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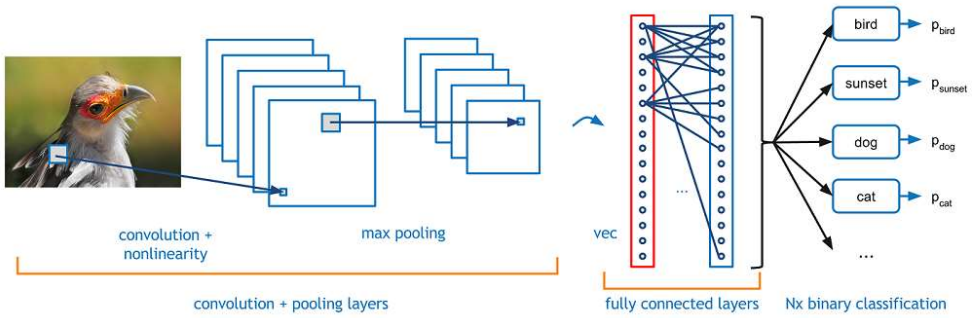
CNN for lesion classification

1. Brief CNN theory

A Convolutional Neural Network (CNN, or ConvNet) is a type of **feed-forward** artificial neural network in which the connectivity pattern between its neurons is inspired by the organization of the animal visual cortex.



> source: https://flickrcode.files.wordpress.com/2014/10/conv-net2.png (https://flickrcode.files.wordpress.com/2014/10/conv-net2.png)

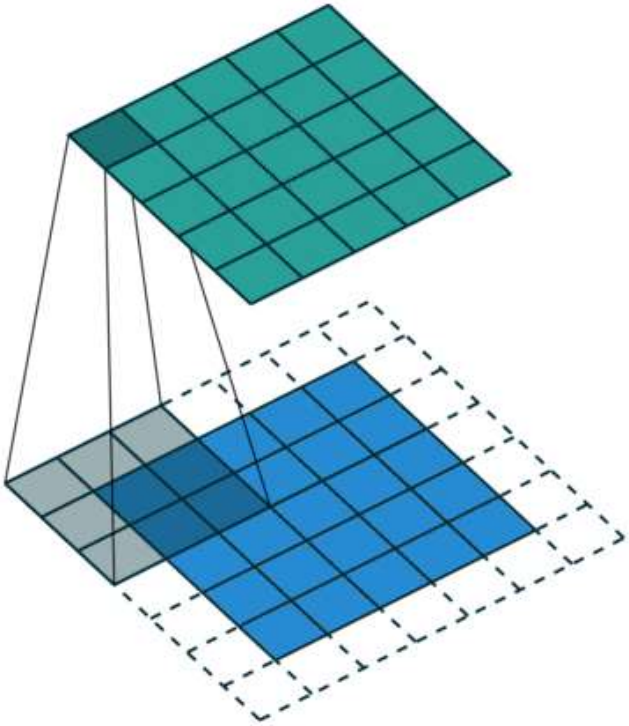
1.1 Structure of a CNN

> A more detailed overview of what CNNs do would be that you take the image, pass it through a series of convolutional, nonlinear, pooling (downsampling), and fully connected layers, and get an output. As we said earlier, the output can be a single class or a probability of classes that best describes the image.

source: [1]

Convolutional Layer

The first layer in a CNN is always a **Convolutional Layer**.



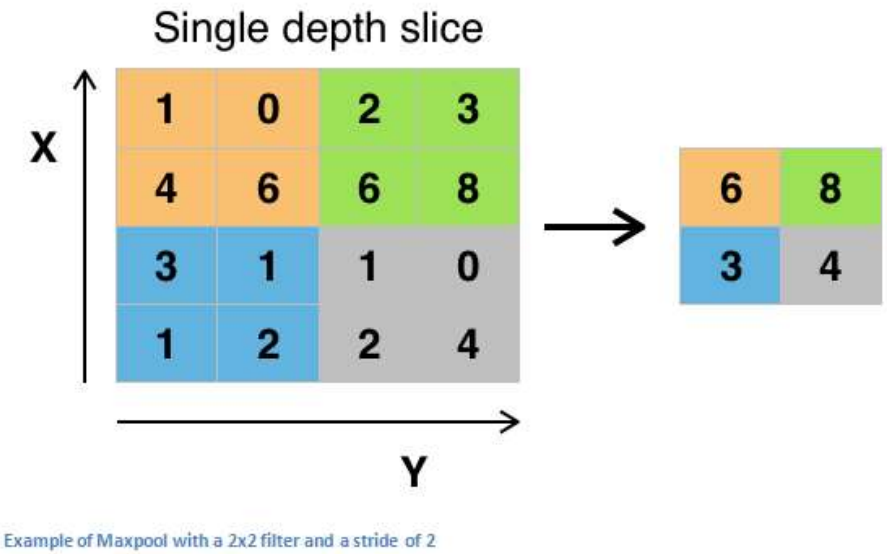
Typical CNN Structure

A traditional CNN architecture consists of other layers interspaced between convolution layers

Input -> Conv -> ReLU -> Conv -> ReLU -> Pool -> ReLU -> Conv -> ReLU -> Pool ->Fully Connected

Pooling layer

After some ReLu layers, **pooling layer** is typically applied.



Example of Maxpool with a 2x2 filter and a stride of 2

Pooling reduces the amount of parameters (helping with computional efficiency) and controls overfitting

2. We build one using keras and tensorflow

2.1 Preparation

In [13]:

```
# setup code for this notebook
import numpy as np
import matplotlib.pyplot as plt
from functions import data, Timer
timer = Timer()

# This makes matplotlib figures appear inline in the notebook
# rather than in a new window.
%matplotlib inline
plt.rcParams['figure.figsize'] = (10.0, 8.0) # set default size of plots
plt.rcParams['image.interpolation'] = 'nearest'
plt.rcParams['image.cmap'] = 'gray'

# Make the notebook reload external python modules;
# see http://stackoverflow.com/questions/1907993/autoreload-of-modules-in-ipython
%load_ext autoreload
%autoreload 2
```

```
The autoreload extension is already loaded. To reload it, use:
  %reload_ext autoreload
```

The ultra sound scan data

- 163 scans total, clinically confirmed as having either bening or malignant (cancerous) lesions
- 100 scans for training, 63 for testing
- Training data was passed through 7 transformations to give us 800 training images total
- We balanced the training data to have half malignant and half benign
- Since the malignant cases were less than benign cases, we use only 528 images for training
- Emperically we have found this improves our overall performance
- Testing images not transformed
- Both training and testing images were resized to 224X224
- Raw pngs then converted to numpy arrays and saved

In [14]:

```
# Import keras libraries
from keras.models import Sequential
from keras.applications.inception_v3 import InceptionV3
from keras.layers.core import Dense, Dropout, Activation, Flatten
from keras.layers.convolutional import Conv2D
from keras.layers.pooling import MaxPooling2D
from keras.layers import GlobalAveragePooling2D
from keras import backend as K
from keras.models import Model
from keras.layers import Input
from functions import data, Timer
```

In [15]:

```
img_rows, img_cols = 224, 224 # 224, 224 works resized down from 360, 528
color_channels = 3

if K.image_data_format() == 'channels_first':
    input_shape = (color_channels, img_rows, img_cols)
else:
    input_shape = (img_rows, img_cols, color_channels)

print('Input shape', input_shape)
```

```
Input shape (224, 224, 3)
```

In [16]:

```
# data loader and generator helper methods
from keras.preprocessing.image import ImageDataGenerator
```

