1_relu[0][0]']

conv3_block10_concat (Concaten  (None, 40, 40, 448)  0          ['conv3_block9_concat[0][0]',
ate)                                                             'conv3_block10_2_conv[0][0]']

conv3_block11_0_bn (BatchNorma  (None, 40, 40, 448)  1792       ['conv3_block10_concat[0][0]']
lization)

conv3_block11_0_relu (Activati  (None, 40, 40, 448)  0          ['conv3_block11_0_bn[0][0]']
on)

conv3_block11_1_conv (Conv2D)  (None, 40, 40, 128)  57344      ['conv3_block11_0_relu[0][0]']

conv3_block11_1_bn (BatchNorma  (None, 40, 40, 128)  512        ['conv3_block11_1_conv[0][0]']
lization)

conv3_block11_1_relu (Activati  (None, 40, 40, 128)  0          ['conv3_block11_1_bn[0][0]']
on)

conv3_block11_2_conv (Conv2D)  (None, 40, 40, 32)   36864      ['conv3_block11_1_relu[0][0]']

conv3_block11_concat (Concaten  (None, 40, 40, 480)  0          ['conv3_block10_concat[0][0]',
ate)                                                             'conv3_block11_2_conv[0][0]']

conv3_block12_0_bn (BatchNorma  (None, 40, 40, 480)  1920       ['conv3_block11_concat[0][0]']
lization)

conv3_block12_0_relu (Activati  (None, 40, 40, 480)  0          ['conv3_block12_0_bn[0][0]']
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on)

conv3_block12_1_conv (Conv2D)  (None, 40, 40, 128)  61440       ['conv3_block12_0_relu[0][0]']

conv3_block12_1_bn (BatchNorma  (None, 40, 40, 128)  512        ['conv3_block12_1_conv[0][0]']
lization)

conv3_block12_1_relu (Activati  (None, 40, 40, 128)  0          ['conv3_block12_1_bn[0][0]']
on)

conv3_block12_2_conv (Conv2D)  (None, 40, 40, 32)   36864       ['conv3_block12_1_relu[0][0]']

conv3_block12_concat (Concaten  (None, 40, 40, 512)  0          ['conv3_block11_concat[0][0]',
ate)                                                             'conv3_block12_2_conv[0][0]']

pool3_bn (BatchNormalization)  (None, 40, 40, 512)  2048        ['conv3_block12_concat[0][0]']

pool3_relu (Activation)        (None, 40, 40, 512)  0           ['pool3_bn[0][0]']

pool3_conv (Conv2D)            (None, 40, 40, 256)  131072      ['pool3_relu[0][0]']

pool3_pool (AveragePooling2D)  (None, 20, 20, 256)  0           ['pool3_conv[0][0]']

conv4_block1_0_bn (BatchNormal  (None, 20, 20, 256)  1024       ['pool3_pool[0][0]']
ization)

conv4_block1_0_relu (Activatio  (None, 20, 20, 256)  0          ['conv4_block1_0_bn[0][0]']
n)

conv4_block1_1_conv (Conv2D)   (None, 20, 20, 128)  32768       ['conv4_block1_0_relu[0][0]']

conv4_block1_1_bn (BatchNormal  (None, 20, 20, 128)  512        ['conv4_block1_1_conv[0][0]']
ization)

conv4_block1_1_relu (Activatio  (None, 20, 20, 128)  0          ['conv4_block1_1_bn[0][0]']
n)

conv4_block1_2_conv (Conv2D)   (None, 20, 20, 32)   36864       ['conv4_block1_1_relu[0][0]']

conv4_block1_concat (Concatena  (None, 20, 20, 288)  0          ['pool3_pool[0][0]',
te)                                                              'conv4_block1_2_conv[0][0]']

conv4_block2_0_bn (BatchNormal  (None, 20, 20, 288)  1152       ['conv4_block1_concat[0][0]']
ization)

conv4_block2_0_relu (Activatio  (None, 20, 20, 288)  0          ['conv4_block2_0_bn[0][0]']
n)

conv4_block2_1_conv (Conv2D)   (None, 20, 20, 128)  36864       ['conv4_block2_0_relu[0][0]']

conv4_block2_1_bn (BatchNormal  (None, 20, 20, 128)  512        ['conv4_block2_1_conv[0][0]']
ization)

conv4_block2_1_relu (Activatio  (None, 20, 20, 128)  0          ['conv4_block2_1_bn[0][0]']
n)

conv4_block2_2_conv (Conv2D)   (None, 20, 20, 32)   36864       ['conv4_block2_1_relu[0][0]']

conv4_block2_concat (Concatena  (None, 20, 20, 320)  0          ['conv4_block1_concat[0][0]',
te)                                                              'conv4_block2_2_conv[0][0]']
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conv4_block3_0_bn (BatchNormal  (None, 20, 20, 320)  1280       ['conv4_block2_concat[0][0]']
ization)

conv4_block3_0_relu (Activatio  (None, 20, 20, 320)  0         ['conv4_block3_0_bn[0][0]']
n)

conv4_block3_1_conv (Conv2D)   (None, 20, 20, 128)  40960      ['conv4_block3_0_relu[0][0]']

conv4_block3_1_bn (BatchNormal  (None, 20, 20, 128)  512       ['conv4_block3_1_conv[0][0]']
ization)

conv4_block3_1_relu (Activatio  (None, 20, 20, 128)  0         ['conv4_block3_1_bn[0][0]']
n)

conv4_block3_2_conv (Conv2D)   (None, 20, 20, 32)   36864      ['conv4_block3_1_relu[0][0]']

conv4_block3_concat (Concatena  (None, 20, 20, 352)  0         ['conv4_block2_concat[0][0]',
te)                                                             'conv4_block3_2_conv[0][0]']

conv4_block4_0_bn (BatchNormal  (None, 20, 20, 352)  1408      ['conv4_block3_concat[0][0]']
ization)

conv4_block4_0_relu (Activatio  (None, 20, 20, 352)  0         ['conv4_block4_0_bn[0][0]']
n)

conv4_block4_1_conv (Conv2D)   (None, 20, 20, 128)  45056      ['conv4_block4_0_relu[0][0]']

conv4_block4_1_bn (BatchNormal  (None, 20, 20, 128)  512       ['conv4_block4_1_conv[0][0]']
ization)

