AI4M_C3_M3_lecture_notebook_gradcam

October 25, 2020

1 Introduction To GradCAM (Part 1) - Lecture Notebook

In this lecture notebook we'll be looking at an introduction to Grad-CAM, a powerful technique for interpreting Convolutional Neural Networks. Grad-CAM stands for Gradient-weighted Class Activation Mapping.

CNN's are very flexible models and their great predictive power comes at the cost of losing interpretability (something that is true for all Artificial Neural Networks). Grad-CAM attempts to solve this by giving us a graphical visualisation of parts of an image that are the most relevant for the CNN when predicting a particular class.

Aside from working on some Grad-CAM concepts we'll also look at how we can use Keras to access some concrete information of our model. Let's dive into it!

```
In [2]: import keras
        from keras import backend as K
        from util import *
```

```
Using TensorFlow backend.
```

The `load_C3M3_model()` function has been taken care of and its internals are out of the scope of this notebook. But if it intrigues you, you can take a look at it in `util.py`

```
In [3]: # Load the model we are going to be using
        model = load_C3M3_model()
```

```
Got loss weights
Loaded DenseNet
Added layers
Compiled Model
Loaded Weights
```

As you may already know, we can check the architecture of our model using the `summary()` method.

After running the code block below we'll see that this model has a lot of layers. One advantage of Grad-CAM over previous attempts of interpreting CNN's (such as CAM) is that it is architecture agnostic. This means it can be used for CNN's with complex architectures such as this one:

```
In [4]: # Print all of the model's layers
        model.summary()
```

```
__________________________________________________________________________________________________
Layer (type)                    Output Shape         Param #     Connected to
==================================================================================================
input_1 (InputLayer)            (None, None, None, 3 0
__________________________________________________________________________________________________
zero_padding2d_1 (ZeroPadding2D (None, None, None, 3 0           input_1[0][0]
__________________________________________________________________________________________________
conv1/conv (Conv2D)             (None, None, None, 6 9408        zero_padding2d_1[0][0]
__________________________________________________________________________________________________
conv1/bn (BatchNormalization)   (None, None, None, 6 256         conv1/conv[0][0]
__________________________________________________________________________________________________
conv1/relu (Activation)         (None, None, None, 6 0           conv1/bn[0][0]
__________________________________________________________________________________________________
zero_padding2d_2 (ZeroPadding2D (None, None, None, 6 0           conv1/relu[0][0]
__________________________________________________________________________________________________
pool1 (MaxPooling2D)            (None, None, None, 6 0           zero_padding2d_2[0][0]
__________________________________________________________________________________________________
conv2_block1_0_bn (BatchNormali (None, None, None, 6 256         pool1[0][0]
__________________________________________________________________________________________________
conv2_block1_0_relu (Activation (None, None, None, 6 0           conv2_block1_0_bn[0][0]
__________________________________________________________________________________________________
conv2_block1_1_conv (Conv2D)    (None, None, None, 1 8192        conv2_block1_0_relu[0][0]
__________________________________________________________________________________________________
conv2_block1_1_bn (BatchNormali (None, None, None, 1 512         conv2_block1_1_conv[0][0]
__________________________________________________________________________________________________
conv2_block1_1_relu (Activation (None, None, None, 1 0           conv2_block1_1_bn[0][0]
__________________________________________________________________________________________________
conv2_block1_2_conv (Conv2D)    (None, None, None, 3 36864       conv2_block1_1_relu[0][0]
__________________________________________________________________________________________________
conv2_block1_concat (Concatenat (None, None, None, 9 0           pool1[0][0]
                                                                 conv2_block1_2_conv[0][0]
__________________________________________________________________________________________________
conv2_block2_0_bn (BatchNormali (None, None, None, 9 384         conv2_block1_concat[0][0]
__________________________________________________________________________________________________
conv2_block2_0_relu (Activation (None, None, None, 9 0           conv2_block2_0_bn[0][0]
__________________________________________________________________________________________________
conv2_block2_1_conv (Conv2D)    (None, None, None, 1 12288       conv2_block2_0_relu[0][0]
__________________________________________________________________________________________________
conv2_block2_1_bn (BatchNormali (None, None, None, 1 512         conv2_block2_1_conv[0][0]
__________________________________________________________________________________________________
conv2_block2_1_relu (Activation (None, None, None, 1 0           conv2_block2_1_bn[0][0]
__________________________________________________________________________________________________
conv2_block2_2_conv (Conv2D)    (None, None, None, 3 36864       conv2_block2_1_relu[0][0]
__________________________________________________________________________________________________
conv2_block2_concat (Concatenat (None, None, None, 1 0           conv2_block1_concat[0][0]
```

```
                                                                 conv2_block2_2_conv[0][0]
__________________________________________________________________________________________________
conv2_block3_0_bn (BatchNormali (None, None, None, 1 512         conv2_block2_concat[0][0]
__________________________________________________________________________________________________
conv2_block3_0_relu (Activation (None, None, None, 1 0           conv2_block3_0_bn[0][0]
__________________________________________________________________________________________________
conv2_block3_1_conv (Conv2D)    (None, None, None, 1 16384       conv2_block3_0_relu[0][0]
__________________________________________________________________________________________________
conv2_block3_1_bn (BatchNormali (None, None, None, 1 512         conv2_block3_1_conv[0][0]
__________________________________________________________________________________________________
conv2_block3_1_relu (Activation (None, None, None, 1 0           conv2_block3_1_bn[0][0]
__________________________________________________________________________________________________
conv2_block3_2_conv (Conv2D)    (None, None, None, 3 36864       conv2_block3_1_relu[0][0]
__________________________________________________________________________________________________
conv2_block3_concat (Concatenat (None, None, None, 1 0           conv2_block2_concat[0][0]
                                                                 conv2_block3_2_conv[0][0]
__________________________________________________________________________________________________
conv2_block4_0_bn (BatchNormali (None, None, None, 1 640         conv2_block3_concat[0][0]
__________________________________________________________________________________________________
conv2_block4_0_relu (Activation (None, None, None, 1 0           conv2_block4_0_bn[0][0]
__________________________________________________________________________________________________
conv2_block4_1_conv (Conv2D)    (None, None, None, 1 20480       conv2_block4_0_relu[0][0]
__________________________________________________________________________________________________
conv2_block4_1_bn (BatchNormali (None, None, None, 1 512         conv2_block4_1_conv[0][0]
__________________________________________________________________________________________________
conv2_block4_1_relu (Activation (None, None, None, 1 0           conv2_block4_1_bn[0][0]
__________________________________________________________________________________________________
conv2_block4_2_conv (Conv2D)    (None, None, None, 3 36864       conv2_block4_1_relu[0][0]
__________________________________________________________________________________________________
conv2_block4_concat (Concatenat (None, None, None, 1 0           conv2_block3_concat[0][0]
                                                                 conv2_block4_2_conv[0][0]
__________________________________________________________________________________________________
conv2_block5_0_bn (BatchNormali (None, None, None, 1 768         conv2_block4_concat[0][0]
__________________________________________________________________________________________________
conv2_block5_0_relu (Activation (None, None, None, 1 0           conv2_block5_0_bn[0][0]
__________________________________________________________________________________________________
conv2_block5_1_conv (Conv2D)    (None, None, None, 1 24576       conv2_block5_0_relu[0][0]
__________________________________________________________________________________________________
conv2_block5_1_bn (BatchNormali (None, None, None, 1 512         conv2_block5_1_conv[0][0]
__________________________________________________________________________________________________
conv2_block5_1_relu (Activation (None, None, None, 1 0           conv2_block5_1_bn[0][0]
__________________________________________________________________________________________________
conv2_block5_2_conv (Conv2D)    (None, None, None, 3 36864       conv2_block5_1_relu[0][0]
__________________________________________________________________________________________________
conv2_block5_concat (Concatenat (None, None, None, 2 0           conv2_block4_concat[0][0]
                                                                 conv2_block5_2_conv[0][0]
__________________________________________________________________________________________________
conv2_block6_0_bn (BatchNormali (None, None, None, 2 896         conv2_block5_concat[0][0]
```