In [17]:

```
# data readers
base = "J:\\final year project\\code and models\\data\\augmented\\"
train_directory = base+'training'
validation_directory = base+'validation'

batch_size = 8

# normalization
train_generator = ImageDataGenerator(rescale=1./255)
validation_generator = ImageDataGenerator(rescale=1./255)

# this is a generator that will read scans found in
# the train directory, and indefinitely generate
# batches of image data
train_generator = train_generator.flow_from_directory(
        train_directory,
        target_size=(img_rows, img_cols),
        batch_size=batch_size,
        class_mode='binary')

# A  similar generator, for validation data
validation_generator = validation_generator.flow_from_directory(
        validation_directory,
        target_size=(img_rows, img_cols),
        batch_size=batch_size,
        class_mode='binary')
```

```
Found 400 images belonging to 2 classes.
Found 128 images belonging to 2 classes.
```

In [18]:

```
# Visualize
from IPython.display import SVG
from keras.utils.vis_utils import model_to_dot

def visualize(model):
    model.summary()
    SVG(model_to_dot(model).create(prog='dot', format='svg'))
```

In [19]:

```
def getModelMemoryUsage(batch_size, model):
    shapes_mem_count = 0
    for l in model.layers:
        single_layer_mem = 1
        for s in l.output_shape:
            if s is None:
                continue
            single_layer_mem *= s
        shapes_mem_count += single_layer_mem

    trainable_count = np.sum([K.count_params(p) for p in set(model.trainable_weights)])
    non_trainable_count = np.sum([K.count_params(p) for p in set(model.non_trainable_weight

    total_memory = 4.0*batch_size*(shapes_mem_count + trainable_count + non_trainable_count
    gbytes = np.round(total_memory / (1024.0 ** 3), 3)
    return str(gbytes) + " GB" , str(gbytes*2)
```

2.2 Retraining InceptionV3 CNN

In [20]:

```
# We define the custom inception based model
def buildBaseModel():
    input_tensor = Input(shape=input_shape)
    base_model = InceptionV3(input_tensor=input_tensor, weights='imagenet', include_top=Fal

    # we add a global spatial average pooling layer
    x = base_model.output
    x = GlobalAveragePooling2D()(x)

    # we add a fully-connected layer
    x = Dense(256, activation='relu')(x)

    #we add a logistic layer for our 2 classes
    predictions = Dense(1, activation='softmax')(x)

    # this is our model, a hybrid inceptionv3
    model = Model(inputs=base_model.input, outputs=predictions)

    # first we train our custom top layer
    # we freeze all convolutional inceptionv3 layers
    for layer in base_model.layers:
        layer.trainable = False

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

    return model
```

In [21]:

```
model = buildBaseModel()
```

In [22]:

```
# helpers for checkpointing and early stopping
from keras.callbacks import ModelCheckpoint , EarlyStopping

def trainModel(model, epochs=5, text="Re training inception model",
               file_name='best_cnn_inc_model.h5'):
    best_model_file = file_name
    early_stop = EarlyStopping(monitor='val_loss', patience=3, verbose=True)
    best_model = ModelCheckpoint(best_model_file, verbose=True, save_best_only=True)

    timer.start()
    network_history = model.fit_generator(
            train_generator,
            steps_per_epoch=800,
            epochs=epochs,
            validation_data = validation_generator,
            validation_steps=256,
            verbose=True,
            callbacks=[best_model])
    timer.stop(text)
    return network_history
```