conv4_block4_1_relu (Activatio  (None, 20, 20, 128)  0         ['conv4_block4_1_bn[0][0]']
n)

conv4_block4_2_conv (Conv2D)   (None, 20, 20, 32)   36864      ['conv4_block4_1_relu[0][0]']

conv4_block4_concat (Concatena  (None, 20, 20, 384)  0         ['conv4_block3_concat[0][0]',
te)                                                             'conv4_block4_2_conv[0][0]']

conv4_block5_0_bn (BatchNormal  (None, 20, 20, 384)  1536      ['conv4_block4_concat[0][0]']
ization)

conv4_block5_0_relu (Activatio  (None, 20, 20, 384)  0         ['conv4_block5_0_bn[0][0]']
n)

conv4_block5_1_conv (Conv2D)   (None, 20, 20, 128)  49152      ['conv4_block5_0_relu[0][0]']

conv4_block5_1_bn (BatchNormal  (None, 20, 20, 128)  512       ['conv4_block5_1_conv[0][0]']
ization)

conv4_block5_1_relu (Activatio  (None, 20, 20, 128)  0         ['conv4_block5_1_bn[0][0]']
n)

conv4_block5_2_conv (Conv2D)   (None, 20, 20, 32)   36864      ['conv4_block5_1_relu[0][0]']

conv4_block5_concat (Concatena  (None, 20, 20, 416)  0         ['conv4_block4_concat[0][0]',
te)                                                             'conv4_block5_2_conv[0][0]']

conv4_block6_0_bn (BatchNormal  (None, 20, 20, 416)  1664      ['conv4_block5_concat[0][0]']
ization)
```

```
conv4_block6_0_relu (Activatio  (None, 20, 20, 416)  0          ['conv4_block6_0_bn[0][0]']
n)

conv4_block6_1_conv (Conv2D)   (None, 20, 20, 128)  53248      ['conv4_block6_0_relu[0][0]']

conv4_block6_1_bn (BatchNormal  (None, 20, 20, 128)  512        ['conv4_block6_1_conv[0][0]']
ization)

conv4_block6_1_relu (Activatio  (None, 20, 20, 128)  0          ['conv4_block6_1_bn[0][0]']
n)

conv4_block6_2_conv (Conv2D)   (None, 20, 20, 32)   36864      ['conv4_block6_1_relu[0][0]']

conv4_block6_concat (Concatena  (None, 20, 20, 448)  0          ['conv4_block5_concat[0][0]',
te)                                                              'conv4_block6_2_conv[0][0]']

conv4_block7_0_bn (BatchNormal  (None, 20, 20, 448)  1792       ['conv4_block6_concat[0][0]']
ization)

conv4_block7_0_relu (Activatio  (None, 20, 20, 448)  0          ['conv4_block7_0_bn[0][0]']
n)

conv4_block7_1_conv (Conv2D)   (None, 20, 20, 128)  57344      ['conv4_block7_0_relu[0][0]']

conv4_block7_1_bn (BatchNormal  (None, 20, 20, 128)  512        ['conv4_block7_1_conv[0][0]']
ization)

conv4_block7_1_relu (Activatio  (None, 20, 20, 128)  0          ['conv4_block7_1_bn[0][0]']
n)

conv4_block7_2_conv (Conv2D)   (None, 20, 20, 32)   36864      ['conv4_block7_1_relu[0][0]']

conv4_block7_concat (Concatena  (None, 20, 20, 480)  0          ['conv4_block6_concat[0][0]',
te)                                                              'conv4_block7_2_conv[0][0]']

conv4_block8_0_bn (BatchNormal  (None, 20, 20, 480)  1920       ['conv4_block7_concat[0][0]']
ization)

conv4_block8_0_relu (Activatio  (None, 20, 20, 480)  0          ['conv4_block8_0_bn[0][0]']
n)

conv4_block8_1_conv (Conv2D)   (None, 20, 20, 128)  61440      ['conv4_block8_0_relu[0][0]']

conv4_block8_1_bn (BatchNormal  (None, 20, 20, 128)  512        ['conv4_block8_1_conv[0][0]']
ization)

conv4_block8_1_relu (Activatio  (None, 20, 20, 128)  0          ['conv4_block8_1_bn[0][0]']
n)

conv4_block8_2_conv (Conv2D)   (None, 20, 20, 32)   36864      ['conv4_block8_1_relu[0][0]']

conv4_block8_concat (Concatena  (None, 20, 20, 512)  0          ['conv4_block7_concat[0][0]',
te)                                                              'conv4_block8_2_conv[0][0]']

conv4_block9_0_bn (BatchNormal  (None, 20, 20, 512)  2048       ['conv4_block8_concat[0][0]']
ization)