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__________________________________________________________________________________________________
conv2_block6_0_relu (Activation (None, None, None, 2 0           conv2_block6_0_bn[0][0]
__________________________________________________________________________________________________
conv2_block6_1_conv (Conv2D)    (None, None, None, 1 28672       conv2_block6_0_relu[0][0]
__________________________________________________________________________________________________
conv2_block6_1_bn (BatchNormali (None, None, None, 1 512         conv2_block6_1_conv[0][0]
__________________________________________________________________________________________________
conv2_block6_1_relu (Activation (None, None, None, 1 0           conv2_block6_1_bn[0][0]
__________________________________________________________________________________________________
conv2_block6_2_conv (Conv2D)    (None, None, None, 3 36864       conv2_block6_1_relu[0][0]
__________________________________________________________________________________________________
conv2_block6_concat (Concatenat (None, None, None, 2 0           conv2_block5_concat[0][0]
                                                                 conv2_block6_2_conv[0][0]
__________________________________________________________________________________________________
pool2_bn (BatchNormalization)   (None, None, None, 2 1024        conv2_block6_concat[0][0]
__________________________________________________________________________________________________
pool2_relu (Activation)         (None, None, None, 2 0           pool2_bn[0][0]
__________________________________________________________________________________________________
pool2_conv (Conv2D)             (None, None, None, 1 32768       pool2_relu[0][0]
__________________________________________________________________________________________________
pool2_pool (AveragePooling2D)   (None, None, None, 1 0           pool2_conv[0][0]
__________________________________________________________________________________________________
conv3_block1_0_bn (BatchNormali (None, None, None, 1 512         pool2_pool[0][0]
__________________________________________________________________________________________________
conv3_block1_0_relu (Activation (None, None, None, 1 0           conv3_block1_0_bn[0][0]
__________________________________________________________________________________________________
conv3_block1_1_conv (Conv2D)    (None, None, None, 1 16384       conv3_block1_0_relu[0][0]
__________________________________________________________________________________________________
conv3_block1_1_bn (BatchNormali (None, None, None, 1 512         conv3_block1_1_conv[0][0]
__________________________________________________________________________________________________
conv3_block1_1_relu (Activation (None, None, None, 1 0           conv3_block1_1_bn[0][0]
__________________________________________________________________________________________________
conv3_block1_2_conv (Conv2D)    (None, None, None, 3 36864       conv3_block1_1_relu[0][0]
__________________________________________________________________________________________________
conv3_block1_concat (Concatenat (None, None, None, 1 0           pool2_pool[0][0]
                                                                 conv3_block1_2_conv[0][0]
__________________________________________________________________________________________________
conv3_block2_0_bn (BatchNormali (None, None, None, 1 640         conv3_block1_concat[0][0]
__________________________________________________________________________________________________
conv3_block2_0_relu (Activation (None, None, None, 1 0           conv3_block2_0_bn[0][0]
__________________________________________________________________________________________________
conv3_block2_1_conv (Conv2D)    (None, None, None, 1 20480       conv3_block2_0_relu[0][0]
__________________________________________________________________________________________________
conv3_block2_1_bn (BatchNormali (None, None, None, 1 512         conv3_block2_1_conv[0][0]
__________________________________________________________________________________________________
conv3_block2_1_relu (Activation (None, None, None, 1 0           conv3_block2_1_bn[0][0]
__________________________________________________________________________________________________
conv3_block2_2_conv (Conv2D)    (None, None, None, 3 36864       conv3_block2_1_relu[0][0]
```

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________________________________________________________________________________________________
conv3_block2_concat (Concatenat (None, None, None, 1 0           conv3_block1_concat[0][0]
                                                                 conv3_block2_2_conv[0][0]
________________________________________________________________________________________________
conv3_block3_0_bn (BatchNormali (None, None, None, 1 768         conv3_block2_concat[0][0]
________________________________________________________________________________________________
conv3_block3_0_relu (Activation (None, None, None, 1 0           conv3_block3_0_bn[0][0]
________________________________________________________________________________________________
conv3_block3_1_conv (Conv2D)    (None, None, None, 1 24576       conv3_block3_0_relu[0][0]
________________________________________________________________________________________________
conv3_block3_1_bn (BatchNormali (None, None, None, 1 512         conv3_block3_1_conv[0][0]
________________________________________________________________________________________________
conv3_block3_1_relu (Activation (None, None, None, 1 0           conv3_block3_1_bn[0][0]
________________________________________________________________________________________________
conv3_block3_2_conv (Conv2D)    (None, None, None, 3 36864       conv3_block3_1_relu[0][0]
________________________________________________________________________________________________
conv3_block3_concat (Concatenat (None, None, None, 2 0           conv3_block2_concat[0][0]
                                                                 conv3_block3_2_conv[0][0]
________________________________________________________________________________________________
conv3_block4_0_bn (BatchNormali (None, None, None, 2 896         conv3_block3_concat[0][0]
________________________________________________________________________________________________
conv3_block4_0_relu (Activation (None, None, None, 2 0           conv3_block4_0_bn[0][0]
________________________________________________________________________________________________
conv3_block4_1_conv (Conv2D)    (None, None, None, 1 28672       conv3_block4_0_relu[0][0]
________________________________________________________________________________________________
conv3_block4_1_bn (BatchNormali (None, None, None, 1 512         conv3_block4_1_conv[0][0]
________________________________________________________________________________________________
conv3_block4_1_relu (Activation (None, None, None, 1 0           conv3_block4_1_bn[0][0]
________________________________________________________________________________________________
conv3_block4_2_conv (Conv2D)    (None, None, None, 3 36864       conv3_block4_1_relu[0][0]
________________________________________________________________________________________________
conv3_block4_concat (Concatenat (None, None, None, 2 0           conv3_block3_concat[0][0]
                                                                 conv3_block4_2_conv[0][0]
________________________________________________________________________________________________
conv3_block5_0_bn (BatchNormali (None, None, None, 2 1024        conv3_block4_concat[0][0]
________________________________________________________________________________________________
conv3_block5_0_relu (Activation (None, None, None, 2 0           conv3_block5_0_bn[0][0]
________________________________________________________________________________________________
conv3_block5_1_conv (Conv2D)    (None, None, None, 1 32768       conv3_block5_0_relu[0][0]
________________________________________________________________________________________________
conv3_block5_1_bn (BatchNormali (None, None, None, 1 512         conv3_block5_1_conv[0][0]
________________________________________________________________________________________________
conv3_block5_1_relu (Activation (None, None, None, 1 0           conv3_block5_1_bn[0][0]
________________________________________________________________________________________________
conv3_block5_2_conv (Conv2D)    (None, None, None, 3 36864       conv3_block5_1_relu[0][0]
________________________________________________________________________________________________
conv3_block5_concat (Concatenat (None, None, None, 2 0           conv3_block4_concat[0][0]
                                                                 conv3_block5_2_conv[0][0]
```

```
__________________________________________________________________________________________________
conv3_block6_0_bn (BatchNormali (None, None, None, 2 1152        conv3_block5_concat[0][0]
__________________________________________________________________________________________________
conv3_block6_0_relu (Activation (None, None, None, 2 0           conv3_block6_0_bn[0][0]
__________________________________________________________________________________________________
conv3_block6_1_conv (Conv2D)    (None, None, None, 1 36864       conv3_block6_0_relu[0][0]
__________________________________________________________________________________________________
conv3_block6_1_bn (BatchNormali (None, None, None, 1 512         conv3_block6_1_conv[0][0]
__________________________________________________________________________________________________
conv3_block6_1_relu (Activation (None, None, None, 1 0           conv3_block6_1_bn[0][0]
__________________________________________________________________________________________________
conv3_block6_2_conv (Conv2D)    (None, None, None, 3 36864       conv3_block6_1_relu[0][0]
__________________________________________________________________________________________________
conv3_block6_concat (Concatenat (None, None, None, 3 0           conv3_block5_concat[0][0]
                                                                 conv3_block6_2_conv[0][0]
__________________________________________________________________________________________________
conv3_block7_0_bn (BatchNormali (None, None, None, 3 1280        conv3_block6_concat[0][0]
__________________________________________________________________________________________________
conv3_block7_0_relu (Activation (None, None, None, 3 0           conv3_block7_0_bn[0][0]
__________________________________________________________________________________________________
conv3_block7_1_conv (Conv2D)    (None, None, None, 1 40960       conv3_block7_0_relu[0][0]
__________________________________________________________________________________________________
conv3_block7_1_bn (BatchNormali (None, None, None, 1 512         conv3_block7_1_conv[0][0]
__________________________________________________________________________________________________
conv3_block7_1_relu (Activation (None, None, None, 1 0           conv3_block7_1_bn[0][0]
__________________________________________________________________________________________________
conv3_block7_2_conv (Conv2D)    (None, None, None, 3 36864       conv3_block7_1_relu[0][0]
__________________________________________________________________________________________________
conv3_block7_concat (Concatenat (None, None, None, 3 0           conv3_block6_concat[0][0]
                                                                 conv3_block7_2_conv[0][0]
__________________________________________________________________________________________________
conv3_block8_0_bn (BatchNormali (None, None, None, 3 1408        conv3_block7_concat[0][0]
__________________________________________________________________________________________________
conv3_block8_0_relu (Activation (None, None, None, 3 0           conv3_block8_0_bn[0][0]
__________________________________________________________________________________________________
conv3_block8_1_conv (Conv2D)    (None, None, None, 1 45056       conv3_block8_0_relu[0][0]
__________________________________________________________________________________________________
conv3_block8_1_bn (BatchNormali (None, None, None, 1 512         conv3_block8_1_conv[0][0]
__________________________________________________________________________________________________
conv3_block8_1_relu (Activation (None, None, None, 1 0           conv3_block8_1_bn[0][0]
__________________________________________________________________________________________________
conv3_block8_2_conv (Conv2D)    (None, None, None, 3 36864       conv3_block8_1_relu[0][0]
__________________________________________________________________________________________________
conv3_block8_concat (Concatenat (None, None, None, 3 0           conv3_block7_concat[0][0]
                                                                 conv3_block8_2_conv[0][0]
__________________________________________________________________________________________________
conv3_block9_0_bn (BatchNormali (None, None, None, 3 1536        conv3_block8_concat[0][0]
__________________________________________________________________________________________________
```

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conv3_block9_0_relu (Activation (None, None, None, 3 0           conv3_block9_0_bn[0][0]
__________________________________________________________________________________________________
conv3_block9_1_conv (Conv2D)    (None, None, None, 1 49152       conv3_block9_0_relu[0][0]
__________________________________________________________________________________________________
conv3_block9_1_bn (BatchNormali (None, None, None, 1 512         conv3_block9_1_conv[0][0]
__________________________________________________________________________________________________
conv3_block9_1_relu (Activation (None, None, None, 1 0           conv3_block9_1_bn[0][0]
__________________________________________________________________________________________________
conv3_block9_2_conv (Conv2D)    (None, None, None, 3 36864       conv3_block9_1_relu[0][0]
__________________________________________________________________________________________________
conv3_block9_concat (Concatenat (None, None, None, 4 0           conv3_block8_concat[0][0]
                                                                 conv3_block9_2_conv[0][0]
__________________________________________________________________________________________________
conv3_block10_0_bn (BatchNormal (None, None, None, 4 1664        conv3_block9_concat[0][0]
__________________________________________________________________________________________________
conv3_block10_0_relu (Activatio (None, None, None, 4 0           conv3_block10_0_bn[0][0]
__________________________________________________________________________________________________
conv3_block10_1_conv (Conv2D)   (None, None, None, 1 53248       conv3_block10_0_relu[0][0]
__________________________________________________________________________________________________
conv3_block10_1_bn (BatchNormal (None, None, None, 1 512         conv3_block10_1_conv[0][0]
__________________________________________________________________________________________________
conv3_block10_1_relu (Activatio (None, None, None, 1 0           conv3_block10_1_bn[0][0]
__________________________________________________________________________________________________
conv3_block10_2_conv (Conv2D)   (None, None, None, 3 36864       conv3_block10_1_relu[0][0]
__________________________________________________________________________________________________
conv3_block10_concat (Concatena (None, None, None, 4 0           conv3_block9_concat[0][0]
                                                                 conv3_block10_2_conv[0][0]
__________________________________________________________________________________________________
conv3_block11_0_bn (BatchNormal (None, None, None, 4 1792        conv3_block10_concat[0][0]
__________________________________________________________________________________________________
conv3_block11_0_relu (Activatio (None, None, None, 4 0           conv3_block11_0_bn[0][0]
__________________________________________________________________________________________________
conv3_block11_1_conv (Conv2D)   (None, None, None, 1 57344       conv3_block11_0_relu[0][0]
__________________________________________________________________________________________________
conv3_block11_1_bn (BatchNormal (None, None, None, 1 512         conv3_block11_1_conv[0][0]
__________________________________________________________________________________________________
conv3_block11_1_relu (Activatio (None, None, None, 1 0           conv3_block11_1_bn[0][0]
__________________________________________________________________________________________________
conv3_block11_2_conv (Conv2D)   (None, None, None, 3 36864       conv3_block11_1_relu[0][0]
__________________________________________________________________________________________________
conv3_block11_concat (Concatena (None, None, None, 4 0           conv3_block10_concat[0][0]
                                                                 conv3_block11_2_conv[0][0]
__________________________________________________________________________________________________
conv3_block12_0_bn (BatchNormal (None, None, None, 4 1920        conv3_block11_concat[0][0]
__________________________________________________________________________________________________
conv3_block12_0_relu (Activatio (None, None, None, 4 0           conv3_block12_0_bn[0][0]
__________________________________________________________________________________________________
conv3_block12_1_conv (Conv2D)   (None, None, None, 1 61440       conv3_block12_0_relu[0][0]
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__________________________________________________________________________________________________
conv3_block12_1_bn (BatchNormal (None, None, None, 1 512         conv3_block12_1_conv[0][0]
__________________________________________________________________________________________________
conv3_block12_1_relu (Activatio (None, None, None, 1 0           conv3_block12_1_bn[0][0]
__________________________________________________________________________________________________
conv3_block12_2_conv (Conv2D)   (None, None, None, 3 36864       conv3_block12_1_relu[0][0]
__________________________________________________________________________________________________
conv3_block12_concat (Concatena (None, None, None, 5 0           conv3_block11_concat[0][0]
                                                                 conv3_block12_2_conv[0][0]
__________________________________________________________________________________________________
pool3_bn (BatchNormalization)   (None, None, None, 5 2048        conv3_block12_concat[0][0]
__________________________________________________________________________________________________
pool3_relu (Activation)         (None, None, None, 5 0           pool3_bn[0][0]
__________________________________________________________________________________________________
pool3_conv (Conv2D)             (None, None, None, 2 131072      pool3_relu[0][0]
__________________________________________________________________________________________________
pool3_pool (AveragePooling2D)   (None, None, None, 2 0           pool3_conv[0][0]
__________________________________________________________________________________________________
conv4_block1_0_bn (BatchNormali (None, None, None, 2 1024        pool3_pool[0][0]
__________________________________________________________________________________________________
conv4_block1_0_relu (Activation (None, None, None, 2 0           conv4_block1_0_bn[0][0]
__________________________________________________________________________________________________
conv4_block1_1_conv (Conv2D)    (None, None, None, 1 32768       conv4_block1_0_relu[0][0]
__________________________________________________________________________________________________
conv4_block1_1_bn (BatchNormali (None, None, None, 1 512         conv4_block1_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block1_1_relu (Activation (None, None, None, 1 0           conv4_block1_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block1_2_conv (Conv2D)    (None, None, None, 3 36864       conv4_block1_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block1_concat (Concatenat (None, None, None, 2 0           pool3_pool[0][0]
                                                                 conv4_block1_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block2_0_bn (BatchNormali (None, None, None, 2 1152        conv4_block1_concat[0][0]
__________________________________________________________________________________________________
conv4_block2_0_relu (Activation (None, None, None, 2 0           conv4_block2_0_bn[0][0]
__________________________________________________________________________________________________
conv4_block2_1_conv (Conv2D)    (None, None, None, 1 36864       conv4_block2_0_relu[0][0]
__________________________________________________________________________________________________
conv4_block2_1_bn (BatchNormali (None, None, None, 1 512         conv4_block2_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block2_1_relu (Activation (None, None, None, 1 0           conv4_block2_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block2_2_conv (Conv2D)    (None, None, None, 3 36864       conv4_block2_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block2_concat (Concatenat (None, None, None, 3 0           conv4_block1_concat[0][0]
                                                                 conv4_block2_2_conv[0][0]
__________________________________________________________________________________________________
```