In [23]:

```
# visualize(model)
model.summary()
gpu, ram = getModelMemoryUsage(batch_size, model)
print("GPU Memory:" + gpu + "RAM:" + ram)
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_2 (InputLayer)         (None, 224, 224, 3)       0
_________________________________________________________________
conv2d_95 (Conv2D)           (None, 111, 111, 32)      864
_________________________________________________________________
batch_normalization_95 (BatchNo (None, 111, 111, 32)   96
_________________________________________________________________
activation_95 (Activation)   (None, 111, 111, 32)      0
_________________________________________________________________
conv2d_96 (Conv2D)           (None, 109, 109, 32)      9216
_________________________________________________________________
batch_normalization_96 (BatchNo (None, 109, 109, 32)   96
_________________________________________________________________
activation_96 (Activation)   (None, 109, 109, 32)      0
_________________________________________________________________
conv2d_97 (Conv2D)           (None, 109, 109, 64)      18432
_________________________________________________________________
batch_normalization_97 (BatchNo (None, 109, 109, 64)   192
_________________________________________________________________
activation_97 (Activation)   (None, 109, 109, 64)      0
_________________________________________________________________
max_pooling2d_5 (MaxPooling2D)  (None, 54, 54, 64)     0
_________________________________________________________________
conv2d_98 (Conv2D)           (None, 54, 54, 80)        5120
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batch_normalization_98 (BatchNo (None, 54, 54, 80)   240         conv2d_98
[0][0]
__________________________________________________________________________
_____
activation_98 (Activation)      (None, 54, 54, 80)   0           batch_norma
lization_98[0][0]
__________________________________________________________________________
_____
conv2d_99 (Conv2D)              (None, 52, 52, 192)  138240      activation_
98[0][0]
__________________________________________________________________________
_____
batch_normalization_99 (BatchNo (None, 52, 52, 192)  576         conv2d_99
[0][0]
__________________________________________________________________________
_____
activation_99 (Activation)      (None, 52, 52, 192)  0           batch_norma
lization_99[0][0]
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_____
max_pooling2d_6 (MaxPooling2D)  (None, 25, 25, 192)  0           activation_
99[0][0]
__________________________________________________________________________
_____
conv2d_103 (Conv2D)             (None, 25, 25, 64)   12288       max_pooling
2d_6[0][0]
__________________________________________________________________________
_____
batch_normalization_103 (BatchN (None, 25, 25, 64)   192         conv2d_103
[0][0]
__________________________________________________________________________
_____
activation_103 (Activation)     (None, 25, 25, 64)   0           batch_norma
lization_103[0][0]
__________________________________________________________________________
_____
conv2d_101 (Conv2D)             (None, 25, 25, 48)   9216        max_pooling
2d_6[0][0]
__________________________________________________________________________
_____
conv2d_104 (Conv2D)             (None, 25, 25, 96)   55296       activation_
103[0][0]
__________________________________________________________________________
_____
batch_normalization_101 (BatchN (None, 25, 25, 48)   144         conv2d_101
[0][0]
__________________________________________________________________________
_____
batch_normalization_104 (BatchN (None, 25, 25, 96)   288         conv2d_104
[0][0]
__________________________________________________________________________
_____
activation_101 (Activation)     (None, 25, 25, 48)   0           batch_norma
lization_101[0][0]
__________________________________________________________________________
_____
activation_104 (Activation)     (None, 25, 25, 96)   0           batch_norma
lization_104[0][0]
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average_pooling2d_10 (AveragePo (None, 25, 25, 192)  0           max_pooling
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2d_6[0][0]
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conv2d_100 (Conv2D)             (None, 25, 25, 64)   12288       max_pooling
2d_6[0][0]
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conv2d_102 (Conv2D)             (None, 25, 25, 64)   76800       activation_
101[0][0]
__________________________________________________________________________________________________
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conv2d_105 (Conv2D)             (None, 25, 25, 96)   82944       activation_
104[0][0]
__________________________________________________________________________________________________
____________________
conv2d_106 (Conv2D)             (None, 25, 25, 32)   6144        average_poo
ling2d_10[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_100 (BatchN (None, 25, 25, 64)   192         conv2d_100
[0][0]
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batch_normalization_102 (BatchN (None, 25, 25, 64)   192         conv2d_102
[0][0]
__________________________________________________________________________________________________
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batch_normalization_105 (BatchN (None, 25, 25, 96)   288         conv2d_105
[0][0]
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batch_normalization_106 (BatchN (None, 25, 25, 32)   96          conv2d_106
[0][0]
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activation_100 (Activation)     (None, 25, 25, 64)   0           batch_norma
lization_100[0][0]
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activation_102 (Activation)     (None, 25, 25, 64)   0           batch_norma
lization_102[0][0]
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activation_105 (Activation)     (None, 25, 25, 96)   0           batch_norma
lization_105[0][0]
__________________________________________________________________________________________________
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activation_106 (Activation)     (None, 25, 25, 32)   0           batch_norma
lization_106[0][0]
__________________________________________________________________________________________________
____________________
mixed0 (Concatenate)            (None, 25, 25, 256)  0           activation_
100[0][0]
                                                                 activation_
102[0][0]
                                                                 activation_
105[0][0]
                                                                 activation_
106[0][0]
__________________________________________________________________________________________________
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conv2d_110 (Conv2D)             (None, 25, 25, 64)   16384       mixed0[0]
[0]
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batch_normalization_110 (BatchN (None, 25, 25, 64)   192         conv2d_110
[0][0]
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activation_110 (Activation)     (None, 25, 25, 64)   0           batch_norma
lization_110[0][0]
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conv2d_108 (Conv2D)             (None, 25, 25, 48)   12288       mixed0[0]
[0]
__________________________________________________________________________
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conv2d_111 (Conv2D)             (None, 25, 25, 96)   55296       activation_
110[0][0]
__________________________________________________________________________
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batch_normalization_108 (BatchN (None, 25, 25, 48)   144         conv2d_108
[0][0]
__________________________________________________________________________
_____
batch_normalization_111 (BatchN (None, 25, 25, 96)   288         conv2d_111
[0][0]
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activation_108 (Activation)     (None, 25, 25, 48)   0           batch_norma
lization_108[0][0]
__________________________________________________________________________
_____
activation_111 (Activation)     (None, 25, 25, 96)   0           batch_norma
lization_111[0][0]
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average_pooling2d_11 (AveragePo (None, 25, 25, 256)  0           mixed0[0]
[0]
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conv2d_107 (Conv2D)             (None, 25, 25, 64)   16384       mixed0[0]
[0]
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conv2d_109 (Conv2D)             (None, 25, 25, 64)   76800       activation_
108[0][0]
__________________________________________________________________________
_____
conv2d_112 (Conv2D)             (None, 25, 25, 96)   82944       activation_
111[0][0]
__________________________________________________________________________
_____
conv2d_113 (Conv2D)             (None, 25, 25, 64)   16384       average_poo
ling2d_11[0][0]
__________________________________________________________________________
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batch_normalization_107 (BatchN (None, 25, 25, 64)   192         conv2d_107
[0][0]
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batch_normalization_109 (BatchN (None, 25, 25, 64)   192         conv2d_109
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[0][0]
__________________________________________________________________________________________________
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batch_normalization_112 (BatchN (None, 25, 25, 96)   288         conv2d_112
[0][0]
__________________________________________________________________________________________________
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batch_normalization_113 (BatchN (None, 25, 25, 64)   192         conv2d_113
[0][0]
__________________________________________________________________________________________________
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activation_107 (Activation)     (None, 25, 25, 64)   0           batch_norma
lization_107[0][0]
__________________________________________________________________________________________________
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activation_109 (Activation)     (None, 25, 25, 64)   0           batch_norma
lization_109[0][0]
__________________________________________________________________________________________________
____________________
activation_112 (Activation)     (None, 25, 25, 96)   0           batch_norma
lization_112[0][0]
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activation_113 (Activation)     (None, 25, 25, 64)   0           batch_norma
lization_113[0][0]
__________________________________________________________________________________________________
____________________
mixed1 (Concatenate)            (None, 25, 25, 288)  0           activation_
107[0][0]
                                                                 activation_
109[0][0]
                                                                 activation_
112[0][0]
                                                                 activation_
113[0][0]
__________________________________________________________________________________________________
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conv2d_117 (Conv2D)             (None, 25, 25, 64)   18432       mixed1[0]
[0]
__________________________________________________________________________________________________
____________________
batch_normalization_117 (BatchN (None, 25, 25, 64)   192         conv2d_117
[0][0]
__________________________________________________________________________________________________
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activation_117 (Activation)     (None, 25, 25, 64)   0           batch_norma
lization_117[0][0]
__________________________________________________________________________________________________
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conv2d_115 (Conv2D)             (None, 25, 25, 48)   13824       mixed1[0]
[0]
__________________________________________________________________________________________________
____________________
conv2d_118 (Conv2D)             (None, 25, 25, 96)   55296       activation_
117[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_115 (BatchN (None, 25, 25, 48)   144         conv2d_115
[0][0]
__________________________________________________________________________________________________
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batch_normalization_118 (BatchN (None, 25, 25, 96)   288         conv2d_118
[0][0]
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activation_115 (Activation)     (None, 25, 25, 48)   0           batch_norma
lization_115[0][0]
__________________________________________________________________________
_____
activation_118 (Activation)     (None, 25, 25, 96)   0           batch_norma
lization_118[0][0]
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average_pooling2d_12 (AveragePo (None, 25, 25, 288)  0           mixed1[0]
[0]
__________________________________________________________________________
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conv2d_114 (Conv2D)             (None, 25, 25, 64)   18432       mixed1[0]
[0]
__________________________________________________________________________
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conv2d_116 (Conv2D)             (None, 25, 25, 64)   76800       activation_
115[0][0]
__________________________________________________________________________
_____
conv2d_119 (Conv2D)             (None, 25, 25, 96)   82944       activation_
118[0][0]
__________________________________________________________________________
_____
conv2d_120 (Conv2D)             (None, 25, 25, 64)   18432       average_poo
ling2d_12[0][0]
__________________________________________________________________________
_____
batch_normalization_114 (BatchN (None, 25, 25, 64)   192         conv2d_114
[0][0]
__________________________________________________________________________
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batch_normalization_116 (BatchN (None, 25, 25, 64)   192         conv2d_116
[0][0]
__________________________________________________________________________
_____
batch_normalization_119 (BatchN (None, 25, 25, 96)   288         conv2d_119
[0][0]
__________________________________________________________________________
_____
batch_normalization_120 (BatchN (None, 25, 25, 64)   192         conv2d_120
[0][0]
__________________________________________________________________________
_____
activation_114 (Activation)     (None, 25, 25, 64)   0           batch_norma
lization_114[0][0]
__________________________________________________________________________
_____
activation_116 (Activation)     (None, 25, 25, 64)   0           batch_norma
lization_116[0][0]
__________________________________________________________________________
_____
activation_119 (Activation)     (None, 25, 25, 96)   0           batch_norma
lization_119[0][0]
__________________________________________________________________________
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activation_120 (Activation)     (None, 25, 25, 64)   0           batch_norma
```