conv4_block9_0_relu (Activatio  (None, 20, 20, 512)  0          ['conv4_block9_0_bn[0][0]']
n)
```

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conv4_block9_1_conv (Conv2D)   (None, 20, 20, 128)  65536       ['conv4_block9_0_relu[0][0]']

conv4_block9_1_bn (BatchNormal  (None, 20, 20, 128)  512        ['conv4_block9_1_conv[0][0]']
ization)

conv4_block9_1_relu (Activatio  (None, 20, 20, 128)  0          ['conv4_block9_1_bn[0][0]']
n)

conv4_block9_2_conv (Conv2D)   (None, 20, 20, 32)   36864       ['conv4_block9_1_relu[0][0]']

conv4_block9_concat (Concatena  (None, 20, 20, 544)  0          ['conv4_block8_concat[0][0]',
te)                                                              'conv4_block9_2_conv[0][0]']

conv4_block10_0_bn (BatchNorma  (None, 20, 20, 544)  2176       ['conv4_block9_concat[0][0]']
lization)

conv4_block10_0_relu (Activati  (None, 20, 20, 544)  0          ['conv4_block10_0_bn[0][0]']
on)

conv4_block10_1_conv (Conv2D)  (None, 20, 20, 128)  69632       ['conv4_block10_0_relu[0][0]']

conv4_block10_1_bn (BatchNorma  (None, 20, 20, 128)  512        ['conv4_block10_1_conv[0][0]']
lization)

conv4_block10_1_relu (Activati  (None, 20, 20, 128)  0          ['conv4_block10_1_bn[0][0]']
on)

conv4_block10_2_conv (Conv2D)  (None, 20, 20, 32)   36864       ['conv4_block10_1_relu[0][0]']

conv4_block10_concat (Concaten  (None, 20, 20, 576)  0          ['conv4_block9_concat[0][0]',
ate)                                                             'conv4_block10_2_conv[0][0]']

conv4_block11_0_bn (BatchNorma  (None, 20, 20, 576)  2304       ['conv4_block10_concat[0][0]']
lization)

conv4_block11_0_relu (Activati  (None, 20, 20, 576)  0          ['conv4_block11_0_bn[0][0]']
on)

conv4_block11_1_conv (Conv2D)  (None, 20, 20, 128)  73728       ['conv4_block11_0_relu[0][0]']

conv4_block11_1_bn (BatchNorma  (None, 20, 20, 128)  512        ['conv4_block11_1_conv[0][0]']
lization)

conv4_block11_1_relu (Activati  (None, 20, 20, 128)  0          ['conv4_block11_1_bn[0][0]']
on)

conv4_block11_2_conv (Conv2D)  (None, 20, 20, 32)   36864       ['conv4_block11_1_relu[0][0]']

conv4_block11_concat (Concaten  (None, 20, 20, 608)  0          ['conv4_block10_concat[0][0]',
ate)                                                             'conv4_block11_2_conv[0][0]']

conv4_block12_0_bn (BatchNorma  (None, 20, 20, 608)  2432       ['conv4_block11_concat[0][0]']
lization)

conv4_block12_0_relu (Activati  (None, 20, 20, 608)  0          ['conv4_block12_0_bn[0][0]']
on)

conv4_block12_1_conv (Conv2D)  (None, 20, 20, 128)  77824       ['conv4_block12_0_relu[0][0]']
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conv4_block12_1_bn (BatchNorma  (None, 20, 20, 128)  512        ['conv4_block12_1_conv[0][0]']
lization)

conv4_block12_1_relu (Activati  (None, 20, 20, 128)  0          ['conv4_block12_1_bn[0][0]']
on)

conv4_block12_2_conv (Conv2D)  (None, 20, 20, 32)   36864      ['conv4_block12_1_relu[0][0]']

conv4_block12_concat (Concaten  (None, 20, 20, 640)  0          ['conv4_block11_concat[0][0]',
ate)                                                             'conv4_block12_2_conv[0][0]']

conv4_block13_0_bn (BatchNorma  (None, 20, 20, 640)  2560       ['conv4_block12_concat[0][0]']
lization)

conv4_block13_0_relu (Activati  (None, 20, 20, 640)  0          ['conv4_block13_0_bn[0][0]']
on)

conv4_block13_1_conv (Conv2D)  (None, 20, 20, 128)  81920      ['conv4_block13_0_relu[0][0]']

conv4_block13_1_bn (BatchNorma  (None, 20, 20, 128)  512        ['conv4_block13_1_conv[0][0]']
lization)

conv4_block13_1_relu (Activati  (None, 20, 20, 128)  0          ['conv4_block13_1_bn[0][0]']
on)

conv4_block13_2_conv (Conv2D)  (None, 20, 20, 32)   36864      ['conv4_block13_1_relu[0][0]']

conv4_block13_concat (Concaten  (None, 20, 20, 672)  0          ['conv4_block12_concat[0][0]',
ate)                                                             'conv4_block13_2_conv[0][0]']

conv4_block14_0_bn (BatchNorma  (None, 20, 20, 672)  2688       ['conv4_block13_concat[0][0]']
lization)

conv4_block14_0_relu (Activati  (None, 20, 20, 672)  0          ['conv4_block14_0_bn[0][0]']
on)

conv4_block14_1_conv (Conv2D)  (None, 20, 20, 128)  86016      ['conv4_block14_0_relu[0][0]']

conv4_block14_1_bn (BatchNorma  (None, 20, 20, 128)  512        ['conv4_block14_1_conv[0][0]']
lization)

conv4_block14_1_relu (Activati  (None, 20, 20, 128)  0          ['conv4_block14_1_bn[0][0]']
on)

conv4_block14_2_conv (Conv2D)  (None, 20, 20, 32)   36864      ['conv4_block14_1_relu[0][0]']

conv4_block14_concat (Concaten  (None, 20, 20, 704)  0          ['conv4_block13_concat[0][0]',
ate)                                                             'conv4_block14_2_conv[0][0]']

conv4_block15_0_bn (BatchNorma  (None, 20, 20, 704)  2816       ['conv4_block14_concat[0][0]']
lization)

conv4_block15_0_relu (Activati  (None, 20, 20, 704)  0          ['conv4_block15_0_bn[0][0]']
on)

conv4_block15_1_conv (Conv2D)  (None, 20, 20, 128)  90112      ['conv4_block15_0_relu[0][0]']

conv4_block15_1_bn (BatchNorma  (None, 20, 20, 128)  512        ['conv4_block15_1_conv[0][0]']
lization)
```

```
conv4_block15_1_relu (Activati  (None, 20, 20, 128)  0         ['conv4_block15_1_bn[0][0]']
on)

conv4_block15_2_conv (Conv2D)  (None, 20, 20, 32)   36864       ['conv4_block15_1_relu[0][0]']

conv4_block15_concat (Concaten  (None, 20, 20, 736)  0         ['conv4_block14_concat[0][0]',
ate)                                                            'conv4_block15_2_conv[0][0]']

conv4_block16_0_bn (BatchNorma  (None, 20, 20, 736)  2944      ['conv4_block15_concat[0][0]']
lization)

conv4_block16_0_relu (Activati  (None, 20, 20, 736)  0         ['conv4_block16_0_bn[0][0]']
on)

conv4_block16_1_conv (Conv2D)  (None, 20, 20, 128)  94208      ['conv4_block16_0_relu[0][0]']

conv4_block16_1_bn (BatchNorma  (None, 20, 20, 128)  512       ['conv4_block16_1_conv[0][0]']
lization)

conv4_block16_1_relu (Activati  (None, 20, 20, 128)  0         ['conv4_block16_1_bn[0][0]']
on)

conv4_block16_2_conv (Conv2D)  (None, 20, 20, 32)   36864       ['conv4_block16_1_relu[0][0]']

conv4_block16_concat (Concaten  (None, 20, 20, 768)  0         ['conv4_block15_concat[0][0]',
ate)                                                            'conv4_block16_2_conv[0][0]']

conv4_block17_0_bn (BatchNorma  (None, 20, 20, 768)  3072      ['conv4_block16_concat[0][0]']
lization)

conv4_block17_0_relu (Activati  (None, 20, 20, 768)  0         ['conv4_block17_0_bn[0][0]']
on)

conv4_block17_1_conv (Conv2D)  (None, 20, 20, 128)  98304      ['conv4_block17_0_relu[0][0]']