```
conv4_block3_0_bn (BatchNormali (None, None, None, 3 1280        conv4_block2_concat[0][0]
__________________________________________________________________________________________________
conv4_block3_0_relu (Activation (None, None, None, 3 0           conv4_block3_0_bn[0][0]
__________________________________________________________________________________________________
conv4_block3_1_conv (Conv2D)    (None, None, None, 1 40960       conv4_block3_0_relu[0][0]
__________________________________________________________________________________________________
conv4_block3_1_bn (BatchNormali (None, None, None, 1 512         conv4_block3_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block3_1_relu (Activation (None, None, None, 1 0           conv4_block3_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block3_2_conv (Conv2D)    (None, None, None, 3 36864       conv4_block3_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block3_concat (Concatenat (None, None, None, 3 0           conv4_block2_concat[0][0]
                                                                 conv4_block3_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block4_0_bn (BatchNormali (None, None, None, 3 1408        conv4_block3_concat[0][0]
__________________________________________________________________________________________________
conv4_block4_0_relu (Activation (None, None, None, 3 0           conv4_block4_0_bn[0][0]
__________________________________________________________________________________________________
conv4_block4_1_conv (Conv2D)    (None, None, None, 1 45056       conv4_block4_0_relu[0][0]
__________________________________________________________________________________________________
conv4_block4_1_bn (BatchNormali (None, None, None, 1 512         conv4_block4_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block4_1_relu (Activation (None, None, None, 1 0           conv4_block4_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block4_2_conv (Conv2D)    (None, None, None, 3 36864       conv4_block4_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block4_concat (Concatenat (None, None, None, 3 0           conv4_block3_concat[0][0]
                                                                 conv4_block4_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block5_0_bn (BatchNormali (None, None, None, 3 1536        conv4_block4_concat[0][0]
__________________________________________________________________________________________________
conv4_block5_0_relu (Activation (None, None, None, 3 0           conv4_block5_0_bn[0][0]
__________________________________________________________________________________________________
conv4_block5_1_conv (Conv2D)    (None, None, None, 1 49152       conv4_block5_0_relu[0][0]
__________________________________________________________________________________________________
conv4_block5_1_bn (BatchNormali (None, None, None, 1 512         conv4_block5_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block5_1_relu (Activation (None, None, None, 1 0           conv4_block5_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block5_2_conv (Conv2D)    (None, None, None, 3 36864       conv4_block5_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block5_concat (Concatenat (None, None, None, 4 0           conv4_block4_concat[0][0]
                                                                 conv4_block5_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block6_0_bn (BatchNormali (None, None, None, 4 1664        conv4_block5_concat[0][0]
__________________________________________________________________________________________________
conv4_block6_0_relu (Activation (None, None, None, 4 0           conv4_block6_0_bn[0][0]
```

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__________________________________________________________________________________________________
conv4_block6_1_conv (Conv2D)    (None, None, None, 1 53248       conv4_block6_0_relu[0][0]
__________________________________________________________________________________________________
conv4_block6_1_bn (BatchNormali (None, None, None, 1 512         conv4_block6_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block6_1_relu (Activation (None, None, None, 1 0           conv4_block6_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block6_2_conv (Conv2D)    (None, None, None, 3 36864       conv4_block6_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block6_concat (Concatenat (None, None, None, 4 0           conv4_block5_concat[0][0]
                                                                 conv4_block6_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block7_0_bn (BatchNormali (None, None, None, 4 1792        conv4_block6_concat[0][0]
__________________________________________________________________________________________________
conv4_block7_0_relu (Activation (None, None, None, 4 0           conv4_block7_0_bn[0][0]
__________________________________________________________________________________________________
conv4_block7_1_conv (Conv2D)    (None, None, None, 1 57344       conv4_block7_0_relu[0][0]
__________________________________________________________________________________________________
conv4_block7_1_bn (BatchNormali (None, None, None, 1 512         conv4_block7_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block7_1_relu (Activation (None, None, None, 1 0           conv4_block7_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block7_2_conv (Conv2D)    (None, None, None, 3 36864       conv4_block7_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block7_concat (Concatenat (None, None, None, 4 0           conv4_block6_concat[0][0]
                                                                 conv4_block7_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block8_0_bn (BatchNormali (None, None, None, 4 1920        conv4_block7_concat[0][0]
__________________________________________________________________________________________________
conv4_block8_0_relu (Activation (None, None, None, 4 0           conv4_block8_0_bn[0][0]
__________________________________________________________________________________________________
conv4_block8_1_conv (Conv2D)    (None, None, None, 1 61440       conv4_block8_0_relu[0][0]
__________________________________________________________________________________________________
conv4_block8_1_bn (BatchNormali (None, None, None, 1 512         conv4_block8_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block8_1_relu (Activation (None, None, None, 1 0           conv4_block8_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block8_2_conv (Conv2D)    (None, None, None, 3 36864       conv4_block8_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block8_concat (Concatenat (None, None, None, 5 0           conv4_block7_concat[0][0]
                                                                 conv4_block8_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block9_0_bn (BatchNormali (None, None, None, 5 2048        conv4_block8_concat[0][0]
__________________________________________________________________________________________________
conv4_block9_0_relu (Activation (None, None, None, 5 0           conv4_block9_0_bn[0][0]
__________________________________________________________________________________________________
conv4_block9_1_conv (Conv2D)    (None, None, None, 1 65536       conv4_block9_0_relu[0][0]
__________________________________________________________________________________________________
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conv4_block9_1_bn (BatchNormali (None, None, None, 1 512         conv4_block9_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block9_1_relu (Activation (None, None, None, 1 0           conv4_block9_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block9_2_conv (Conv2D)    (None, None, None, 3 36864       conv4_block9_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block9_concat (Concatenat (None, None, None, 5 0           conv4_block8_concat[0][0]
                                                                 conv4_block9_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block10_0_bn (BatchNormal (None, None, None, 5 2176        conv4_block9_concat[0][0]
__________________________________________________________________________________________________
conv4_block10_0_relu (Activatio (None, None, None, 5 0           conv4_block10_0_bn[0][0]
__________________________________________________________________________________________________
conv4_block10_1_conv (Conv2D)   (None, None, None, 1 69632       conv4_block10_0_relu[0][0]
__________________________________________________________________________________________________
conv4_block10_1_bn (BatchNormal (None, None, None, 1 512         conv4_block10_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block10_1_relu (Activatio (None, None, None, 1 0           conv4_block10_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block10_2_conv (Conv2D)   (None, None, None, 3 36864       conv4_block10_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block10_concat (Concatena (None, None, None, 5 0           conv4_block9_concat[0][0]
                                                                 conv4_block10_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block11_0_bn (BatchNormal (None, None, None, 5 2304        conv4_block10_concat[0][0]
__________________________________________________________________________________________________
conv4_block11_0_relu (Activatio (None, None, None, 5 0           conv4_block11_0_bn[0][0]
__________________________________________________________________________________________________
conv4_block11_1_conv (Conv2D)   (None, None, None, 1 73728       conv4_block11_0_relu[0][0]
__________________________________________________________________________________________________
conv4_block11_1_bn (BatchNormal (None, None, None, 1 512         conv4_block11_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block11_1_relu (Activatio (None, None, None, 1 0           conv4_block11_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block11_2_conv (Conv2D)   (None, None, None, 3 36864       conv4_block11_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block11_concat (Concatena (None, None, None, 6 0           conv4_block10_concat[0][0]
                                                                 conv4_block11_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block12_0_bn (BatchNormal (None, None, None, 6 2432        conv4_block11_concat[0][0]
__________________________________________________________________________________________________
conv4_block12_0_relu (Activatio (None, None, None, 6 0           conv4_block12_0_bn[0][0]
__________________________________________________________________________________________________
conv4_block12_1_conv (Conv2D)   (None, None, None, 1 77824       conv4_block12_0_relu[0][0]
__________________________________________________________________________________________________
conv4_block12_1_bn (BatchNormal (None, None, None, 1 512         conv4_block12_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block12_1_relu (Activatio (None, None, None, 1 0           conv4_block12_1_bn[0][0]
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__________________________________________________________________________________________________
conv4_block12_2_conv (Conv2D)   (None, None, None, 3 36864       conv4_block12_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block12_concat (Concatena (None, None, None, 6 0           conv4_block11_concat[0][0]
                                                                 conv4_block12_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block13_0_bn (BatchNormal (None, None, None, 6 2560        conv4_block12_concat[0][0]
__________________________________________________________________________________________________
conv4_block13_0_relu (Activatio (None, None, None, 6 0           conv4_block13_0_bn[0][0]
__________________________________________________________________________________________________
conv4_block13_1_conv (Conv2D)   (None, None, None, 1 81920       conv4_block13_0_relu[0][0]
__________________________________________________________________________________________________
conv4_block13_1_bn (BatchNormal (None, None, None, 1 512         conv4_block13_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block13_1_relu (Activatio (None, None, None, 1 0           conv4_block13_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block13_2_conv (Conv2D)   (None, None, None, 3 36864       conv4_block13_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block13_concat (Concatena (None, None, None, 6 0           conv4_block12_concat[0][0]
                                                                 conv4_block13_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block14_0_bn (BatchNormal (None, None, None, 6 2688        conv4_block13_concat[0][0]
__________________________________________________________________________________________________
conv4_block14_0_relu (Activatio (None, None, None, 6 0           conv4_block14_0_bn[0][0]
__________________________________________________________________________________________________
conv4_block14_1_conv (Conv2D)   (None, None, None, 1 86016       conv4_block14_0_relu[0][0]
__________________________________________________________________________________________________
conv4_block14_1_bn (BatchNormal (None, None, None, 1 512         conv4_block14_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block14_1_relu (Activatio (None, None, None, 1 0           conv4_block14_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block14_2_conv (Conv2D)   (None, None, None, 3 36864       conv4_block14_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block14_concat (Concatena (None, None, None, 7 0           conv4_block13_concat[0][0]
                                                                 conv4_block14_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block15_0_bn (BatchNormal (None, None, None, 7 2816        conv4_block14_concat[0][0]
__________________________________________________________________________________________________
conv4_block15_0_relu (Activatio (None, None, None, 7 0           conv4_block15_0_bn[0][0]
__________________________________________________________________________________________________
conv4_block15_1_conv (Conv2D)   (None, None, None, 1 90112       conv4_block15_0_relu[0][0]
__________________________________________________________________________________________________
conv4_block15_1_bn (BatchNormal (None, None, None, 1 512         conv4_block15_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block15_1_relu (Activatio (None, None, None, 1 0           conv4_block15_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block15_2_conv (Conv2D)   (None, None, None, 3 36864       conv4_block15_1_relu[0][0]
__________________________________________________________________________________________________
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conv4_block15_concat (Concatena (None, None, None, 7 0           conv4_block14_concat[0][0]
                                                                 conv4_block15_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block16_0_bn (BatchNormal (None, None, None, 7 2944        conv4_block15_concat[0][0]
__________________________________________________________________________________________________
conv4_block16_0_relu (Activatio (None, None, None, 7 0           conv4_block16_0_bn[0][0]
__________________________________________________________________________________________________
conv4_block16_1_conv (Conv2D)   (None, None, None, 1 94208       conv4_block16_0_relu[0][0]
__________________________________________________________________________________________________
conv4_block16_1_bn (BatchNormal (None, None, None, 1 512         conv4_block16_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block16_1_relu (Activatio (None, None, None, 1 0           conv4_block16_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block16_2_conv (Conv2D)   (None, None, None, 3 36864       conv4_block16_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block16_concat (Concatena (None, None, None, 7 0           conv4_block15_concat[0][0]
                                                                 conv4_block16_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block17_0_bn (BatchNormal (None, None, None, 7 3072        conv4_block16_concat[0][0]
__________________________________________________________________________________________________
conv4_block17_0_relu (Activatio (None, None, None, 7 0           conv4_block17_0_bn[0][0]