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lization_120[0][0]
__________________________________________________________________________________________________
____________________
mixed2 (Concatenate)            (None, 25, 25, 288)  0           activation_
114[0][0]
                                                                 activation_
116[0][0]
                                                                 activation_
119[0][0]
                                                                 activation_
120[0][0]
__________________________________________________________________________________________________
____________________
conv2d_122 (Conv2D)             (None, 25, 25, 64)   18432       mixed2[0]
[0]
__________________________________________________________________________________________________
____________________
batch_normalization_122 (BatchN (None, 25, 25, 64)   192         conv2d_122
[0][0]
__________________________________________________________________________________________________
____________________
activation_122 (Activation)     (None, 25, 25, 64)   0           batch_norma
lization_122[0][0]
__________________________________________________________________________________________________
____________________
conv2d_123 (Conv2D)             (None, 25, 25, 96)   55296       activation_
122[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_123 (BatchN (None, 25, 25, 96)   288         conv2d_123
[0][0]
__________________________________________________________________________________________________
____________________
activation_123 (Activation)     (None, 25, 25, 96)   0           batch_norma
lization_123[0][0]
__________________________________________________________________________________________________
____________________
conv2d_121 (Conv2D)             (None, 12, 12, 384)  995328      mixed2[0]
[0]
__________________________________________________________________________________________________
____________________
conv2d_124 (Conv2D)             (None, 12, 12, 96)   82944       activation_
123[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_121 (BatchN (None, 12, 12, 384)  1152        conv2d_121
[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_124 (BatchN (None, 12, 12, 96)   288         conv2d_124
[0][0]
__________________________________________________________________________________________________
____________________
activation_121 (Activation)     (None, 12, 12, 384)  0           batch_norma
lization_121[0][0]
__________________________________________________________________________________________________
____________________
activation_124 (Activation)     (None, 12, 12, 96)   0           batch_norma
lization_124[0][0]
__________________________________________________________________________________________________
____________________
```

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max_pooling2d_7 (MaxPooling2D)  (None, 12, 12, 288)  0           mixed2[0]
[0]
__________________________________________________________________________
_____
mixed3 (Concatenate)            (None, 12, 12, 768)  0           activation_
121[0][0]
                                                                 activation_
124[0][0]
                                                                 max_pooling
2d_7[0][0]
__________________________________________________________________________
_____
conv2d_129 (Conv2D)             (None, 12, 12, 128)  98304       mixed3[0]
[0]
__________________________________________________________________________
_____
batch_normalization_129 (BatchN (None, 12, 12, 128)  384         conv2d_129
[0][0]
__________________________________________________________________________
_____
activation_129 (Activation)     (None, 12, 12, 128)  0           batch_norma
lization_129[0][0]
__________________________________________________________________________
_____
conv2d_130 (Conv2D)             (None, 12, 12, 128)  114688      activation_
129[0][0]
__________________________________________________________________________
_____
batch_normalization_130 (BatchN (None, 12, 12, 128)  384         conv2d_130
[0][0]
__________________________________________________________________________
_____
activation_130 (Activation)     (None, 12, 12, 128)  0           batch_norma
lization_130[0][0]
__________________________________________________________________________
_____
conv2d_126 (Conv2D)             (None, 12, 12, 128)  98304       mixed3[0]
[0]
__________________________________________________________________________
_____
conv2d_131 (Conv2D)             (None, 12, 12, 128)  114688      activation_
130[0][0]
__________________________________________________________________________
_____
batch_normalization_126 (BatchN (None, 12, 12, 128)  384         conv2d_126
[0][0]
__________________________________________________________________________
_____
batch_normalization_131 (BatchN (None, 12, 12, 128)  384         conv2d_131
[0][0]
__________________________________________________________________________
_____
activation_126 (Activation)     (None, 12, 12, 128)  0           batch_norma
lization_126[0][0]
__________________________________________________________________________
_____
activation_131 (Activation)     (None, 12, 12, 128)  0           batch_norma
lization_131[0][0]
__________________________________________________________________________
_____
conv2d_127 (Conv2D)             (None, 12, 12, 128)  114688      activation_
```

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126[0][0]
__________________________________________________________________________________________________
____________________
conv2d_132 (Conv2D)             (None, 12, 12, 128)  114688      activation_
131[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_127 (BatchN (None, 12, 12, 128)  384         conv2d_127
[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_132 (BatchN (None, 12, 12, 128)  384         conv2d_132
[0][0]
__________________________________________________________________________________________________
____________________
activation_127 (Activation)     (None, 12, 12, 128)  0           batch_norma
lization_127[0][0]
__________________________________________________________________________________________________
____________________
activation_132 (Activation)     (None, 12, 12, 128)  0           batch_norma
lization_132[0][0]
__________________________________________________________________________________________________
____________________
average_pooling2d_13 (AveragePo (None, 12, 12, 768)  0           mixed3[0]
[0]
__________________________________________________________________________________________________
____________________
conv2d_125 (Conv2D)             (None, 12, 12, 192)  147456      mixed3[0]
[0]
__________________________________________________________________________________________________
____________________
conv2d_128 (Conv2D)             (None, 12, 12, 192)  172032      activation_
127[0][0]
__________________________________________________________________________________________________
____________________
conv2d_133 (Conv2D)             (None, 12, 12, 192)  172032      activation_
132[0][0]
__________________________________________________________________________________________________
____________________
conv2d_134 (Conv2D)             (None, 12, 12, 192)  147456      average_poo
ling2d_13[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_125 (BatchN (None, 12, 12, 192)  576         conv2d_125
[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_128 (BatchN (None, 12, 12, 192)  576         conv2d_128
[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_133 (BatchN (None, 12, 12, 192)  576         conv2d_133
[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_134 (BatchN (None, 12, 12, 192)  576         conv2d_134
[0][0]
__________________________________________________________________________________________________
____________________
activation_125 (Activation)     (None, 12, 12, 192)  0           batch_norma
lization_125[0][0]
```

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____________________________________________________________________________________________________
____________________
activation_128 (Activation)     (None, 12, 12, 192)  0           batch_norma
lization_128[0][0]
____________________________________________________________________________________________________
____________________
activation_133 (Activation)     (None, 12, 12, 192)  0           batch_norma
lization_133[0][0]
____________________________________________________________________________________________________
____________________
activation_134 (Activation)     (None, 12, 12, 192)  0           batch_norma
lization_134[0][0]
____________________________________________________________________________________________________
____________________
mixed4 (Concatenate)            (None, 12, 12, 768)  0           activation_
125[0][0]
                                                                 activation_
128[0][0]
                                                                 activation_
133[0][0]
                                                                 activation_
134[0][0]
____________________________________________________________________________________________________
____________________
conv2d_139 (Conv2D)             (None, 12, 12, 160)  122880      mixed4[0]
[0]
____________________________________________________________________________________________________
____________________
batch_normalization_139 (BatchN (None, 12, 12, 160)  480         conv2d_139
[0][0]
____________________________________________________________________________________________________
____________________
activation_139 (Activation)     (None, 12, 12, 160)  0           batch_norma
lization_139[0][0]
____________________________________________________________________________________________________
____________________
conv2d_140 (Conv2D)             (None, 12, 12, 160)  179200      activation_
139[0][0]
____________________________________________________________________________________________________
____________________
batch_normalization_140 (BatchN (None, 12, 12, 160)  480         conv2d_140
[0][0]
____________________________________________________________________________________________________
____________________
activation_140 (Activation)     (None, 12, 12, 160)  0           batch_norma
lization_140[0][0]
____________________________________________________________________________________________________
____________________
conv2d_136 (Conv2D)             (None, 12, 12, 160)  122880      mixed4[0]
[0]
____________________________________________________________________________________________________
____________________
conv2d_141 (Conv2D)             (None, 12, 12, 160)  179200      activation_
140[0][0]
____________________________________________________________________________________________________
____________________
batch_normalization_136 (BatchN (None, 12, 12, 160)  480         conv2d_136
[0][0]
____________________________________________________________________________________________________
____________________
batch_normalization_141 (BatchN (None, 12, 12, 160)  480         conv2d_141
```