conv4_block17_1_bn (BatchNorma  (None, 20, 20, 128)  512       ['conv4_block17_1_conv[0][0]']
lization)

conv4_block17_1_relu (Activati  (None, 20, 20, 128)  0         ['conv4_block17_1_bn[0][0]']
on)

conv4_block17_2_conv (Conv2D)  (None, 20, 20, 32)   36864       ['conv4_block17_1_relu[0][0]']

conv4_block17_concat (Concaten  (None, 20, 20, 800)  0         ['conv4_block16_concat[0][0]',
ate)                                                            'conv4_block17_2_conv[0][0]']

conv4_block18_0_bn (BatchNorma  (None, 20, 20, 800)  3200      ['conv4_block17_concat[0][0]']
lization)

conv4_block18_0_relu (Activati  (None, 20, 20, 800)  0         ['conv4_block18_0_bn[0][0]']
on)

conv4_block18_1_conv (Conv2D)  (None, 20, 20, 128)  102400     ['conv4_block18_0_relu[0][0]']

conv4_block18_1_bn (BatchNorma  (None, 20, 20, 128)  512       ['conv4_block18_1_conv[0][0]']
lization)

conv4_block18_1_relu (Activati  (None, 20, 20, 128)  0         ['conv4_block18_1_bn[0][0]']
on)
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conv4_block18_2_conv (Conv2D)  (None, 20, 20, 32)   36864       ['conv4_block18_1_relu[0][0]']

conv4_block18_concat (Concaten  (None, 20, 20, 832)  0          ['conv4_block17_concat[0][0]',
ate)                                                             'conv4_block18_2_conv[0][0]']

conv4_block19_0_bn (BatchNorma  (None, 20, 20, 832)  3328       ['conv4_block18_concat[0][0]']
lization)

conv4_block19_0_relu (Activati  (None, 20, 20, 832)  0          ['conv4_block19_0_bn[0][0]']
on)

conv4_block19_1_conv (Conv2D)  (None, 20, 20, 128)  106496      ['conv4_block19_0_relu[0][0]']

conv4_block19_1_bn (BatchNorma  (None, 20, 20, 128)  512        ['conv4_block19_1_conv[0][0]']
lization)

conv4_block19_1_relu (Activati  (None, 20, 20, 128)  0          ['conv4_block19_1_bn[0][0]']
on)

conv4_block19_2_conv (Conv2D)  (None, 20, 20, 32)   36864       ['conv4_block19_1_relu[0][0]']

conv4_block19_concat (Concaten  (None, 20, 20, 864)  0          ['conv4_block18_concat[0][0]',
ate)                                                             'conv4_block19_2_conv[0][0]']

conv4_block20_0_bn (BatchNorma  (None, 20, 20, 864)  3456       ['conv4_block19_concat[0][0]']
lization)

conv4_block20_0_relu (Activati  (None, 20, 20, 864)  0          ['conv4_block20_0_bn[0][0]']
on)

conv4_block20_1_conv (Conv2D)  (None, 20, 20, 128)  110592      ['conv4_block20_0_relu[0][0]']

conv4_block20_1_bn (BatchNorma  (None, 20, 20, 128)  512        ['conv4_block20_1_conv[0][0]']
lization)

conv4_block20_1_relu (Activati  (None, 20, 20, 128)  0          ['conv4_block20_1_bn[0][0]']
on)

conv4_block20_2_conv (Conv2D)  (None, 20, 20, 32)   36864       ['conv4_block20_1_relu[0][0]']

conv4_block20_concat (Concaten  (None, 20, 20, 896)  0          ['conv4_block19_concat[0][0]',
ate)                                                             'conv4_block20_2_conv[0][0]']

conv4_block21_0_bn (BatchNorma  (None, 20, 20, 896)  3584       ['conv4_block20_concat[0][0]']
lization)

conv4_block21_0_relu (Activati  (None, 20, 20, 896)  0          ['conv4_block21_0_bn[0][0]']
on)

conv4_block21_1_conv (Conv2D)  (None, 20, 20, 128)  114688      ['conv4_block21_0_relu[0][0]']

conv4_block21_1_bn (BatchNorma  (None, 20, 20, 128)  512        ['conv4_block21_1_conv[0][0]']
lization)

conv4_block21_1_relu (Activati  (None, 20, 20, 128)  0          ['conv4_block21_1_bn[0][0]']
on)

conv4_block21_2_conv (Conv2D)  (None, 20, 20, 32)   36864       ['conv4_block21_1_relu[0][0]']

conv4_block21_concat (Concaten  (None, 20, 20, 928)  0          ['conv4_block20_concat[0][0]',
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ate)                                                              'conv4_block21_2_conv[0][0]']

conv4_block22_0_bn (BatchNorma  (None, 20, 20, 928)  3712       ['conv4_block21_concat[0][0]']
lization)

conv4_block22_0_relu (Activati  (None, 20, 20, 928)  0          ['conv4_block22_0_bn[0][0]']
on)

conv4_block22_1_conv (Conv2D)  (None, 20, 20, 128)  118784     ['conv4_block22_0_relu[0][0]']

conv4_block22_1_bn (BatchNorma  (None, 20, 20, 128)  512        ['conv4_block22_1_conv[0][0]']
lization)

conv4_block22_1_relu (Activati  (None, 20, 20, 128)  0          ['conv4_block22_1_bn[0][0]']
on)

conv4_block22_2_conv (Conv2D)  (None, 20, 20, 32)   36864      ['conv4_block22_1_relu[0][0]']

conv4_block22_concat (Concaten  (None, 20, 20, 960)  0          ['conv4_block21_concat[0][0]',
ate)                                                              'conv4_block22_2_conv[0][0]']

conv4_block23_0_bn (BatchNorma  (None, 20, 20, 960)  3840       ['conv4_block22_concat[0][0]']
lization)

conv4_block23_0_relu (Activati  (None, 20, 20, 960)  0          ['conv4_block23_0_bn[0][0]']
on)

conv4_block23_1_conv (Conv2D)  (None, 20, 20, 128)  122880     ['conv4_block23_0_relu[0][0]']

conv4_block23_1_bn (BatchNorma  (None, 20, 20, 128)  512        ['conv4_block23_1_conv[0][0]']
lization)

conv4_block23_1_relu (Activati  (None, 20, 20, 128)  0          ['conv4_block23_1_bn[0][0]']
on)

conv4_block23_2_conv (Conv2D)  (None, 20, 20, 32)   36864      ['conv4_block23_1_relu[0][0]']

conv4_block23_concat (Concaten  (None, 20, 20, 992)  0          ['conv4_block22_concat[0][0]',
ate)                                                              'conv4_block23_2_conv[0][0]']

conv4_block24_0_bn (BatchNorma  (None, 20, 20, 992)  3968       ['conv4_block23_concat[0][0]']
lization)

conv4_block24_0_relu (Activati  (None, 20, 20, 992)  0          ['conv4_block24_0_bn[0][0]']
on)

conv4_block24_1_conv (Conv2D)  (None, 20, 20, 128)  126976     ['conv4_block24_0_relu[0][0]']

conv4_block24_1_bn (BatchNorma  (None, 20, 20, 128)  512        ['conv4_block24_1_conv[0][0]']
lization)

conv4_block24_1_relu (Activati  (None, 20, 20, 128)  0          ['conv4_block24_1_bn[0][0]']
on)

conv4_block24_2_conv (Conv2D)  (None, 20, 20, 32)   36864      ['conv4_block24_1_relu[0][0]']

conv4_block24_concat (Concaten  (None, 20, 20, 1024  0          ['conv4_block23_concat[0][0]',
ate)                           )                                  'conv4_block24_2_conv[0][0]']

pool4_bn (BatchNormalization)  (None, 20, 20, 1024  4096       ['conv4_block24_concat[0][0]']
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                                )

pool4_relu (Activation)        (None, 20, 20, 1024  0           ['pool4_bn[0][0]']
                                )

pool4_conv (Conv2D)            (None, 20, 20, 512)  524288      ['pool4_relu[0][0]']

pool4_pool (AveragePooling2D)  (None, 10, 10, 512)  0           ['pool4_conv[0][0]']