__________________________________________________________________________________________________
conv4_block17_1_conv (Conv2D)   (None, None, None, 1 98304       conv4_block17_0_relu[0][0]
__________________________________________________________________________________________________
conv4_block17_1_bn (BatchNormal (None, None, None, 1 512         conv4_block17_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block17_1_relu (Activatio (None, None, None, 1 0           conv4_block17_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block17_2_conv (Conv2D)   (None, None, None, 3 36864       conv4_block17_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block17_concat (Concatena (None, None, None, 8 0           conv4_block16_concat[0][0]
                                                                 conv4_block17_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block18_0_bn (BatchNormal (None, None, None, 8 3200        conv4_block17_concat[0][0]
__________________________________________________________________________________________________
conv4_block18_0_relu (Activatio (None, None, None, 8 0           conv4_block18_0_bn[0][0]
__________________________________________________________________________________________________
conv4_block18_1_conv (Conv2D)   (None, None, None, 1 102400      conv4_block18_0_relu[0][0]
__________________________________________________________________________________________________
conv4_block18_1_bn (BatchNormal (None, None, None, 1 512         conv4_block18_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block18_1_relu (Activatio (None, None, None, 1 0           conv4_block18_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block18_2_conv (Conv2D)   (None, None, None, 3 36864       conv4_block18_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block18_concat (Concatena (None, None, None, 8 0           conv4_block17_concat[0][0]
                                                                 conv4_block18_2_conv[0][0]
__________________________________________________________________________________________________
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conv4_block19_0_bn (BatchNormal (None, None, None, 8 3328        conv4_block18_concat[0][0]
__________________________________________________________________________________________________
conv4_block19_0_relu (Activatio (None, None, None, 8 0           conv4_block19_0_bn[0][0]
__________________________________________________________________________________________________
conv4_block19_1_conv (Conv2D)   (None, None, None, 1 106496      conv4_block19_0_relu[0][0]
__________________________________________________________________________________________________
conv4_block19_1_bn (BatchNormal (None, None, None, 1 512         conv4_block19_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block19_1_relu (Activatio (None, None, None, 1 0           conv4_block19_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block19_2_conv (Conv2D)   (None, None, None, 3 36864       conv4_block19_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block19_concat (Concatena (None, None, None, 8 0           conv4_block18_concat[0][0]
                                                                 conv4_block19_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block20_0_bn (BatchNormal (None, None, None, 8 3456        conv4_block19_concat[0][0]
__________________________________________________________________________________________________
conv4_block20_0_relu (Activatio (None, None, None, 8 0           conv4_block20_0_bn[0][0]
__________________________________________________________________________________________________
conv4_block20_1_conv (Conv2D)   (None, None, None, 1 110592      conv4_block20_0_relu[0][0]
__________________________________________________________________________________________________
conv4_block20_1_bn (BatchNormal (None, None, None, 1 512         conv4_block20_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block20_1_relu (Activatio (None, None, None, 1 0           conv4_block20_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block20_2_conv (Conv2D)   (None, None, None, 3 36864       conv4_block20_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block20_concat (Concatena (None, None, None, 8 0           conv4_block19_concat[0][0]
                                                                 conv4_block20_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block21_0_bn (BatchNormal (None, None, None, 8 3584        conv4_block20_concat[0][0]
__________________________________________________________________________________________________
conv4_block21_0_relu (Activatio (None, None, None, 8 0           conv4_block21_0_bn[0][0]
__________________________________________________________________________________________________
conv4_block21_1_conv (Conv2D)   (None, None, None, 1 114688      conv4_block21_0_relu[0][0]
__________________________________________________________________________________________________
conv4_block21_1_bn (BatchNormal (None, None, None, 1 512         conv4_block21_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block21_1_relu (Activatio (None, None, None, 1 0           conv4_block21_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block21_2_conv (Conv2D)   (None, None, None, 3 36864       conv4_block21_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block21_concat (Concatena (None, None, None, 9 0           conv4_block20_concat[0][0]
                                                                 conv4_block21_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block22_0_bn (BatchNormal (None, None, None, 9 3712        conv4_block21_concat[0][0]
__________________________________________________________________________________________________
conv4_block22_0_relu (Activatio (None, None, None, 9 0           conv4_block22_0_bn[0][0]
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__________________________________________________________________________________________________
conv4_block22_1_conv (Conv2D)   (None, None, None, 1 118784      conv4_block22_0_relu[0][0]
__________________________________________________________________________________________________
conv4_block22_1_bn (BatchNormal (None, None, None, 1 512         conv4_block22_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block22_1_relu (Activatio (None, None, None, 1 0           conv4_block22_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block22_2_conv (Conv2D)   (None, None, None, 3 36864       conv4_block22_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block22_concat (Concatena (None, None, None, 9 0           conv4_block21_concat[0][0]
                                                                 conv4_block22_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block23_0_bn (BatchNormal (None, None, None, 9 3840        conv4_block22_concat[0][0]
__________________________________________________________________________________________________
conv4_block23_0_relu (Activatio (None, None, None, 9 0           conv4_block23_0_bn[0][0]
__________________________________________________________________________________________________
conv4_block23_1_conv (Conv2D)   (None, None, None, 1 122880      conv4_block23_0_relu[0][0]
__________________________________________________________________________________________________
conv4_block23_1_bn (BatchNormal (None, None, None, 1 512         conv4_block23_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block23_1_relu (Activatio (None, None, None, 1 0           conv4_block23_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block23_2_conv (Conv2D)   (None, None, None, 3 36864       conv4_block23_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block23_concat (Concatena (None, None, None, 9 0           conv4_block22_concat[0][0]
                                                                 conv4_block23_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block24_0_bn (BatchNormal (None, None, None, 9 3968        conv4_block23_concat[0][0]
__________________________________________________________________________________________________
conv4_block24_0_relu (Activatio (None, None, None, 9 0           conv4_block24_0_bn[0][0]
__________________________________________________________________________________________________
conv4_block24_1_conv (Conv2D)   (None, None, None, 1 126976      conv4_block24_0_relu[0][0]
__________________________________________________________________________________________________
conv4_block24_1_bn (BatchNormal (None, None, None, 1 512         conv4_block24_1_conv[0][0]
__________________________________________________________________________________________________
conv4_block24_1_relu (Activatio (None, None, None, 1 0           conv4_block24_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block24_2_conv (Conv2D)   (None, None, None, 3 36864       conv4_block24_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block24_concat (Concatena (None, None, None, 1 0           conv4_block23_concat[0][0]
                                                                 conv4_block24_2_conv[0][0]
__________________________________________________________________________________________________
pool4_bn (BatchNormalization)   (None, None, None, 1 4096        conv4_block24_concat[0][0]
__________________________________________________________________________________________________
pool4_relu (Activation)         (None, None, None, 1 0           pool4_bn[0][0]
__________________________________________________________________________________________________
pool4_conv (Conv2D)             (None, None, None, 5 524288      pool4_relu[0][0]
__________________________________________________________________________________________________
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pool4_pool (AveragePooling2D)   (None, None, None, 5 0           pool4_conv[0][0]
__________________________________________________________________________________________________
conv5_block1_0_bn (BatchNormali (None, None, None, 5 2048        pool4_pool[0][0]
__________________________________________________________________________________________________
conv5_block1_0_relu (Activation (None, None, None, 5 0           conv5_block1_0_bn[0][0]
__________________________________________________________________________________________________
conv5_block1_1_conv (Conv2D)    (None, None, None, 1 65536       conv5_block1_0_relu[0][0]
__________________________________________________________________________________________________
conv5_block1_1_bn (BatchNormali (None, None, None, 1 512         conv5_block1_1_conv[0][0]
__________________________________________________________________________________________________
conv5_block1_1_relu (Activation (None, None, None, 1 0           conv5_block1_1_bn[0][0]
__________________________________________________________________________________________________
conv5_block1_2_conv (Conv2D)    (None, None, None, 3 36864       conv5_block1_1_relu[0][0]
__________________________________________________________________________________________________
conv5_block1_concat (Concatenat (None, None, None, 5 0           pool4_pool[0][0]
                                                                 conv5_block1_2_conv[0][0]
__________________________________________________________________________________________________
conv5_block2_0_bn (BatchNormali (None, None, None, 5 2176        conv5_block1_concat[0][0]
__________________________________________________________________________________________________
conv5_block2_0_relu (Activation (None, None, None, 5 0           conv5_block2_0_bn[0][0]
__________________________________________________________________________________________________
conv5_block2_1_conv (Conv2D)    (None, None, None, 1 69632       conv5_block2_0_relu[0][0]
__________________________________________________________________________________________________
conv5_block2_1_bn (BatchNormali (None, None, None, 1 512         conv5_block2_1_conv[0][0]
__________________________________________________________________________________________________
conv5_block2_1_relu (Activation (None, None, None, 1 0           conv5_block2_1_bn[0][0]
__________________________________________________________________________________________________
conv5_block2_2_conv (Conv2D)    (None, None, None, 3 36864       conv5_block2_1_relu[0][0]
__________________________________________________________________________________________________
conv5_block2_concat (Concatenat (None, None, None, 5 0           conv5_block1_concat[0][0]
                                                                 conv5_block2_2_conv[0][0]
__________________________________________________________________________________________________
conv5_block3_0_bn (BatchNormali (None, None, None, 5 2304        conv5_block2_concat[0][0]
__________________________________________________________________________________________________
conv5_block3_0_relu (Activation (None, None, None, 5 0           conv5_block3_0_bn[0][0]
__________________________________________________________________________________________________
conv5_block3_1_conv (Conv2D)    (None, None, None, 1 73728       conv5_block3_0_relu[0][0]
__________________________________________________________________________________________________
conv5_block3_1_bn (BatchNormali (None, None, None, 1 512         conv5_block3_1_conv[0][0]
__________________________________________________________________________________________________
conv5_block3_1_relu (Activation (None, None, None, 1 0           conv5_block3_1_bn[0][0]
__________________________________________________________________________________________________
conv5_block3_2_conv (Conv2D)    (None, None, None, 3 36864       conv5_block3_1_relu[0][0]
__________________________________________________________________________________________________
conv5_block3_concat (Concatenat (None, None, None, 6 0           conv5_block2_concat[0][0]
                                                                 conv5_block3_2_conv[0][0]
__________________________________________________________________________________________________
conv5_block4_0_bn (BatchNormali (None, None, None, 6 2432        conv5_block3_concat[0][0]
```

```
________________________________________________________________________________________________________
conv5_block4_0_relu (Activation (None, None, None, 6 0           conv5_block4_0_bn[0][0]
________________________________________________________________________________________________________
conv5_block4_1_conv (Conv2D)    (None, None, None, 1 77824       conv5_block4_0_relu[0][0]
________________________________________________________________________________________________________
conv5_block4_1_bn (BatchNormali (None, None, None, 1 512         conv5_block4_1_conv[0][0]
________________________________________________________________________________________________________
conv5_block4_1_relu (Activation (None, None, None, 1 0           conv5_block4_1_bn[0][0]
________________________________________________________________________________________________________
conv5_block4_2_conv (Conv2D)    (None, None, None, 3 36864       conv5_block4_1_relu[0][0]
________________________________________________________________________________________________________
conv5_block4_concat (Concatenat (None, None, None, 6 0           conv5_block3_concat[0][0]
                                                                 conv5_block4_2_conv[0][0]
________________________________________________________________________________________________________
conv5_block5_0_bn (BatchNormali (None, None, None, 6 2560        conv5_block4_concat[0][0]
________________________________________________________________________________________________________
conv5_block5_0_relu (Activation (None, None, None, 6 0           conv5_block5_0_bn[0][0]
________________________________________________________________________________________________________
conv5_block5_1_conv (Conv2D)    (None, None, None, 1 81920       conv5_block5_0_relu[0][0]
________________________________________________________________________________________________________
conv5_block5_1_bn (BatchNormali (None, None, None, 1 512         conv5_block5_1_conv[0][0]
________________________________________________________________________________________________________
conv5_block5_1_relu (Activation (None, None, None, 1 0           conv5_block5_1_bn[0][0]
________________________________________________________________________________________________________
conv5_block5_2_conv (Conv2D)    (None, None, None, 3 36864       conv5_block5_1_relu[0][0]