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[0][0]
__________________________________________________________________________________________________
____________________
activation_136 (Activation)     (None, 12, 12, 160)  0           batch_norma
lization_136[0][0]
__________________________________________________________________________________________________
____________________
activation_141 (Activation)     (None, 12, 12, 160)  0           batch_norma
lization_141[0][0]
__________________________________________________________________________________________________
____________________
conv2d_137 (Conv2D)             (None, 12, 12, 160)  179200      activation_
136[0][0]
__________________________________________________________________________________________________
____________________
conv2d_142 (Conv2D)             (None, 12, 12, 160)  179200      activation_
141[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_137 (BatchN (None, 12, 12, 160)  480         conv2d_137
[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_142 (BatchN (None, 12, 12, 160)  480         conv2d_142
[0][0]
__________________________________________________________________________________________________
____________________
activation_137 (Activation)     (None, 12, 12, 160)  0           batch_norma
lization_137[0][0]
__________________________________________________________________________________________________
____________________
activation_142 (Activation)     (None, 12, 12, 160)  0           batch_norma
lization_142[0][0]
__________________________________________________________________________________________________
____________________
average_pooling2d_14 (AveragePo (None, 12, 12, 768)  0           mixed4[0]
[0]
__________________________________________________________________________________________________
____________________
conv2d_135 (Conv2D)             (None, 12, 12, 192)  147456      mixed4[0]
[0]
__________________________________________________________________________________________________
____________________
conv2d_138 (Conv2D)             (None, 12, 12, 192)  215040      activation_
137[0][0]
__________________________________________________________________________________________________
____________________
conv2d_143 (Conv2D)             (None, 12, 12, 192)  215040      activation_
142[0][0]
__________________________________________________________________________________________________
____________________
conv2d_144 (Conv2D)             (None, 12, 12, 192)  147456      average_poo
ling2d_14[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_135 (BatchN (None, 12, 12, 192)  576         conv2d_135
[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_138 (BatchN (None, 12, 12, 192)  576         conv2d_138
[0][0]
```

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__________________________________________________________________________________________________
____________________
batch_normalization_143 (BatchN (None, 12, 12, 192)  576         conv2d_143
[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_144 (BatchN (None, 12, 12, 192)  576         conv2d_144
[0][0]
__________________________________________________________________________________________________
____________________
activation_135 (Activation)     (None, 12, 12, 192)  0           batch_norma
lization_135[0][0]
__________________________________________________________________________________________________
____________________
activation_138 (Activation)     (None, 12, 12, 192)  0           batch_norma
lization_138[0][0]
__________________________________________________________________________________________________
____________________
activation_143 (Activation)     (None, 12, 12, 192)  0           batch_norma
lization_143[0][0]
__________________________________________________________________________________________________
____________________
activation_144 (Activation)     (None, 12, 12, 192)  0           batch_norma
lization_144[0][0]
__________________________________________________________________________________________________
____________________
mixed5 (Concatenate)            (None, 12, 12, 768)  0           activation_
135[0][0]
                                                                 activation_
138[0][0]
                                                                 activation_
143[0][0]
                                                                 activation_
144[0][0]
__________________________________________________________________________________________________
____________________
conv2d_149 (Conv2D)             (None, 12, 12, 160)  122880      mixed5[0]
[0]
__________________________________________________________________________________________________
____________________
batch_normalization_149 (BatchN (None, 12, 12, 160)  480         conv2d_149
[0][0]
__________________________________________________________________________________________________
____________________
activation_149 (Activation)     (None, 12, 12, 160)  0           batch_norma
lization_149[0][0]
__________________________________________________________________________________________________
____________________
conv2d_150 (Conv2D)             (None, 12, 12, 160)  179200      activation_
149[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_150 (BatchN (None, 12, 12, 160)  480         conv2d_150
[0][0]
__________________________________________________________________________________________________
____________________
activation_150 (Activation)     (None, 12, 12, 160)  0           batch_norma
lization_150[0][0]
__________________________________________________________________________________________________
____________________
conv2d_146 (Conv2D)             (None, 12, 12, 160)  122880      mixed5[0]
```

```
[0]
__________________________________________________________________________________________________
____________________
conv2d_151 (Conv2D)             (None, 12, 12, 160)  179200      activation_
150[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_146 (BatchN (None, 12, 12, 160)  480         conv2d_146
[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_151 (BatchN (None, 12, 12, 160)  480         conv2d_151
[0][0]
__________________________________________________________________________________________________
____________________
activation_146 (Activation)     (None, 12, 12, 160)  0           batch_norma
lization_146[0][0]
__________________________________________________________________________________________________
____________________
activation_151 (Activation)     (None, 12, 12, 160)  0           batch_norma
lization_151[0][0]
__________________________________________________________________________________________________
____________________
conv2d_147 (Conv2D)             (None, 12, 12, 160)  179200      activation_
146[0][0]
__________________________________________________________________________________________________
____________________
conv2d_152 (Conv2D)             (None, 12, 12, 160)  179200      activation_
151[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_147 (BatchN (None, 12, 12, 160)  480         conv2d_147
[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_152 (BatchN (None, 12, 12, 160)  480         conv2d_152
[0][0]
__________________________________________________________________________________________________
____________________
activation_147 (Activation)     (None, 12, 12, 160)  0           batch_norma
lization_147[0][0]
__________________________________________________________________________________________________
____________________
activation_152 (Activation)     (None, 12, 12, 160)  0           batch_norma
lization_152[0][0]
__________________________________________________________________________________________________
____________________
average_pooling2d_15 (AveragePo (None, 12, 12, 768)  0           mixed5[0]
[0]
__________________________________________________________________________________________________
____________________
conv2d_145 (Conv2D)             (None, 12, 12, 192)  147456      mixed5[0]
[0]
__________________________________________________________________________________________________
____________________
conv2d_148 (Conv2D)             (None, 12, 12, 192)  215040      activation_
147[0][0]
__________________________________________________________________________________________________
____________________
conv2d_153 (Conv2D)             (None, 12, 12, 192)  215040      activation_
152[0][0]
```