conv5_block1_0_bn (BatchNormal  (None, 10, 10, 512)  2048       ['pool4_pool[0][0]']
ization)

conv5_block1_0_relu (Activatio  (None, 10, 10, 512)  0          ['conv5_block1_0_bn[0][0]']
n)

conv5_block1_1_conv (Conv2D)   (None, 10, 10, 128)  65536       ['conv5_block1_0_relu[0][0]']

conv5_block1_1_bn (BatchNormal  (None, 10, 10, 128)  512        ['conv5_block1_1_conv[0][0]']
ization)

conv5_block1_1_relu (Activatio  (None, 10, 10, 128)  0          ['conv5_block1_1_bn[0][0]']
n)

conv5_block1_2_conv (Conv2D)   (None, 10, 10, 32)   36864       ['conv5_block1_1_relu[0][0]']

conv5_block1_concat (Concatena  (None, 10, 10, 544)  0          ['pool4_pool[0][0]',
te)                                                              'conv5_block1_2_conv[0][0]']

conv5_block2_0_bn (BatchNormal  (None, 10, 10, 544)  2176       ['conv5_block1_concat[0][0]']
ization)

conv5_block2_0_relu (Activatio  (None, 10, 10, 544)  0          ['conv5_block2_0_bn[0][0]']
n)

conv5_block2_1_conv (Conv2D)   (None, 10, 10, 128)  69632       ['conv5_block2_0_relu[0][0]']

conv5_block2_1_bn (BatchNormal  (None, 10, 10, 128)  512        ['conv5_block2_1_conv[0][0]']
ization)

conv5_block2_1_relu (Activatio  (None, 10, 10, 128)  0          ['conv5_block2_1_bn[0][0]']
n)

conv5_block2_2_conv (Conv2D)   (None, 10, 10, 32)   36864       ['conv5_block2_1_relu[0][0]']

conv5_block2_concat (Concatena  (None, 10, 10, 576)  0          ['conv5_block1_concat[0][0]',
te)                                                              'conv5_block2_2_conv[0][0]']

conv5_block3_0_bn (BatchNormal  (None, 10, 10, 576)  2304       ['conv5_block2_concat[0][0]']
ization)

conv5_block3_0_relu (Activatio  (None, 10, 10, 576)  0          ['conv5_block3_0_bn[0][0]']
n)

conv5_block3_1_conv (Conv2D)   (None, 10, 10, 128)  73728       ['conv5_block3_0_relu[0][0]']

conv5_block3_1_bn (BatchNormal  (None, 10, 10, 128)  512        ['conv5_block3_1_conv[0][0]']
ization)

conv5_block3_1_relu (Activatio  (None, 10, 10, 128)  0          ['conv5_block3_1_bn[0][0]']
n)
```

```
conv5_block3_2_conv (Conv2D)   (None, 10, 10, 32)   36864       ['conv5_block3_1_relu[0][0]']

conv5_block3_concat (Concatena  (None, 10, 10, 608)  0         ['conv5_block2_concat[0][0]',
te)                                                              'conv5_block3_2_conv[0][0]']

conv5_block4_0_bn (BatchNormal  (None, 10, 10, 608)  2432      ['conv5_block3_concat[0][0]']
ization)

conv5_block4_0_relu (Activatio  (None, 10, 10, 608)  0         ['conv5_block4_0_bn[0][0]']
n)

conv5_block4_1_conv (Conv2D)   (None, 10, 10, 128)  77824       ['conv5_block4_0_relu[0][0]']

conv5_block4_1_bn (BatchNormal  (None, 10, 10, 128)  512       ['conv5_block4_1_conv[0][0]']
ization)

conv5_block4_1_relu (Activatio  (None, 10, 10, 128)  0         ['conv5_block4_1_bn[0][0]']
n)

conv5_block4_2_conv (Conv2D)   (None, 10, 10, 32)   36864       ['conv5_block4_1_relu[0][0]']

conv5_block4_concat (Concatena  (None, 10, 10, 640)  0         ['conv5_block3_concat[0][0]',
te)                                                              'conv5_block4_2_conv[0][0]']

conv5_block5_0_bn (BatchNormal  (None, 10, 10, 640)  2560      ['conv5_block4_concat[0][0]']
ization)

conv5_block5_0_relu (Activatio  (None, 10, 10, 640)  0         ['conv5_block5_0_bn[0][0]']
n)

conv5_block5_1_conv (Conv2D)   (None, 10, 10, 128)  81920       ['conv5_block5_0_relu[0][0]']

conv5_block5_1_bn (BatchNormal  (None, 10, 10, 128)  512       ['conv5_block5_1_conv[0][0]']
ization)

conv5_block5_1_relu (Activatio  (None, 10, 10, 128)  0         ['conv5_block5_1_bn[0][0]']
n)

conv5_block5_2_conv (Conv2D)   (None, 10, 10, 32)   36864       ['conv5_block5_1_relu[0][0]']

conv5_block5_concat (Concatena  (None, 10, 10, 672)  0         ['conv5_block4_concat[0][0]',
te)                                                              'conv5_block5_2_conv[0][0]']

conv5_block6_0_bn (BatchNormal  (None, 10, 10, 672)  2688      ['conv5_block5_concat[0][0]']
ization)

conv5_block6_0_relu (Activatio  (None, 10, 10, 672)  0         ['conv5_block6_0_bn[0][0]']
n)

conv5_block6_1_conv (Conv2D)   (None, 10, 10, 128)  86016       ['conv5_block6_0_relu[0][0]']

conv5_block6_1_bn (BatchNormal  (None, 10, 10, 128)  512       ['conv5_block6_1_conv[0][0]']
ization)

conv5_block6_1_relu (Activatio  (None, 10, 10, 128)  0         ['conv5_block6_1_bn[0][0]']
n)

conv5_block6_2_conv (Conv2D)   (None, 10, 10, 32)   36864       ['conv5_block6_1_relu[0][0]']
```

```
conv5_block6_concat (Concatena  (None, 10, 10, 704)  0          ['conv5_block5_concat[0][0]',
te)                                                              'conv5_block6_2_conv[0][0]']

conv5_block7_0_bn (BatchNormal  (None, 10, 10, 704)  2816       ['conv5_block6_concat[0][0]']
ization)

conv5_block7_0_relu (Activatio  (None, 10, 10, 704)  0          ['conv5_block7_0_bn[0][0]']
n)

conv5_block7_1_conv (Conv2D)   (None, 10, 10, 128)  90112       ['conv5_block7_0_relu[0][0]']

conv5_block7_1_bn (BatchNormal  (None, 10, 10, 128)  512        ['conv5_block7_1_conv[0][0]']
ization)

conv5_block7_1_relu (Activatio  (None, 10, 10, 128)  0          ['conv5_block7_1_bn[0][0]']
n)

conv5_block7_2_conv (Conv2D)   (None, 10, 10, 32)   36864       ['conv5_block7_1_relu[0][0]']

conv5_block7_concat (Concatena  (None, 10, 10, 736)  0          ['conv5_block6_concat[0][0]',
te)                                                              'conv5_block7_2_conv[0][0]']

conv5_block8_0_bn (BatchNormal  (None, 10, 10, 736)  2944       ['conv5_block7_concat[0][0]']
ization)

conv5_block8_0_relu (Activatio  (None, 10, 10, 736)  0          ['conv5_block8_0_bn[0][0]']
n)

conv5_block8_1_conv (Conv2D)   (None, 10, 10, 128)  94208       ['conv5_block8_0_relu[0][0]']

conv5_block8_1_bn (BatchNormal  (None, 10, 10, 128)  512        ['conv5_block8_1_conv[0][0]']
ization)

conv5_block8_1_relu (Activatio  (None, 10, 10, 128)  0          ['conv5_block8_1_bn[0][0]']
n)

conv5_block8_2_conv (Conv2D)   (None, 10, 10, 32)   36864       ['conv5_block8_1_relu[0][0]']

conv5_block8_concat (Concatena  (None, 10, 10, 768)  0          ['conv5_block7_concat[0][0]',
te)                                                              'conv5_block8_2_conv[0][0]']

conv5_block9_0_bn (BatchNormal  (None, 10, 10, 768)  3072       ['conv5_block8_concat[0][0]']
ization)

conv5_block9_0_relu (Activatio  (None, 10, 10, 768)  0          ['conv5_block9_0_bn[0][0]']
n)

conv5_block9_1_conv (Conv2D)   (None, 10, 10, 128)  98304       ['conv5_block9_0_relu[0][0]']

conv5_block9_1_bn (BatchNormal  (None, 10, 10, 128)  512        ['conv5_block9_1_conv[0][0]']