________________________________________________________________________________________________________
conv5_block5_concat (Concatenat (None, None, None, 6 0           conv5_block4_concat[0][0]
                                                                 conv5_block5_2_conv[0][0]
________________________________________________________________________________________________________
conv5_block6_0_bn (BatchNormali (None, None, None, 6 2688        conv5_block5_concat[0][0]
________________________________________________________________________________________________________
conv5_block6_0_relu (Activation (None, None, None, 6 0           conv5_block6_0_bn[0][0]
________________________________________________________________________________________________________
conv5_block6_1_conv (Conv2D)    (None, None, None, 1 86016       conv5_block6_0_relu[0][0]
________________________________________________________________________________________________________
conv5_block6_1_bn (BatchNormali (None, None, None, 1 512         conv5_block6_1_conv[0][0]
________________________________________________________________________________________________________
conv5_block6_1_relu (Activation (None, None, None, 1 0           conv5_block6_1_bn[0][0]
________________________________________________________________________________________________________
conv5_block6_2_conv (Conv2D)    (None, None, None, 3 36864       conv5_block6_1_relu[0][0]
________________________________________________________________________________________________________
conv5_block6_concat (Concatenat (None, None, None, 7 0           conv5_block5_concat[0][0]
                                                                 conv5_block6_2_conv[0][0]
________________________________________________________________________________________________________
conv5_block7_0_bn (BatchNormali (None, None, None, 7 2816        conv5_block6_concat[0][0]
________________________________________________________________________________________________________
conv5_block7_0_relu (Activation (None, None, None, 7 0           conv5_block7_0_bn[0][0]
________________________________________________________________________________________________________
```

```
conv5_block7_1_conv (Conv2D)    (None, None, None, 1 90112       conv5_block7_0_relu[0][0]
__________________________________________________________________________________________________
conv5_block7_1_bn (BatchNormali (None, None, None, 1 512         conv5_block7_1_conv[0][0]
__________________________________________________________________________________________________
conv5_block7_1_relu (Activation (None, None, None, 1 0           conv5_block7_1_bn[0][0]
__________________________________________________________________________________________________
conv5_block7_2_conv (Conv2D)    (None, None, None, 3 36864       conv5_block7_1_relu[0][0]
__________________________________________________________________________________________________
conv5_block7_concat (Concatenat (None, None, None, 7 0           conv5_block6_concat[0][0]
                                                                 conv5_block7_2_conv[0][0]
__________________________________________________________________________________________________
conv5_block8_0_bn (BatchNormali (None, None, None, 7 2944        conv5_block7_concat[0][0]
__________________________________________________________________________________________________
conv5_block8_0_relu (Activation (None, None, None, 7 0           conv5_block8_0_bn[0][0]
__________________________________________________________________________________________________
conv5_block8_1_conv (Conv2D)    (None, None, None, 1 94208       conv5_block8_0_relu[0][0]
__________________________________________________________________________________________________
conv5_block8_1_bn (BatchNormali (None, None, None, 1 512         conv5_block8_1_conv[0][0]
__________________________________________________________________________________________________
conv5_block8_1_relu (Activation (None, None, None, 1 0           conv5_block8_1_bn[0][0]
__________________________________________________________________________________________________
conv5_block8_2_conv (Conv2D)    (None, None, None, 3 36864       conv5_block8_1_relu[0][0]
__________________________________________________________________________________________________
conv5_block8_concat (Concatenat (None, None, None, 7 0           conv5_block7_concat[0][0]
                                                                 conv5_block8_2_conv[0][0]
__________________________________________________________________________________________________
conv5_block9_0_bn (BatchNormali (None, None, None, 7 3072        conv5_block8_concat[0][0]
__________________________________________________________________________________________________
conv5_block9_0_relu (Activation (None, None, None, 7 0           conv5_block9_0_bn[0][0]
__________________________________________________________________________________________________
conv5_block9_1_conv (Conv2D)    (None, None, None, 1 98304       conv5_block9_0_relu[0][0]
__________________________________________________________________________________________________
conv5_block9_1_bn (BatchNormali (None, None, None, 1 512         conv5_block9_1_conv[0][0]
__________________________________________________________________________________________________
conv5_block9_1_relu (Activation (None, None, None, 1 0           conv5_block9_1_bn[0][0]
__________________________________________________________________________________________________
conv5_block9_2_conv (Conv2D)    (None, None, None, 3 36864       conv5_block9_1_relu[0][0]
__________________________________________________________________________________________________
conv5_block9_concat (Concatenat (None, None, None, 8 0           conv5_block8_concat[0][0]
                                                                 conv5_block9_2_conv[0][0]
__________________________________________________________________________________________________
conv5_block10_0_bn (BatchNormal (None, None, None, 8 3200        conv5_block9_concat[0][0]
__________________________________________________________________________________________________
conv5_block10_0_relu (Activatio (None, None, None, 8 0           conv5_block10_0_bn[0][0]
__________________________________________________________________________________________________
conv5_block10_1_conv (Conv2D)   (None, None, None, 1 102400      conv5_block10_0_relu[0][0]
__________________________________________________________________________________________________
conv5_block10_1_bn (BatchNormal (None, None, None, 1 512         conv5_block10_1_conv[0][0]
```

```
__________________________________________________________________________________________________
conv5_block10_1_relu (Activatio (None, None, None, 1 0           conv5_block10_1_bn[0][0]
__________________________________________________________________________________________________
conv5_block10_2_conv (Conv2D)   (None, None, None, 3 36864       conv5_block10_1_relu[0][0]
__________________________________________________________________________________________________
conv5_block10_concat (Concatena (None, None, None, 8 0           conv5_block9_concat[0][0]
                                                                 conv5_block10_2_conv[0][0]
__________________________________________________________________________________________________
conv5_block11_0_bn (BatchNormal (None, None, None, 8 3328        conv5_block10_concat[0][0]
__________________________________________________________________________________________________
conv5_block11_0_relu (Activatio (None, None, None, 8 0           conv5_block11_0_bn[0][0]
__________________________________________________________________________________________________
conv5_block11_1_conv (Conv2D)   (None, None, None, 1 106496      conv5_block11_0_relu[0][0]
__________________________________________________________________________________________________
conv5_block11_1_bn (BatchNormal (None, None, None, 1 512         conv5_block11_1_conv[0][0]
__________________________________________________________________________________________________
conv5_block11_1_relu (Activatio (None, None, None, 1 0           conv5_block11_1_bn[0][0]
__________________________________________________________________________________________________
conv5_block11_2_conv (Conv2D)   (None, None, None, 3 36864       conv5_block11_1_relu[0][0]
__________________________________________________________________________________________________
conv5_block11_concat (Concatena (None, None, None, 8 0           conv5_block10_concat[0][0]
                                                                 conv5_block11_2_conv[0][0]
__________________________________________________________________________________________________
conv5_block12_0_bn (BatchNormal (None, None, None, 8 3456        conv5_block11_concat[0][0]
__________________________________________________________________________________________________
conv5_block12_0_relu (Activatio (None, None, None, 8 0           conv5_block12_0_bn[0][0]
__________________________________________________________________________________________________
conv5_block12_1_conv (Conv2D)   (None, None, None, 1 110592      conv5_block12_0_relu[0][0]
__________________________________________________________________________________________________
conv5_block12_1_bn (BatchNormal (None, None, None, 1 512         conv5_block12_1_conv[0][0]
__________________________________________________________________________________________________
conv5_block12_1_relu (Activatio (None, None, None, 1 0           conv5_block12_1_bn[0][0]
__________________________________________________________________________________________________
conv5_block12_2_conv (Conv2D)   (None, None, None, 3 36864       conv5_block12_1_relu[0][0]
__________________________________________________________________________________________________
conv5_block12_concat (Concatena (None, None, None, 8 0           conv5_block11_concat[0][0]
                                                                 conv5_block12_2_conv[0][0]
__________________________________________________________________________________________________
conv5_block13_0_bn (BatchNormal (None, None, None, 8 3584        conv5_block12_concat[0][0]
__________________________________________________________________________________________________
conv5_block13_0_relu (Activatio (None, None, None, 8 0           conv5_block13_0_bn[0][0]
__________________________________________________________________________________________________
conv5_block13_1_conv (Conv2D)   (None, None, None, 1 114688      conv5_block13_0_relu[0][0]
__________________________________________________________________________________________________
conv5_block13_1_bn (BatchNormal (None, None, None, 1 512         conv5_block13_1_conv[0][0]
__________________________________________________________________________________________________
conv5_block13_1_relu (Activatio (None, None, None, 1 0           conv5_block13_1_bn[0][0]
__________________________________________________________________________________________________
```

```
conv5_block13_2_conv (Conv2D)   (None, None, None, 3 36864       conv5_block13_1_relu[0][0]
__________________________________________________________________________________________________
conv5_block13_concat (Concatena (None, None, None, 9 0           conv5_block12_concat[0][0]
                                                                 conv5_block13_2_conv[0][0]
__________________________________________________________________________________________________
conv5_block14_0_bn (BatchNormal (None, None, None, 9 3712        conv5_block13_concat[0][0]
__________________________________________________________________________________________________
conv5_block14_0_relu (Activatio (None, None, None, 9 0           conv5_block14_0_bn[0][0]
__________________________________________________________________________________________________
conv5_block14_1_conv (Conv2D)   (None, None, None, 1 118784      conv5_block14_0_relu[0][0]
__________________________________________________________________________________________________
conv5_block14_1_bn (BatchNormal (None, None, None, 1 512         conv5_block14_1_conv[0][0]
__________________________________________________________________________________________________
conv5_block14_1_relu (Activatio (None, None, None, 1 0           conv5_block14_1_bn[0][0]
__________________________________________________________________________________________________
conv5_block14_2_conv (Conv2D)   (None, None, None, 3 36864       conv5_block14_1_relu[0][0]
__________________________________________________________________________________________________
conv5_block14_concat (Concatena (None, None, None, 9 0           conv5_block13_concat[0][0]
                                                                 conv5_block14_2_conv[0][0]
__________________________________________________________________________________________________
conv5_block15_0_bn (BatchNormal (None, None, None, 9 3840        conv5_block14_concat[0][0]
__________________________________________________________________________________________________
conv5_block15_0_relu (Activatio (None, None, None, 9 0           conv5_block15_0_bn[0][0]
__________________________________________________________________________________________________
conv5_block15_1_conv (Conv2D)   (None, None, None, 1 122880      conv5_block15_0_relu[0][0]
__________________________________________________________________________________________________
conv5_block15_1_bn (BatchNormal (None, None, None, 1 512         conv5_block15_1_conv[0][0]
__________________________________________________________________________________________________
conv5_block15_1_relu (Activatio (None, None, None, 1 0           conv5_block15_1_bn[0][0]
__________________________________________________________________________________________________
conv5_block15_2_conv (Conv2D)   (None, None, None, 3 36864       conv5_block15_1_relu[0][0]
__________________________________________________________________________________________________
conv5_block15_concat (Concatena (None, None, None, 9 0           conv5_block14_concat[0][0]
                                                                 conv5_block15_2_conv[0][0]
__________________________________________________________________________________________________
conv5_block16_0_bn (BatchNormal (None, None, None, 9 3968        conv5_block15_concat[0][0]
__________________________________________________________________________________________________
conv5_block16_0_relu (Activatio (None, None, None, 9 0           conv5_block16_0_bn[0][0]
__________________________________________________________________________________________________
conv5_block16_1_conv (Conv2D)   (None, None, None, 1 126976      conv5_block16_0_relu[0][0]
__________________________________________________________________________________________________
conv5_block16_1_bn (BatchNormal (None, None, None, 1 512         conv5_block16_1_conv[0][0]
__________________________________________________________________________________________________
conv5_block16_1_relu (Activatio (None, None, None, 1 0           conv5_block16_1_bn[0][0]
__________________________________________________________________________________________________
conv5_block16_2_conv (Conv2D)   (None, None, None, 3 36864       conv5_block16_1_relu[0][0]
__________________________________________________________________________________________________
conv5_block16_concat (Concatena (None, None, None, 1 0           conv5_block15_concat[0][0]
```

```
                                                               conv5_block16_2_conv[0][0]
__________________________________________________________________________________________________
bn (BatchNormalization)         (None, None, None, 1 4096        conv5_block16_concat[0][0]
__________________________________________________________________________________________________
global_average_pooling2d_1 (Glo (None, 1024)         0           bn[0][0]
__________________________________________________________________________________________________
dense_1 (Dense)                 (None, 14)           14350       global_average_pooling2d_1[0]
==================================================================================================
Total params: 7,051,854
Trainable params: 6,968,206
Non-trainable params: 83,648
__________________________________________________________________________________________________
```