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____________________________________________________________________________________________________
____________________
conv2d_154 (Conv2D)             (None, 12, 12, 192)  147456      average_poo
ling2d_15[0][0]
____________________________________________________________________________________________________
____________________
batch_normalization_145 (BatchN (None, 12, 12, 192)  576         conv2d_145
[0][0]
____________________________________________________________________________________________________
____________________
batch_normalization_148 (BatchN (None, 12, 12, 192)  576         conv2d_148
[0][0]
____________________________________________________________________________________________________
____________________
batch_normalization_153 (BatchN (None, 12, 12, 192)  576         conv2d_153
[0][0]
____________________________________________________________________________________________________
____________________
batch_normalization_154 (BatchN (None, 12, 12, 192)  576         conv2d_154
[0][0]
____________________________________________________________________________________________________
____________________
activation_145 (Activation)     (None, 12, 12, 192)  0           batch_norma
lization_145[0][0]
____________________________________________________________________________________________________
____________________
activation_148 (Activation)     (None, 12, 12, 192)  0           batch_norma
lization_148[0][0]
____________________________________________________________________________________________________
____________________
activation_153 (Activation)     (None, 12, 12, 192)  0           batch_norma
lization_153[0][0]
____________________________________________________________________________________________________
____________________
activation_154 (Activation)     (None, 12, 12, 192)  0           batch_norma
lization_154[0][0]
____________________________________________________________________________________________________
____________________
mixed6 (Concatenate)            (None, 12, 12, 768)  0           activation_
145[0][0]
                                                                 activation_
148[0][0]
                                                                 activation_
153[0][0]
                                                                 activation_
154[0][0]
____________________________________________________________________________________________________
____________________
conv2d_159 (Conv2D)             (None, 12, 12, 192)  147456      mixed6[0]
[0]
____________________________________________________________________________________________________
____________________
batch_normalization_159 (BatchN (None, 12, 12, 192)  576         conv2d_159
[0][0]
____________________________________________________________________________________________________
____________________
activation_159 (Activation)     (None, 12, 12, 192)  0           batch_norma
lization_159[0][0]
____________________________________________________________________________________________________
____________________
conv2d_160 (Conv2D)             (None, 12, 12, 192)  258048      activation_
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159[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_160 (BatchN (None, 12, 12, 192)  576         conv2d_160
[0][0]
__________________________________________________________________________________________________
____________________
activation_160 (Activation)     (None, 12, 12, 192)  0           batch_norma
lization_160[0][0]
__________________________________________________________________________________________________
____________________
conv2d_156 (Conv2D)             (None, 12, 12, 192)  147456      mixed6[0]
[0]
__________________________________________________________________________________________________
____________________
conv2d_161 (Conv2D)             (None, 12, 12, 192)  258048      activation_
160[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_156 (BatchN (None, 12, 12, 192)  576         conv2d_156
[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_161 (BatchN (None, 12, 12, 192)  576         conv2d_161
[0][0]
__________________________________________________________________________________________________
____________________
activation_156 (Activation)     (None, 12, 12, 192)  0           batch_norma
lization_156[0][0]
__________________________________________________________________________________________________
____________________
activation_161 (Activation)     (None, 12, 12, 192)  0           batch_norma
lization_161[0][0]
__________________________________________________________________________________________________
____________________
conv2d_157 (Conv2D)             (None, 12, 12, 192)  258048      activation_
156[0][0]
__________________________________________________________________________________________________
____________________
conv2d_162 (Conv2D)             (None, 12, 12, 192)  258048      activation_
161[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_157 (BatchN (None, 12, 12, 192)  576         conv2d_157
[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_162 (BatchN (None, 12, 12, 192)  576         conv2d_162
[0][0]
__________________________________________________________________________________________________
____________________
activation_157 (Activation)     (None, 12, 12, 192)  0           batch_norma
lization_157[0][0]
__________________________________________________________________________________________________
____________________
activation_162 (Activation)     (None, 12, 12, 192)  0           batch_norma
lization_162[0][0]
__________________________________________________________________________________________________
____________________
average_pooling2d_16 (AveragePo (None, 12, 12, 768)  0           mixed6[0]
[0]
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____________________________________________________________________________________________________
____________________
conv2d_155 (Conv2D)              (None, 12, 12, 192)  147456      mixed6[0]
[0]
____________________________________________________________________________________________________
____________________
conv2d_158 (Conv2D)              (None, 12, 12, 192)  258048      activation_
157[0][0]
____________________________________________________________________________________________________
____________________
conv2d_163 (Conv2D)              (None, 12, 12, 192)  258048      activation_
162[0][0]
____________________________________________________________________________________________________
____________________
conv2d_164 (Conv2D)              (None, 12, 12, 192)  147456      average_poo
ling2d_16[0][0]
____________________________________________________________________________________________________
____________________
batch_normalization_155 (BatchN (None, 12, 12, 192)  576         conv2d_155
[0][0]
____________________________________________________________________________________________________
____________________
batch_normalization_158 (BatchN (None, 12, 12, 192)  576         conv2d_158
[0][0]
____________________________________________________________________________________________________
____________________
batch_normalization_163 (BatchN (None, 12, 12, 192)  576         conv2d_163
[0][0]
____________________________________________________________________________________________________
____________________
batch_normalization_164 (BatchN (None, 12, 12, 192)  576         conv2d_164
[0][0]
____________________________________________________________________________________________________
____________________
activation_155 (Activation)      (None, 12, 12, 192)  0           batch_norma
lization_155[0][0]
____________________________________________________________________________________________________
____________________
activation_158 (Activation)      (None, 12, 12, 192)  0           batch_norma
lization_158[0][0]
____________________________________________________________________________________________________
____________________
activation_163 (Activation)      (None, 12, 12, 192)  0           batch_norma
lization_163[0][0]
____________________________________________________________________________________________________
____________________
activation_164 (Activation)      (None, 12, 12, 192)  0           batch_norma
lization_164[0][0]
____________________________________________________________________________________________________
____________________
mixed7 (Concatenate)             (None, 12, 12, 768)  0           activation_
155[0][0]
                                                                  activation_
158[0][0]
                                                                  activation_
163[0][0]
                                                                  activation_
164[0][0]
____________________________________________________________________________________________________
____________________
conv2d_167 (Conv2D)              (None, 12, 12, 192)  147456      mixed7[0]
```

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[0]
__________________________________________________________________________________________________
____________________
batch_normalization_167 (BatchN (None, 12, 12, 192)  576         conv2d_167
[0][0]
__________________________________________________________________________________________________
____________________
activation_167 (Activation)     (None, 12, 12, 192)  0           batch_norma
lization_167[0][0]
__________________________________________________________________________________________________
____________________
conv2d_168 (Conv2D)             (None, 12, 12, 192)  258048      activation_
167[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_168 (BatchN (None, 12, 12, 192)  576         conv2d_168
[0][0]
__________________________________________________________________________________________________
____________________
activation_168 (Activation)     (None, 12, 12, 192)  0           batch_norma
lization_168[0][0]
__________________________________________________________________________________________________
____________________
conv2d_165 (Conv2D)             (None, 12, 12, 192)  147456      mixed7[0]
[0]
__________________________________________________________________________________________________
____________________
conv2d_169 (Conv2D)             (None, 12, 12, 192)  258048      activation_
168[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_165 (BatchN (None, 12, 12, 192)  576         conv2d_165
[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_169 (BatchN (None, 12, 12, 192)  576         conv2d_169
[0][0]
__________________________________________________________________________________________________
____________________
activation_165 (Activation)     (None, 12, 12, 192)  0           batch_norma
lization_165[0][0]
__________________________________________________________________________________________________
____________________
activation_169 (Activation)     (None, 12, 12, 192)  0           batch_norma
lization_169[0][0]
__________________________________________________________________________________________________
____________________
conv2d_166 (Conv2D)             (None, 5, 5, 320)    552960      activation_
165[0][0]
__________________________________________________________________________________________________
____________________
conv2d_170 (Conv2D)             (None, 5, 5, 192)    331776      activation_
169[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_166 (BatchN (None, 5, 5, 320)    960         conv2d_166
[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_170 (BatchN (None, 5, 5, 192)    576         conv2d_170
[0][0]
```