ization)

conv5_block9_1_relu (Activatio  (None, 10, 10, 128)  0          ['conv5_block9_1_bn[0][0]']
n)

conv5_block9_2_conv (Conv2D)   (None, 10, 10, 32)   36864       ['conv5_block9_1_relu[0][0]']

conv5_block9_concat (Concatena  (None, 10, 10, 800)  0          ['conv5_block8_concat[0][0]',
te)                                                              'conv5_block9_2_conv[0][0]']
```

```
conv5_block10_0_bn (BatchNorma  (None, 10, 10, 800)  3200       ['conv5_block9_concat[0][0]']
lization)

conv5_block10_0_relu (Activati  (None, 10, 10, 800)  0          ['conv5_block10_0_bn[0][0]']
on)

conv5_block10_1_conv (Conv2D)  (None, 10, 10, 128)  102400      ['conv5_block10_0_relu[0][0]']

conv5_block10_1_bn (BatchNorma  (None, 10, 10, 128)  512        ['conv5_block10_1_conv[0][0]']
lization)

conv5_block10_1_relu (Activati  (None, 10, 10, 128)  0          ['conv5_block10_1_bn[0][0]']
on)

conv5_block10_2_conv (Conv2D)  (None, 10, 10, 32)   36864       ['conv5_block10_1_relu[0][0]']

conv5_block10_concat (Concaten  (None, 10, 10, 832)  0          ['conv5_block9_concat[0][0]',
ate)                                                             'conv5_block10_2_conv[0][0]']

conv5_block11_0_bn (BatchNorma  (None, 10, 10, 832)  3328       ['conv5_block10_concat[0][0]']
lization)

conv5_block11_0_relu (Activati  (None, 10, 10, 832)  0          ['conv5_block11_0_bn[0][0]']
on)

conv5_block11_1_conv (Conv2D)  (None, 10, 10, 128)  106496      ['conv5_block11_0_relu[0][0]']

conv5_block11_1_bn (BatchNorma  (None, 10, 10, 128)  512        ['conv5_block11_1_conv[0][0]']
lization)

conv5_block11_1_relu (Activati  (None, 10, 10, 128)  0          ['conv5_block11_1_bn[0][0]']
on)

conv5_block11_2_conv (Conv2D)  (None, 10, 10, 32)   36864       ['conv5_block11_1_relu[0][0]']

conv5_block11_concat (Concaten  (None, 10, 10, 864)  0          ['conv5_block10_concat[0][0]',
ate)                                                             'conv5_block11_2_conv[0][0]']

conv5_block12_0_bn (BatchNorma  (None, 10, 10, 864)  3456       ['conv5_block11_concat[0][0]']
lization)

conv5_block12_0_relu (Activati  (None, 10, 10, 864)  0          ['conv5_block12_0_bn[0][0]']
on)

conv5_block12_1_conv (Conv2D)  (None, 10, 10, 128)  110592      ['conv5_block12_0_relu[0][0]']

conv5_block12_1_bn (BatchNorma  (None, 10, 10, 128)  512        ['conv5_block12_1_conv[0][0]']
lization)

conv5_block12_1_relu (Activati  (None, 10, 10, 128)  0          ['conv5_block12_1_bn[0][0]']
on)

conv5_block12_2_conv (Conv2D)  (None, 10, 10, 32)   36864       ['conv5_block12_1_relu[0][0]']

conv5_block12_concat (Concaten  (None, 10, 10, 896)  0          ['conv5_block11_concat[0][0]',
ate)                                                             'conv5_block12_2_conv[0][0]']

conv5_block13_0_bn (BatchNorma  (None, 10, 10, 896)  3584       ['conv5_block12_concat[0][0]']
lization)
```

```
conv5_block13_0_relu (Activati  (None, 10, 10, 896)  0         ['conv5_block13_0_bn[0][0]']
on)

conv5_block13_1_conv (Conv2D)  (None, 10, 10, 128)  114688      ['conv5_block13_0_relu[0][0]']

conv5_block13_1_bn (BatchNorma  (None, 10, 10, 128)  512       ['conv5_block13_1_conv[0][0]']
lization)

conv5_block13_1_relu (Activati  (None, 10, 10, 128)  0         ['conv5_block13_1_bn[0][0]']
on)

conv5_block13_2_conv (Conv2D)  (None, 10, 10, 32)   36864       ['conv5_block13_1_relu[0][0]']

conv5_block13_concat (Concaten  (None, 10, 10, 928)  0         ['conv5_block12_concat[0][0]',
ate)                                                            'conv5_block13_2_conv[0][0]']

conv5_block14_0_bn (BatchNorma  (None, 10, 10, 928)  3712      ['conv5_block13_concat[0][0]']
lization)

conv5_block14_0_relu (Activati  (None, 10, 10, 928)  0         ['conv5_block14_0_bn[0][0]']
on)

conv5_block14_1_conv (Conv2D)  (None, 10, 10, 128)  118784      ['conv5_block14_0_relu[0][0]']

conv5_block14_1_bn (BatchNorma  (None, 10, 10, 128)  512       ['conv5_block14_1_conv[0][0]']
lization)

conv5_block14_1_relu (Activati  (None, 10, 10, 128)  0         ['conv5_block14_1_bn[0][0]']
on)

conv5_block14_2_conv (Conv2D)  (None, 10, 10, 32)   36864       ['conv5_block14_1_relu[0][0]']

conv5_block14_concat (Concaten  (None, 10, 10, 960)  0         ['conv5_block13_concat[0][0]',
ate)                                                            'conv5_block14_2_conv[0][0]']

conv5_block15_0_bn (BatchNorma  (None, 10, 10, 960)  3840      ['conv5_block14_concat[0][0]']
lization)

conv5_block15_0_relu (Activati  (None, 10, 10, 960)  0         ['conv5_block15_0_bn[0][0]']
on)

conv5_block15_1_conv (Conv2D)  (None, 10, 10, 128)  122880      ['conv5_block15_0_relu[0][0]']

conv5_block15_1_bn (BatchNorma  (None, 10, 10, 128)  512       ['conv5_block15_1_conv[0][0]']
lization)

conv5_block15_1_relu (Activati  (None, 10, 10, 128)  0         ['conv5_block15_1_bn[0][0]']
on)

conv5_block15_2_conv (Conv2D)  (None, 10, 10, 32)   36864       ['conv5_block15_1_relu[0][0]']

conv5_block15_concat (Concaten  (None, 10, 10, 992)  0         ['conv5_block14_concat[0][0]',
ate)                                                            'conv5_block15_2_conv[0][0]']

conv5_block16_0_bn (BatchNorma  (None, 10, 10, 992)  3968      ['conv5_block15_concat[0][0]']
lization)

conv5_block16_0_relu (Activati  (None, 10, 10, 992)  0         ['conv5_block16_0_bn[0][0]']
on)
```

```
 conv5_block16_1_conv (Conv2D)  (None, 10, 10, 128)  126976      ['conv5_block16_0_relu[0][0]']

 conv5_block16_1_bn (BatchNorma  (None, 10, 10, 128)  512        ['conv5_block16_1_conv[0][0]']
 lization)

 conv5_block16_1_relu (Activati  (None, 10, 10, 128)  0          ['conv5_block16_1_bn[0][0]']
 on)

 conv5_block16_2_conv (Conv2D)  (None, 10, 10, 32)   36864       ['conv5_block16_1_relu[0][0]']

 conv5_block16_concat (Concaten  (None, 10, 10, 1024  0          ['conv5_block15_concat[0][0]',
 ate)                           )                                 'conv5_block16_2_conv[0][0]']

 bn (BatchNormalization)        (None, 10, 10, 1024  4096        ['conv5_block16_concat[0][0]']
                                )

 relu (Activation)              (None, 10, 10, 1024  0           ['bn[0][0]']
                                )

 avg_pool (GlobalAveragePooling  (None, 1024)        0           ['relu[0][0]']
 2D)

==================================================================================================
Total params: 7,037,504
Trainable params: 6,953,856
Non-trainable params: 83,648
__________________________________________________________________________________________________
```