Keras models include abundant information about the elements that make them up. You can check all of the available methods and attributes of this class by using the `dir()` method:

```
In [5]: # Printing out methods and attributes for Keras model
        print(f"Keras' models have the following methods and attributes: \n\n{dir(model)}")
```

```
Keras' models have the following methods and attributes:

['__call__', '__class__', '__delattr__', '__dict__', '__dir__', '__doc__', '__eq__', '__format_
```

Wow, this certainly is a lot! These models are indeed very complex.

What we are interested in are the layers of the model which can be easily accessed as an attribute using the dot notation. They are a list of layers, which can be confirmed by checking its type:

```
In [6]: # Check the type of the model's layers
        type(model.layers)
```

```
Out[6]: list
```

```
In [7]: # Print 5 first layers along with their names
        for i in range(5):
            l = model.layers[i]
            print(f"Layer number {i}: \n{l} \nWith name: {l.name} \n")
```

```
Layer number 0:
<keras.engine.topology.InputLayer object at 0x7ff350cece80>
With name: input_1

Layer number 1:
<keras.layers.convolutional.ZeroPadding2D object at 0x7ff350cb00f0>
With name: zero_padding2d_1

Layer number 2:
```

```
<keras.layers.convolutional.Conv2D object at 0x7ff350cb0128>
With name: conv1/conv

Layer number 3:
<keras.layers.normalization.BatchNormalization object at 0x7ff350cb03c8>
With name: conv1/bn

Layer number 4:
<keras.layers.core.Activation object at 0x7ff350a399e8>
With name: conv1/relu
```

Let's check how many layers our model has:

```
In [8]: # Print number of layers in our model
        print(f"The model has {len(model.layers)} layers")
```

```
The model has 428 layers
```

Our main goal is interpreting the representations which the neural net is creating for classifying our images. But as you can see this architecture has many layers.

Actually we are really interested in the representations that the convolutional layers produce because these are the layers that (hopefully) recognize concrete elements within the images. We are also interested in the "concatenate" layers because in our model's arquitecture they concatenate convolutional layers.

Let's check how many of those we have:

```
In [9]: # Number of layers that are of type "Convolutional" or "Concatenate"
        len([l for l in model.layers if ("conv" in str(type(l))) or ("Concatenate" in str(type
```

```
Out[9]: 180
```

This number is still very big to try to interpret each one of these layers individually.

One characteristic of CNN's is that the earlier layers capture low-level features such as edges in an image while the deeper layers capture high-level concepts such as physical features of a "Cat".

Because of this **Grad-CAM usually focuses on the last layers, as they provide a better picture of what the network is paying attention to when classifying a particular class**. Let's grab the last concatenate layer of our model. Luckily Keras API makes this quite easy:

```
In [10]: # Save the desired layer in a variable
         layer = model.layers[424]

         # Print layer
         layer
```

```
Out[10]: <keras.layers.merge.Concatenate at 0x7ff2248889e8>
```

This approach is not the best since we will need to know the exact index of the desired layer. Luckily we can use the `get_layer()` method in conjunction with the layer's name to get the same result.

Remember you can get the name from the information displayed earlier with the `summary()` method.

```
In [11]: # Save the desired layer in a variable
         layer = model.get_layer("conv5_block16_concat")

         # Print layer
         layer

Out[11]: <keras.layers.merge.Concatenate at 0x7ff2248889e8>
```

Let's check what methods and attributes we have available when working with this layer:

```
In [12]: # Printing out methods and attributes for Keras' layer
         print(f"Keras' layers have the following methods and attributes: \n\n{dir(layer)}")

Keras' layers have the following methods and attributes:

['__call__', '__class__', '__delattr__', '__dict__', '__dir__', '__doc__', '__eq__', '__format_
```

Since we want to know the representations which this layer is abstracting from the images we should be interested in the output from this layer. Luckily we have this attribute available:

```
In [13]: # Print layer's output
         layer.output

Out[13]: <tf.Tensor 'conv5_block16_concat/concat:0' shape=(?, ?, ?, 1024) dtype=float32>
```

Do you notice something odd? The shape of this tensor is undefined for some dimensions. This is because this tensor is just a placeholder and it doesn't really contain information about the activations that occurred in this layer.

To compute the actual activation values given an input we will need to use a **Keras function**.

This function accepts lists of input and output placeholders and can be used with an actual input to compute the respective output of the layer associated to the placeholder for that given input.