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____________________________________________________________________________________________________
____________________
activation_166 (Activation)     (None, 5, 5, 320)    0           batch_norma
lization_166[0][0]
____________________________________________________________________________________________________
____________________
activation_170 (Activation)     (None, 5, 5, 192)    0           batch_norma
lization_170[0][0]
____________________________________________________________________________________________________
____________________
max_pooling2d_8 (MaxPooling2D)  (None, 5, 5, 768)    0           mixed7[0]
[0]
____________________________________________________________________________________________________
____________________
mixed8 (Concatenate)            (None, 5, 5, 1280)   0           activation_
166[0][0]
                                                                 activation_
170[0][0]
                                                                 max_pooling
2d_8[0][0]
____________________________________________________________________________________________________
____________________
conv2d_175 (Conv2D)             (None, 5, 5, 448)    573440      mixed8[0]
[0]
____________________________________________________________________________________________________
____________________
batch_normalization_175 (BatchN (None, 5, 5, 448)    1344        conv2d_175
[0][0]
____________________________________________________________________________________________________
____________________
activation_175 (Activation)     (None, 5, 5, 448)    0           batch_norma
lization_175[0][0]
____________________________________________________________________________________________________
____________________
conv2d_172 (Conv2D)             (None, 5, 5, 384)    491520      mixed8[0]
[0]
____________________________________________________________________________________________________
____________________
conv2d_176 (Conv2D)             (None, 5, 5, 384)    1548288     activation_
175[0][0]
____________________________________________________________________________________________________
____________________
batch_normalization_172 (BatchN (None, 5, 5, 384)    1152        conv2d_172
[0][0]
____________________________________________________________________________________________________
____________________
batch_normalization_176 (BatchN (None, 5, 5, 384)    1152        conv2d_176
[0][0]
____________________________________________________________________________________________________
____________________
activation_172 (Activation)     (None, 5, 5, 384)    0           batch_norma
lization_172[0][0]
____________________________________________________________________________________________________
____________________
activation_176 (Activation)     (None, 5, 5, 384)    0           batch_norma
lization_176[0][0]
____________________________________________________________________________________________________
____________________
conv2d_173 (Conv2D)             (None, 5, 5, 384)    442368      activation_
172[0][0]
____________________________________________________________________________________________________
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____________________
conv2d_174 (Conv2D)             (None, 5, 5, 384)    442368      activation_
172[0][0]
__________________________________________________________________________
____________________
conv2d_177 (Conv2D)             (None, 5, 5, 384)    442368      activation_
176[0][0]
__________________________________________________________________________
____________________
conv2d_178 (Conv2D)             (None, 5, 5, 384)    442368      activation_
176[0][0]
__________________________________________________________________________
____________________
average_pooling2d_17 (AveragePo (None, 5, 5, 1280)   0           mixed8[0]
[0]
__________________________________________________________________________
____________________
conv2d_171 (Conv2D)             (None, 5, 5, 320)    409600      mixed8[0]
[0]
__________________________________________________________________________
____________________
batch_normalization_173 (BatchN (None, 5, 5, 384)    1152        conv2d_173
[0][0]
__________________________________________________________________________
____________________
batch_normalization_174 (BatchN (None, 5, 5, 384)    1152        conv2d_174
[0][0]
__________________________________________________________________________
____________________
batch_normalization_177 (BatchN (None, 5, 5, 384)    1152        conv2d_177
[0][0]
__________________________________________________________________________
____________________
batch_normalization_178 (BatchN (None, 5, 5, 384)    1152        conv2d_178
[0][0]
__________________________________________________________________________
____________________
conv2d_179 (Conv2D)             (None, 5, 5, 192)    245760      average_poo
ling2d_17[0][0]
__________________________________________________________________________
____________________
batch_normalization_171 (BatchN (None, 5, 5, 320)    960         conv2d_171
[0][0]
__________________________________________________________________________
____________________
activation_173 (Activation)     (None, 5, 5, 384)    0           batch_norma
lization_173[0][0]
__________________________________________________________________________
____________________
activation_174 (Activation)     (None, 5, 5, 384)    0           batch_norma
lization_174[0][0]
__________________________________________________________________________
____________________
activation_177 (Activation)     (None, 5, 5, 384)    0           batch_norma
lization_177[0][0]
__________________________________________________________________________
____________________
activation_178 (Activation)     (None, 5, 5, 384)    0           batch_norma
lization_178[0][0]
__________________________________________________________________________
____________________
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batch_normalization_179 (BatchN (None, 5, 5, 192)    576         conv2d_179
[0][0]
__________________________________________________________________________
_____________________
activation_171 (Activation)     (None, 5, 5, 320)    0           batch_norma
lization_171[0][0]
__________________________________________________________________________
_____________________
mixed9_0 (Concatenate)          (None, 5, 5, 768)    0           activation_
173[0][0]
                                                                 activation_
174[0][0]
__________________________________________________________________________
_____________________
concatenate_3 (Concatenate)     (None, 5, 5, 768)    0           activation_
177[0][0]
                                                                 activation_
178[0][0]
__________________________________________________________________________
_____________________
activation_179 (Activation)     (None, 5, 5, 192)    0           batch_norma
lization_179[0][0]
__________________________________________________________________________
_____________________
mixed9 (Concatenate)            (None, 5, 5, 2048)   0           activation_
171[0][0]
                                                                 mixed9_0[0]
[0]
                                                                 concatenate
_3[0][0]
                                                                 activation_
179[0][0]
__________________________________________________________________________
_____________________
conv2d_184 (Conv2D)             (None, 5, 5, 448)    917504      mixed9[0]
[0]
__________________________________________________________________________
_____________________
batch_normalization_184 (BatchN (None, 5, 5, 448)    1344        conv2d_184
[0][0]
__________________________________________________________________________
_____________________
activation_184 (Activation)     (None, 5, 5, 448)    0           batch_norma
lization_184[0][0]
__________________________________________________________________________
_____________________
conv2d_181 (Conv2D)             (None, 5, 5, 384)    786432      mixed9[0]
[0]
__________________________________________________________________________
_____________________
conv2d_185 (Conv2D)             (None, 5, 5, 384)    1548288     activation_
184[0][0]
__________________________________________________________________________
_____________________
batch_normalization_181 (BatchN (None, 5, 5, 384)    1152        conv2d_181
[0][0]
__________________________________________________________________________
_____________________
batch_normalization_185 (BatchN (None, 5, 5, 384)    1152        conv2d_185
[0][0]
__________________________________________________________________________
```

```
____________________
activation_181 (Activation)     (None, 5, 5, 384)    0           batch_norma
lization_181[0][0]
__________________________________________________________________________
____________________
activation_185 (Activation)     (None, 5, 5, 384)    0           batch_norma
lization_185[0][0]
__________________________________________________________________________
____________________
conv2d_182 (Conv2D)             (None, 5, 5, 384)    442368      activation_
181[0][0]
__________________________________________________________________________
____________________
conv2d_183 (Conv2D)             (None, 5, 5, 384)    442368      activation_
181[0][0]
__________________________________________________________________________
____________________
conv2d_186 (Conv2D)             (None, 5, 5, 384)    442368      activation_
185[0][0]
__________________________________________________________________________
____________________
conv2d_187 (Conv2D)             (None, 5, 5, 384)    442368      activation_
185[0][0]
__________________________________________________________________________
____________________
average_pooling2d_18 (AveragePo (None, 5, 5, 2048)   0           mixed9[0]
[0]
__________________________________________________________________________
____________________
conv2d_180 (Conv2D)             (None, 5, 5, 320)    655360      mixed9[0]
[0]
__________________________________________________________________________
____________________
batch_normalization_182 (BatchN (None, 5, 5, 384)    1152        conv2d_182
[0][0]
__________________________________________________________________________
____________________
batch_normalization_183 (BatchN (None, 5, 5, 384)    1152        conv2d_183
[0][0]
__________________________________________________________________________
____________________
batch_normalization_186 (BatchN (None, 5, 5, 384)    1152        conv2d_186
[0][0]
__________________________________________________________________________
____________________
batch_normalization_187 (BatchN (None, 5, 5, 384)    1152        conv2d_187
[0][0]
__________________________________________________________________________
____________________
conv2d_188 (Conv2D)             (None, 5, 5, 192)    393216      average_poo
ling2d_18[0][0]
__________________________________________________________________________
____________________
batch_normalization_180 (BatchN (None, 5, 5, 320)    960         conv2d_180
[0][0]
__________________________________________________________________________
____________________
activation_182 (Activation)     (None, 5, 5, 384)    0           batch_norma
lization_182[0][0]
__________________________________________________________________________
____________________
```