In [21]:
```
layers = base_model.layers
print(f"The model has {len(layers)} layers")

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

```
The model has 428 layers
The input shape KerasTensor(type_spec=TensorSpec(shape=(None, 320, 320, 3), dtype=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=tf.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'])

r = model.fit(
    train,
    epochs=10,
    validation_data=validation,
    class_weight=class_weight,
```

```
    steps_per_epoch=100,
    validation_steps=25,
)
```

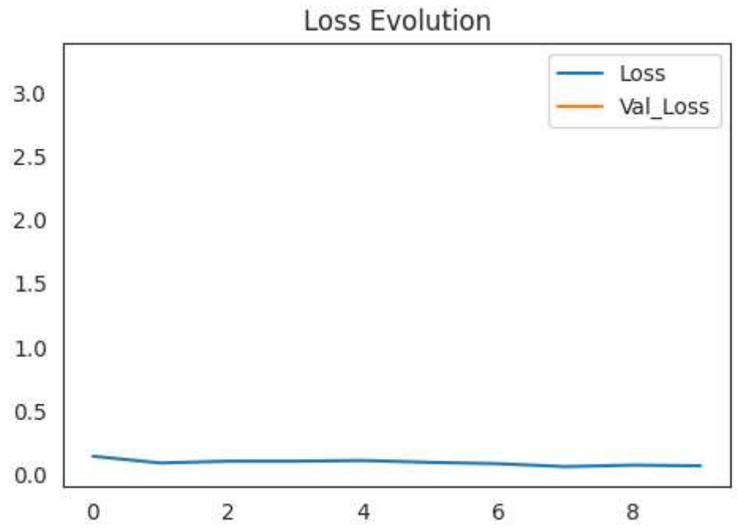
```
Epoch 1/10
100/100 [==============================] - 108s 338ms/step - loss: 0.1437 - accuracy: 0.8413 - val_loss: 3.2256 - val_accuracy: 0.5000
Epoch 2/10
100/100 [==============================] - 30s 294ms/step - loss: 0.0910 - accuracy: 0.9025
Epoch 3/10
100/100 [==============================] - 31s 307ms/step - loss: 0.1048 - accuracy: 0.8913
Epoch 4/10
100/100 [==============================] - 30s 304ms/step - loss: 0.1049 - accuracy: 0.8913
Epoch 5/10
100/100 [==============================] - 30s 298ms/step - loss: 0.1105 - accuracy: 0.8913
Epoch 6/10
100/100 [==============================] - 31s 311ms/step - loss: 0.0955 - accuracy: 0.9013
Epoch 7/10
100/100 [==============================] - 30s 297ms/step - loss: 0.0856 - accuracy: 0.8963
Epoch 8/10
100/100 [==============================] - 30s 294ms/step - loss: 0.0623 - accuracy: 0.9413
Epoch 9/10
100/100 [==============================] - 30s 300ms/step - loss: 0.0740 - accuracy: 0.9250
Epoch 10/10
100/100 [==============================] - 29s 291ms/step - loss: 0.0685 - accuracy: 0.9237
```

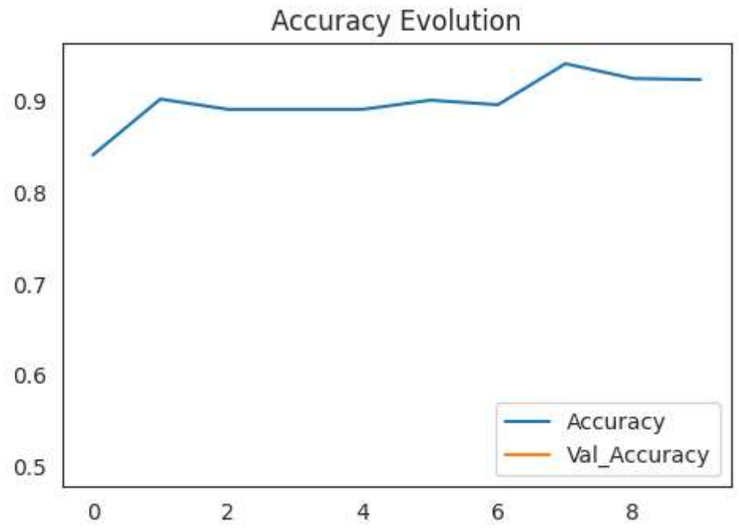
In [23]:
```
plt.figure(figsize=(12, 8))

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[23]:
```
Text(0.5, 1.0, 'Accuracy Evolution')
```





In [24]:
```
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 [==============================] - 25s 40ms/step - loss: 1.0404 - accuracy: 0.7901
Test Accuracy: 79.01%
652/652 [==============================] - 172s 264ms/step - loss: 0.1495 - accuracy: 0.9473
Train Accuracy: 94.73%
```

Evaluation

In [25]:
```
predicted_vals = model.predict(test, steps=len(test))
```

```
624/624 [==============================] - 27s 41ms/step
```

In [26]:
```
print(confusion_matrix(test.classes, predicted_vals > 0.5))
pd.DataFrame(classification_report(test.classes, predicted_vals > 0.5, output_dict=True))
```

```
[[109 125]
 [  1 389]]
```

Out[26]:

	0	1	accuracy	macro avg	weighted avg
precision	0.990909	0.756809	0.798077	0.873859	0.844597
recall	0.465812	0.997436	0.798077	0.731624	0.798077
f1-score	0.633721	0.860619	0.798077	0.747170	0.775533
support	234.000000	390.000000	0.798077	624.000000	624.000000

In [27]:
```
print(confusion_matrix(test.classes, predicted_vals > 0.7))
pd.DataFrame(classification_report(test.classes, predicted_vals > 0.7, output_dict=True))
```

```
[[126 108]
 [  4 386]]
```

Out[27]:

	0	1	accuracy	macro avg	weighted avg
precision	0.969231	0.781377	0.820513	0.875304	0.851822
recall	0.538462	0.989744	0.820513	0.764103	0.820513
f1-score	0.692308	0.873303	0.820513	0.782805	0.805430
support	234.000000	390.000000	0.820513	624.000000	624.000000