Before jumping onto the Keras function we should rewind a little bit to get the placeholder tensor associated with the input. You can get this from the model's input:

```
In [14]: # Print model's input tensor placeholder
         model.input

Out[14]: <tf.Tensor 'input_1:0' shape=(?, ?, ?, 3) dtype=float32>
```

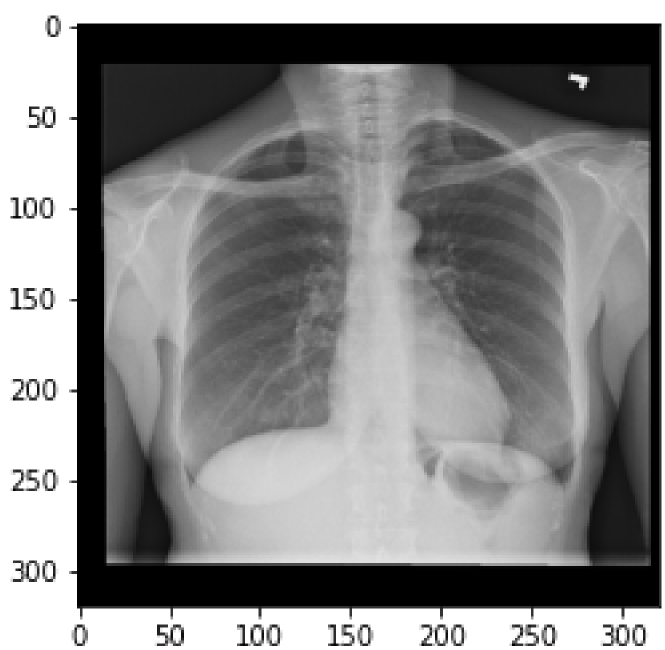
We can see that this is a placeholder as well. Now let's instantiate our Keras function using Keras backend. Please be aware that this **function expects its arguments as lists or tuples**:

```
In [15]: # Instantiate the function to compute the activations of the last convolutional layer
         last_layer_activations_function = K.function([model.input], [layer.output])

         # Print the Keras function
         last_layer_activations_function
```

```
Out[15]: <keras.backend.tensorflow_backend.Function at 0x7ff221316ba8>
```

Let's test the functions for computing the last layer activation which we just defined on a particular image. Don't worry about the code to load the image, this has been taken care of for you. You should only care that an image ready to be processed will be saved in the x variable:

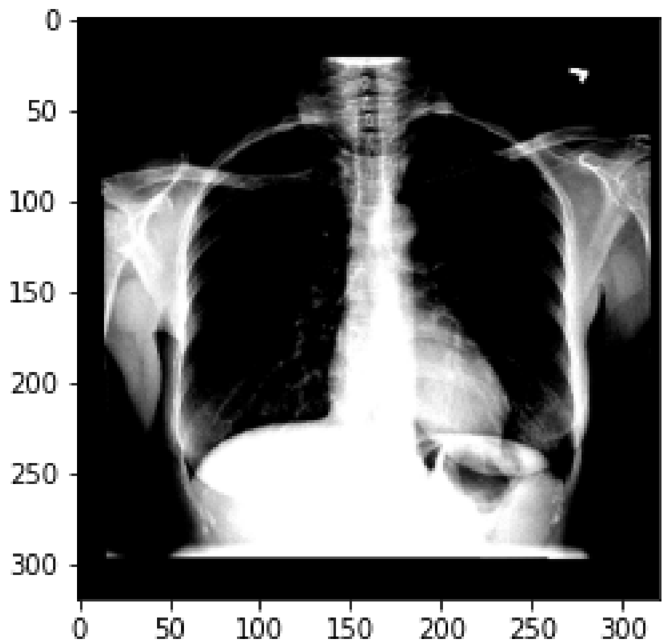
```
In [16]: # Load dataframe that contains information about the dataset of images
         df = pd.read_csv("nih_new/train-small.csv")

         # Path to the actual image
         im_path = 'nih_new/images-small/00000599_000.png'

         # Load the image and save it to a variable
         x = load_image(im_path, df, preprocess=False)

         # Display the image
         plt.imshow(x, cmap = 'gray')
         plt.show()
```



We should normalize this image before going forward, this has also been taken care of:

```
In [17]: # Calculate mean and standard deviation of a batch of images
         mean, std = get_mean_std_per_batch(df)

         # Normalize image
         x = load_image_normalize(im_path, mean, std)
         # Display the image
         plt.imshow(x.squeeze(), cmap = 'gray')
         plt.show()
```

```
Clipping input data to the valid range for imshow with RGB data ([0..1] for floats or [0..255]
```



Now we have everything we need to compute the actual values of the last layer activations. In this case we should also **provide the input as a list or tuple**:

```
In [18]: # Run the function on the image and save it in a variable
         actual_activations = last_layer_activations_function([x])
         actual_activations
```

```
Out[18]: [array([[[[-0.23702383,  0.1054067 , -0.09539237, ...,  0.19466937,
                   -0.07553095,  0.21800742],
                  [-0.3608293 , -0.49694395, -0.8985988 , ...,  0.28263342,
                   -0.08797086,  0.32878476],
                  [-0.2681642 , -0.26400208, -0.89956033, ...,  0.23807381,
                   -0.07753395,  0.271367  ],
                  ...,
                  [-0.3738516 , -0.29830033, -0.8859294 , ...,  0.13269609,
```

```
  -0.09081772,  0.16981669],
 [-0.25935197, -0.05493974, -0.51206   , ...,  0.28128588,
  -0.11679479,  0.32220238],
 [-0.241157  ,  0.23221722, -0.08264475, ...,  0.14615746,
  -0.07138451,  0.21461329]],

[[-0.3868346 ,  0.04625287, -0.48729265, ...,  0.24962625,
  -0.11925422,  0.31549245],
 [-0.17229678, -0.41012964, -0.26488608, ...,  0.4301238 ,
  -0.15064242,  0.493559  ],
 [-0.48088574, -0.47438028, -0.42633063, ...,  0.2581186 ,
  -0.11581598,  0.33084315],
 ...,
 [-0.34574437, -0.6549144 , -0.57052696, ...,  0.15628804,
  -0.10776094,  0.18880478],
 [-0.54574436, -0.9951541 , -0.54874784, ...,  0.32031807,
  -0.13615817,  0.3260019 ],
 [-0.56063986, -0.21032241,  0.00390708, ...,  0.18183768,
  -0.0682081 ,  0.21392506]],

[[-0.4730839 , -0.02347994, -0.43232355, ...,  0.27270523,
  -0.11322275,  0.2432285 ],
 [-1.2484052 , -1.0704248 , -0.3053118 , ...,  0.454308  ,
  -0.1501662 ,  0.35555303],
 [-0.8810173 , -0.6242399 , -0.5386256 , ...,  0.29572266,
  -0.09585512,  0.20475927],
 ...,
 [-1.3751011 ,  0.13930295,  0.23743618, ...,  0.06184677,
  -0.05869364,  0.08984356],
 [-0.8771509 , -0.04209949,  1.1667961 , ...,  0.18854713,
  -0.06257953,  0.15155955],
 [-0.7432046 , -0.19918242,  0.9913299 , ...,  0.0793993 ,
  -0.02839849,  0.08045889]],

...,

[[-0.5960772 , -0.00482173,  0.14680746, ...,  0.3655157 ,
  -0.15409034,  0.48892158],
 [-0.37668312,  0.71335745, -0.031999  , ...,  0.4122941 ,
  -0.1257244 ,  0.73066866],
 [-2.0470808 , -1.2017248 , -0.78999186, ...,  0.19864726,
   0.17223702,  0.8854867 ],
 ...,
 [-2.0258265 , -0.8218878 , -0.6006702 , ...,  0.00795583,
   0.11177041,  1.42233   ],
 [-1.6262685 ,  0.09990728, -0.5643097 , ...,  0.16129252,
  -0.07851787,  1.5067396 ],
 [-0.8862725 ,  0.07348883,  0.32334697, ..., -0.12776697,
```

```
             0.10194322,  1.0539756 ]],

          [[-0.6044072 , -0.0240733 , -0.49380025, ...,  0.28898105,
            -0.15708804,  0.4663337 ],
           [-0.524331  ,  0.13514982, -0.45060417, ...,  0.44769403,
            -0.2381051 ,  0.65325516],
           [-0.44161716,  0.6040169 , -1.5322777 , ...,  0.3392639 ,
            -0.15121244,  0.52864605],
           ...,
           [-0.78013825, -0.0961304 , -1.0196183 , ...,  0.07627262,
            -0.08315185,  0.7585078 ],
           [-0.26460856,  0.41444945, -0.9215252 , ...,  0.29149723,
            -0.22252335,  0.89126205],
           [-0.5027085 , -0.11727619, -0.5962626 , ...,  0.04195292,
            -0.08922879,  0.7027127 ]],

          [[-0.89180255,  0.21321994,  0.496118  , ...,  0.26252916,
            -0.11067075,  0.24559288],
           [-0.9888345 , -0.17132482,  0.3721898 , ...,  0.34661293,
            -0.12382239,  0.3389768 ],
           [-0.65068513, -0.00451049, -0.27235806, ...,  0.2712055 ,
            -0.09665748,  0.28318712],
           ...,
           [-0.5136519 ,  0.70400333, -0.06819835, ...,  0.16268368,
            -0.08299141,  0.24743526],
           [-0.5870072 ,  0.3031031 ,  0.22909215, ...,  0.25060678,
            -0.11670539,  0.30383188],
           [-0.61077654,  0.22875792,  0.54413295, ...,  0.1768849 ,
            -0.05819542,  0.25265226]]]], dtype=float32)]
```

An important intermediary step is to trim the batch dimension which can be done like this. This is necessary because we are applying Grad-CAM to a single image rather than to a batch of images:

```
In [19]: # Remove batch dimension
         actual_activations = actual_activations[0][0, :]
```

```
In [20]: # Print shape of the activation array
         print(f"Activations of last convolutional layer have shape: {actual_activations.shape

         # Print activation array
         actual_activations
```

```
Activations of last convolutional layer have shape: (10, 10, 1024)
```

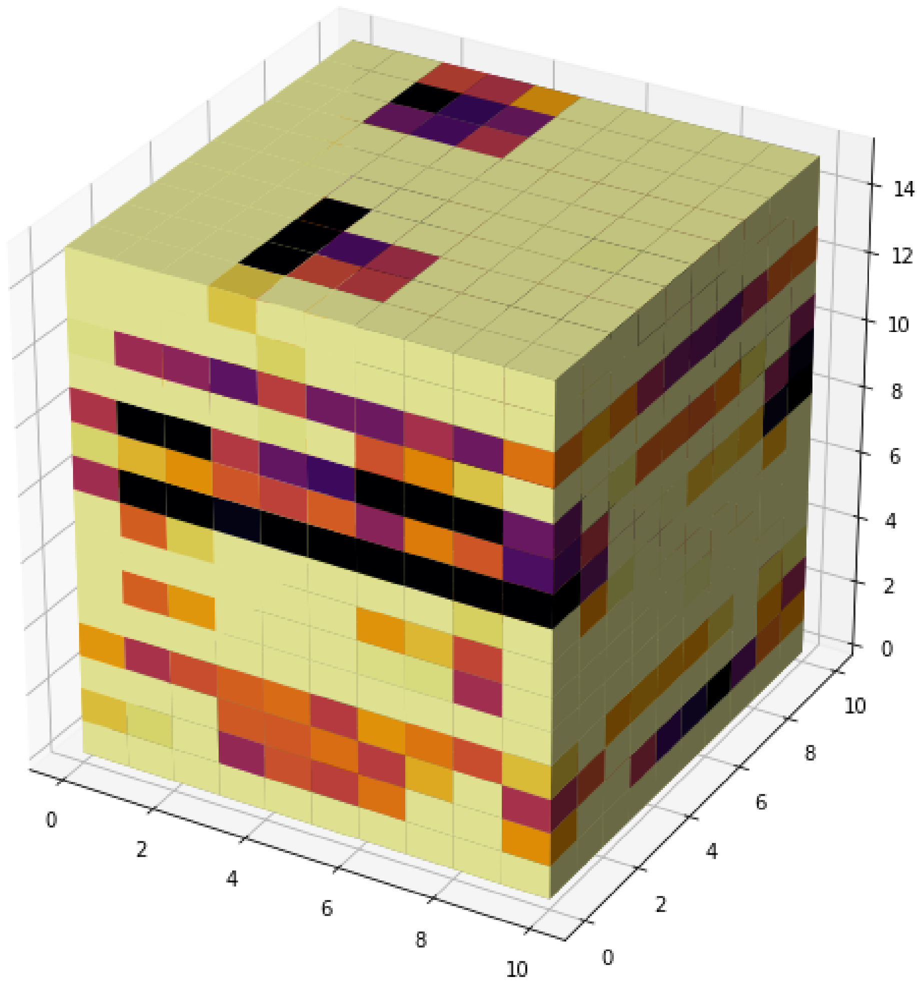
```
Out[20]: array([[[-0.23702383,  0.1054067 , -0.09539237, ...,  0.19466937,
                  -0.07553095,  0.21800742],
                 [-0.3608293 , -0.49694395, -0.8985988 , ...,  0.28263342,
```

```
 -0.08797086,  0.32878476],
[-0.2681642 , -0.26400208, -0.89956033, ...,  0.23807381,
 -0.07753395,  0.271367  ],
...,
[-0.3738516 , -0.29830033, -0.8859294 , ...,  0.13269609,
 -0.09081772,  0.16981669],
[-0.25935197, -0.05493974, -0.51206   , ...,  0.28128588,
 -0.11679479,  0.32220238],
[-0.241157  ,  0.23221722, -0.08264475, ...,  0.14615746,
 -0.07138451,  0.21461329]],

[[-0.3868346 ,  0.04625287, -0.48729265, ...,  0.24962625,
  -0.11925422,  0.31549245],
 [-0.17229678, -0.41012964, -0.26488608, ...,  0.4301238 ,
  -0.15064242,  0.493559  ],
 [-0.48088574, -0.47438028, -0.42633063, ...,  0.2581186 ,
  -0.11581598,  0.33084315],
 ...,
 [-0.34574437, -0.6549144 , -0.57052696, ...,  0.15628804,
  -0.10776094,  0.18880478],
 [-0.54574436, -0.9951541 , -0.54874784, ...,  0.32031807,
  -0.13615817,  0.3260019 ],
 [-0.56063986, -0.21032241,  0.00390708, ...,  0.18183768,
  -0.0682081 ,  0.21392506]],

[[-0.4730839 , -0.02347994, -0.43232355, ...,  0.27270523,
  -0.11322275,  0.2432285 ],
 [-1.2484052 , -1.0704248 , -0.3053118 , ...,  0.454308  ,
  -0.1501662 ,  0.35555303],
 [-0.8810173 , -0.6242399 , -0.5386256 , ...,  0.29572266,
  -0.09585512,  0.20475927],
 ...,
 [-1.3751011 ,  0.13930295,  0.23743618, ...,  0.06184677,
  -0.05869364,  0.08984356],
 [-0.8771509 , -0.04209949,  1.1667961 , ...,  0.18854713,
  -0.06257953,  0.15155955],
 [-0.7432046 , -0.19918242,  0.9913299 , ...,  0.0793993 ,
  -0.02839849,  0.08045889]],

...,

[[-0.5960772 , -0.00482173,  0.14680746, ...,  0.3655157 ,
  -0.15409034,  0.48892158],
 [-0.37668312,  0.71335745, -0.031999  , ...,  0.4122941 ,
  -0.1257244 ,  0.73066866],
 [-2.0470808 , -1.2017248 , -0.78999186, ...,  0.19864726,
   0.17223702,  0.8854867 ],
 ...,
```

```
        [-2.0258265 , -0.8218878 , -0.6006702 , ...,  0.00795583,
          0.11177041,  1.42233   ],
        [-1.6262685 ,  0.09990728, -0.5643097 , ...,  0.16129252,
         -0.07851787,  1.5067396 ],
        [-0.8862725 ,  0.07348883,  0.32334697, ..., -0.12776697,
          0.10194322,  1.0539756 ]],

       [[-0.6044072 , -0.0240733 , -0.49380025, ...,  0.28898105,
         -0.15708804,  0.4663337 ],
        [-0.524331  ,  0.13514982, -0.45060417, ...,  0.44769403,
         -0.2381051 ,  0.65325516],
        [-0.44161716,  0.6040169 , -1.5322777 , ...,  0.3392639 ,
         -0.15121244,  0.52864605],
        ...,
        [-0.78013825, -0.0961304 , -1.0196183 , ...,  0.07627262,
         -0.08315185,  0.7585078 ],
        [-0.26460856,  0.41444945, -0.9215252 , ...,  0.29149723,
         -0.22252335,  0.89126205],
        [-0.5027085 , -0.11727619, -0.5962626 , ...,  0.04195292,
         -0.08922879,  0.7027127 ]],

       [[-0.89180255,  0.21321994,  0.496118  , ...,  0.26252916,
         -0.11067075,  0.24559288],
        [-0.9888345 , -0.17132482,  0.3721898 , ...,  0.34661293,
         -0.12382239,  0.3389768 ],
        [-0.65068513, -0.00451049, -0.27235806, ...,  0.2712055 ,
         -0.09665748,  0.28318712],
        ...,
        [-0.5136519 ,  0.70400333, -0.06819835, ...,  0.16268368,
         -0.08299141,  0.24743526],
        [-0.5870072 ,  0.3031031 ,  0.22909215, ...,  0.25060678,
         -0.11670539,  0.30383188],
        [-0.61077654,  0.22875792,  0.54413295, ...,  0.1768849 ,
         -0.05819542,  0.25265226]]], dtype=float32)
```

In [31]:
```python
print(actual_activations.shape)
from mpl_toolkits.mplot3d import Axes3D
fig = plt.figure(figsize =(10,10))
ax = fig.gca(projection='3d')
cmap = plt.get_cmap("inferno_r")
ax.voxels(actual_activations[:, : , 0:15], facecolors= cmap(actual_activations[: , :
plt.show()
```

```
(10, 10, 1024)
```



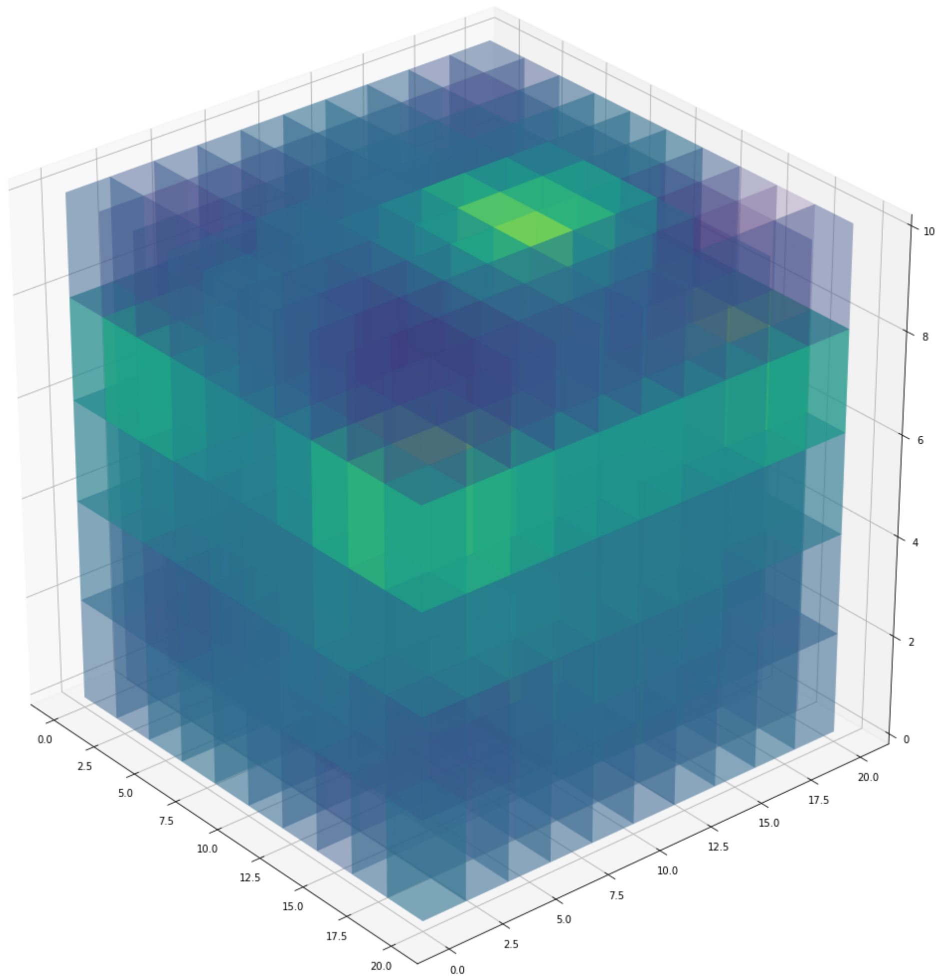
Looks like everything worked out nicely! This is all for this lecture notebook (Grad-CAM Part 1). In Part 2 we will see how to calculate the gradients of the model's output with respect to the activations in this layer. This is the "Grad" part of Grad-CAM.

Congratulations on finishing this lecture notebook! Hopefully you will now have a better understanding of how to leverage Keras's API power for computing activations in specific layers. Keep it up!

In [41]:
```
import numpy as np
from matplotlib import cm

def normalize(arr):
    arr_min = np.min(arr)
    return (arr-arr_min)/(np.max(arr)-arr_min)
def explode(data):
    shape_arr = np.array(data.shape)
```

```
    size = shape_arr[:3]*2 - 1
    exploded = np.zeros(np.concatenate([size, shape_arr[3:]]), dtype=data.dtype)
    exploded[::2, ::2, ::2] = data
    return exploded

def expand_coordinates(indices):
    x, y, z = indices
    x[1::2, :, :] += 1
    y[:, 1::2, :] += 1
    z[:, :, 1::2] += 1
    return x, y, z

def plot_cube(cube, angle=320):
    cube = normalize(cube)

    facecolors = cm.viridis(cube)
    facecolors[:,:,:,-1] = cube
    facecolors = explode(facecolors)

    filled = facecolors[:,:,:,-1] != 0
    x, y, z = expand_coordinates(np.indices(np.array(filled.shape) + 1))

    fig = plt.figure(figsize=(20, 20))
    ax = fig.gca(projection='3d')
    ax.view_init(30, angle)
    #ax.set_xlim(right=10*2)
    #ax.set_ylim(top=10*2)
    #ax.set_zlim(top=10*2)

    ax.voxels(x, y, z, filled, facecolors=facecolors, shade=False)
    plt.show()
```

In [44]:
```
plot_cube(actual_activations[:,:,1000:1005])
```



0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
0
2
4
6
8
10