```
activation_183 (Activation)     (None, 5, 5, 384)    0           batch_norma
lization_183[0][0]
__________________________________________________________________________
_____
activation_186 (Activation)     (None, 5, 5, 384)    0           batch_norma
lization_186[0][0]
__________________________________________________________________________
_____
activation_187 (Activation)     (None, 5, 5, 384)    0           batch_norma
lization_187[0][0]
__________________________________________________________________________
_____
batch_normalization_188 (BatchN (None, 5, 5, 192)    576         conv2d_188
[0][0]
__________________________________________________________________________
_____
activation_180 (Activation)     (None, 5, 5, 320)    0           batch_norma
lization_180[0][0]
__________________________________________________________________________
_____
mixed9_1 (Concatenate)          (None, 5, 5, 768)    0           activation_
182[0][0]
                                                                 activation_
183[0][0]
__________________________________________________________________________
_____
concatenate_4 (Concatenate)     (None, 5, 5, 768)    0           activation_
186[0][0]
                                                                 activation_
187[0][0]
__________________________________________________________________________
_____
activation_188 (Activation)     (None, 5, 5, 192)    0           batch_norma
lization_188[0][0]
__________________________________________________________________________
_____
mixed10 (Concatenate)           (None, 5, 5, 2048)   0           activation_
180[0][0]
                                                                 mixed9_1[0]
[0]
                                                                 concatenate
_4[0][0]
                                                                 activation_
188[0][0]
__________________________________________________________________________
_____
global_average_pooling2d_2 (Glo (None, 2048)         0           mixed10[0]
[0]
__________________________________________________________________________
_____
dense_3 (Dense)                 (None, 256)          524544      global_aver
age_pooling2d_2[0][0]
__________________________________________________________________________
_____
dense_4 (Dense)                 (None, 1)            257         dense_3[0]
[0]
==========================================================================
======================
Total params: 22,327,585
Trainable params: 524,801
Non-trainable params: 21,802,784
```

```
GPU Memory:1.164 GBRAM:2.328
```

In [24]:

```
history = trainModel(model,
                     1,
                     "Re training on our data with frozen inception layers", "5 lower.h5")
```

```
Epoch 1/1
800/800 [==============================] - 242s 302ms/step - loss: 7.9712 -
acc: 0.5000 - val_loss: 7.9712 - val_acc: 0.5000

Epoch 00001: val_loss improved from inf to 7.97119, saving model to 5 lower.
h5
Timing:: took 4 minutes Re training on our data with frozen inception layers
---------------------------------
```

In [26]:

```
# building the rest of the model

# here we choose to retrain the top 2 inception blocks
for layer in model.layers[:249]:
    layer.trainable = False
for layer in model.layers[249:]:
    layer.trainable = True

# we now recompile the model for our layer modifications to take effect
from keras.optimizers import SGD
model.compile(optimizer='adagrad',
              loss='binary_crossentropy',
              metrics=['accuracy'])

history_2 = trainModel(model,
                       1,
                       "Re training the full inception model",
                       '5 upper.h5')
```

```
Epoch 1/1
800/800 [==============================] - 316s 395ms/step - loss: 7.9712 -
acc: 0.5000 - val_loss: 7.9712 - val_acc: 0.5000

Epoch 00001: val_loss improved from inf to 7.97119, saving model to 5 upper.
h5
Timing:: took 5 minutes Re training the full inception model
---------------------------------
```

In [27]:

```
def plot(network_history):
    plt.figure()
    plt.xlabel('Epochs')
    plt.ylabel('Loss')
    plt.plot(network_history.history['loss'])
    plt.plot(network_history.history['val_loss'])
    plt.legend(['Training', 'Validation'])

    plt.figure()
    plt.xlabel('Epochs')
    plt.ylabel('Accuracy')
    plt.plot(network_history.history['acc'])
    plt.plot(network_history.history['val_acc'])
    plt.legend(['Training', 'Validation'], loc='lower right')
```

2.3 Evaluating the CNNs performance

Evaluating the lower frozen CNN performance

In [28]:

```
# Get test data
x_test, y_test = data.getTestData()
print('Test data shape: ', x_test.shape)
print('Test labels shape: ', y_test.shape)
```

```
Test data shape:  (63, 224, 224, 3)
Test labels shape:  (63, 1)
```

In [29]:

```
X_test = x_test/255
```

In [30]:

```
# load and evaluate best model
from keras.models import load_model
best_model = load_model('5 lower.h5')
best_model.summary()
```

```
_____________________________
average_pooling2d_14 (AveragePo (None, 12, 12, 768)  0           mixed4[0]
[0]
____________________________________________________________________________
_____________________________
conv2d_135 (Conv2D)             (None, 12, 12, 192)  147456      mixed4[0]
[0]
____________________________________________________________________________
_____________________________
conv2d_138 (Conv2D)             (None, 12, 12, 192)  215040      activatio
n_137[0][0]
____________________________________________________________________________
_____________________________
conv2d_143 (Conv2D)             (None, 12, 12, 192)  215040      activatio
n_142[0][0]
____________________________________________________________________________
_____________________________
conv2d_144 (Conv2D)             (None, 12, 12, 192)  147456      average_p
ooling2d_14[0][0]
____________________________________________________________________________
```

In [31]:

```
best_model.predict(x_test)
```

Out[31]:

```
array([[ 1.],
       [ 1.],
       [ 1.],
       [ 1.],
       [ 1.],
       [ 1.],
       [ 1.],
       [ 1.],
       [ 1.],
       [ 1.],
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```

```
       [ 1.],
       [ 1.],
       [ 1.],
       [ 1.],
       [ 1.],
       [ 1.],
       [ 1.],
       [ 1.]], dtype=float32)
```

In [32]:

```
# Evaluate all
from sklearn.metrics import confusion_matrix
expected = y_test
prediction = best_model.predict(x_test)
x, y, fn, tp = confusion_matrix(y_test, prediction).ravel()
print(fn, tp)
```

```
0 21
```

The model only predicts malignant cases. This means the models performance is poor. In this case transfer learning has not been of much help because of the difference between the natural images that were used to train the Inception model and very different from breast ultrasounds but also, our dataset is not sufficiently large for newly learned features to significantly affect the hybrid models output hence the poor performance.

Evaluating the uppper retrained CNN performance

In [34]:

```
# load and evaluate best model
from keras.models import load_model
best_model = load_model('5 upper.h5')
best_model.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
Connected to
=================================================================
input_2 (InputLayer)         (None, 224, 224, 3)       0

_________________________________________________________________
conv2d_95 (Conv2D)           (None, 111, 111, 32)      864
input_2[0][0]
_________________________________________________________________
batch_normalization_95 (BatchNo (None, 111, 111, 32)      96
conv2d_95[0][0]
_________________________________________________________________
activation_95 (Activation)   (None, 111, 111, 32)      0
batch_nor
```

In [35]:

```
best_model.predict(x_test)
```

Out[35]:

```
array([[ 1.],
       [ 1.],
       [ 1.],
       [ 1.],
       [ 1.],
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       [ 1.],
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       [ 1.],
```

```
       [ 1.],
       [ 1.],
       [ 1.],
       [ 1.],
       [ 1.],
       [ 1.],
       [ 1.],
       [ 1.]], dtype=float32)
```

In [36]:

```
expected = y_test
prediction = best_model.predict(x_test)
x, y, fn, tp = confusion_matrix(y_test, prediction).ravel()
print(fn, tp)
```

```
0 21
```

The model only predicts malignant cases. This means the models performance is poor. In this case transfer learning has not been of much help because of the difference between the natural images that were used to train the Inception model and very different from breast ultrasounds but also, our dataset is not sufficiently large for newly learned features to significantly affect the hybrid models output hence the poor performance.

References for images and some content:

[1] https://adeshpande3.github.io/adeshpande3.github.io/ ()
[2] "Neural Networks and Deep Learning" (http://neuralnetworksanddeeplearning.com/) by Michael Nielsen.
[3] Deep learning with TensorFlow and Keras by Valerio Maggio

In [ ]: