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 [1]:  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 [2]:  # 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 [3]:  # Print all of the model's layers
         model.summary()
```

```
_____

_____
Layer (type)                    Output Shape          Param #        C
onnected to
============================================================================
==============================
input_1 (InputLayer)            (None, None, None, 3 0

_____
zero_padding2d_1 (ZeroPadding2D (None, None, None, 3 0              i
nput_1[0][0]

_____
conv1/conv (Conv2D)             (None, None, None, 6 9408           z
ero_padding2d_1[0][0]

_____
conv1/bn (BatchNormalization)   (None, None, None, 6 256            c
onv1/conv[0][0]

_____
conv1/relu (Activation)         (None, None, None, 6 0              c
onv1/bn[0][0]

_____
zero_padding2d_2 (ZeroPadding2D (None, None, None, 6 0              c
onv1/relu[0][0]

_____
pool1 (MaxPooling2D)            (None, None, None, 6 0              z
ero_padding2d_2[0][0]

_____
conv2_block1_0_bn (BatchNormali (None, None, None, 6 256            p
ool1[0][0]

_____
conv2_block1_0_relu (Activation (None, None, None, 6 0              c
onv2_block1_0_bn[0][0]

_____
conv2_block1_1_conv (Conv2D)    (None, None, None, 1 8192           c
onv2_block1_0_relu[0][0]

_____
conv2_block1_1_bn (BatchNormali (None, None, None, 1 512            c
onv2_block1_1_conv[0][0]

_____
conv2_block1_1_relu (Activation (None, None, None, 1 0              c
onv2_block1_1_bn[0][0]

_____
conv2_block1_2_conv (Conv2D)    (None, None, None, 3 36864          c
```

onv2_block1_1_relu[0][0]

_____

conv2_block1_concat (Concatenat (None, None, None, 9 0   p
ool1[0][0]

                                                          c
onv2_block1_2_conv[0][0]

_____

conv2_block2_0_bn (BatchNormali (None, None, None, 9 384   c
onv2_block1_concat[0][0]

_____

conv2_block2_0_relu (Activation (None, None, None, 9 0   c
onv2_block2_0_bn[0][0]

_____

conv2_block2_1_conv (Conv2D)   (None, None, None, 1 12288   c
onv2_block2_0_relu[0][0]

_____

conv2_block2_1_bn (BatchNormali (None, None, None, 1 512   c
onv2_block2_1_conv[0][0]

_____

conv2_block2_1_relu (Activation (None, None, None, 1 0   c
onv2_block2_1_bn[0][0]

_____

conv2_block2_2_conv (Conv2D)   (None, None, None, 3 36864   c
onv2_block2_1_relu[0][0]

_____

conv2_block2_concat (Concatenat (None, None, None, 1 0   c
onv2_block1_concat[0][0]

                                                          c
onv2_block2_2_conv[0][0]

_____

conv2_block3_0_bn (BatchNormali (None, None, None, 1 512   c
onv2_block2_concat[0][0]

_____

conv2_block3_0_relu (Activation (None, None, None, 1 0   c
onv2_block3_0_bn[0][0]

_____

conv2_block3_1_conv (Conv2D)   (None, None, None, 1 16384   c
onv2_block3_0_relu[0][0]

_____

conv2_block3_1_bn (BatchNormali (None, None, None, 1 512   c
onv2_block3_1_conv[0][0]

conv2_block3_1_relu (Activation	(None, None, None, 1	0	c
onv2_block3_1_bn[0][0]			

conv2_block3_2_conv (Conv2D)	(None, None, None, 3	36864	c
onv2_block3_1_relu[0][0]			

conv2_block3_concat (Concatenat	(None, None, None, 1	0	c
onv2_block2_concat[0][0]			
			c
onv2_block3_2_conv[0][0]			

conv2_block4_0_bn (BatchNormali	(None, None, None, 1	640	c
onv2_block3_concat[0][0]			

conv2_block4_0_relu (Activation	(None, None, None, 1	0	c
onv2_block4_0_bn[0][0]			

conv2_block4_1_conv (Conv2D)	(None, None, None, 1	20480	c
onv2_block4_0_relu[0][0]			

conv2_block4_1_bn (BatchNormali	(None, None, None, 1	512	c
onv2_block4_1_conv[0][0]			

conv2_block4_1_relu (Activation	(None, None, None, 1	0	c
onv2_block4_1_bn[0][0]			

conv2_block4_2_conv (Conv2D)	(None, None, None, 3	36864	c
onv2_block4_1_relu[0][0]			

conv2_block4_concat (Concatenat	(None, None, None, 1	0	c
onv2_block3_concat[0][0]			
			c
onv2_block4_2_conv[0][0]			

conv2_block5_0_bn (BatchNormali	(None, None, None, 1	768	c
onv2_block4_concat[0][0]			

conv2_block5_0_relu (Activation	(None, None, None, 1	0	c
onv2_block5_0_bn[0][0]			

conv2_block5_1_conv (Conv2D) onv2_block5_0_relu[0][0]	(None, None, None, 1 24576	c
conv2_block5_1_bn (BatchNormali onv2_block5_1_conv[0][0]	(None, None, None, 1 512	c
conv2_block5_1_relu (Activation onv2_block5_1_bn[0][0]	(None, None, None, 1 0	c
conv2_block5_2_conv (Conv2D) onv2_block5_1_relu[0][0]	(None, None, None, 3 36864	c
conv2_block5_concat (Concatenat onv2_block4_concat[0][0] onv2_block5_2_conv[0][0]	(None, None, None, 2 0	c c
conv2_block6_0_bn (BatchNormali onv2_block5_concat[0][0]	(None, None, None, 2 896	c
conv2_block6_0_relu (Activation onv2_block6_0_bn[0][0]	(None, None, None, 2 0	c
conv2_block6_1_conv (Conv2D) onv2_block6_0_relu[0][0]	(None, None, None, 1 28672	c
conv2_block6_1_bn (BatchNormali onv2_block6_1_conv[0][0]	(None, None, None, 1 512	c
conv2_block6_1_relu (Activation onv2_block6_1_bn[0][0]	(None, None, None, 1 0	c
conv2_block6_2_conv (Conv2D) onv2_block6_1_relu[0][0]	(None, None, None, 3 36864	c
conv2_block6_concat (Concatenat onv2_block5_concat[0][0] onv2_block6_2_conv[0][0]	(None, None, None, 2 0	c c

pool2_bn (BatchNormalization) onv2_block6_concat[0][0]	(None, None, None, 2	1024	c
pool2_relu (Activation) ool2_bn[0][0]	(None, None, None, 2	0	p
pool2_conv (Conv2D) ool2_relu[0][0]	(None, None, None, 1	32768	p
pool2_pool (AveragePooling2D) ool2_conv[0][0]	(None, None, None, 1	0	p
conv3_block1_0_bn (BatchNormali ool2_pool[0][0]	(None, None, None, 1	512	p
conv3_block1_0_relu (Activation onv3_block1_0_bn[0][0]	(None, None, None, 1	0	c
conv3_block1_1_conv (Conv2D) onv3_block1_0_relu[0][0]	(None, None, None, 1	16384	c
conv3_block1_1_bn (BatchNormali onv3_block1_1_conv[0][0]	(None, None, None, 1	512	c
conv3_block1_1_relu (Activation onv3_block1_1_bn[0][0]	(None, None, None, 1	0	c
conv3_block1_2_conv (Conv2D) onv3_block1_1_relu[0][0]	(None, None, None, 3	36864	c
conv3_block1_concat (Concatenat ool2_pool[0][0] onv3_block1_2_conv[0][0]	(None, None, None, 1	0	p c
conv3_block2_0_bn (BatchNormali onv3_block1_concat[0][0]	(None, None, None, 1	640	c
conv3_block2_0_relu (Activation onv3_block2_0_bn[0][0]	(None, None, None, 1	0	c

conv3_block2_1_conv (Conv2D) onv3_block2_0_relu[0][0]	(None, None, None, 1 20480	c
conv3_block2_1_bn (BatchNormali onv3_block2_1_conv[0][0]	(None, None, None, 1 512	c
conv3_block2_1_relu (Activation onv3_block2_1_bn[0][0]	(None, None, None, 1 0	c
conv3_block2_2_conv (Conv2D) onv3_block2_1_relu[0][0]	(None, None, None, 3 36864	c
conv3_block2_concat (Concatenat onv3_block1_concat[0][0]	(None, None, None, 1 0	c c
onv3_block2_2_conv[0][0]		
conv3_block3_0_bn (BatchNormali onv3_block2_concat[0][0]	(None, None, None, 1 768	c
conv3_block3_0_relu (Activation onv3_block3_0_bn[0][0]	(None, None, None, 1 0	c
conv3_block3_1_conv (Conv2D) onv3_block3_0_relu[0][0]	(None, None, None, 1 24576	c
conv3_block3_1_bn (BatchNormali onv3_block3_1_conv[0][0]	(None, None, None, 1 512	c
conv3_block3_1_relu (Activation onv3_block3_1_bn[0][0]	(None, None, None, 1 0	c
conv3_block3_2_conv (Conv2D) onv3_block3_1_relu[0][0]	(None, None, None, 3 36864	c
conv3_block3_concat (Concatenat onv3_block2_concat[0][0]	(None, None, None, 2 0	c c
onv3_block3_2_conv[0][0]		

conv3_block4_0_bn (BatchNormali onv3_block3_concat[0][0]	(None, None, None, 2	896		c
conv3_block4_0_relu (Activation onv3_block4_0_bn[0][0]	(None, None, None, 2	0		c
conv3_block4_1_conv (Conv2D) onv3_block4_0_relu[0][0]	(None, None, None, 1	28672		c
conv3_block4_1_bn (BatchNormali onv3_block4_1_conv[0][0]	(None, None, None, 1	512		c
conv3_block4_1_relu (Activation onv3_block4_1_bn[0][0]	(None, None, None, 1	0		c
conv3_block4_2_conv (Conv2D) onv3_block4_1_relu[0][0]	(None, None, None, 3	36864		c
conv3_block4_concat (Concatenat onv3_block3_concat[0][0]	(None, None, None, 2	0		c
onv3_block4_2_conv[0][0]				c
conv3_block5_0_bn (BatchNormali onv3_block4_concat[0][0]	(None, None, None, 2	1024		c
conv3_block5_0_relu (Activation onv3_block5_0_bn[0][0]	(None, None, None, 2	0		c
conv3_block5_1_conv (Conv2D) onv3_block5_0_relu[0][0]	(None, None, None, 1	32768		c
conv3_block5_1_bn (BatchNormali onv3_block5_1_conv[0][0]	(None, None, None, 1	512		c
conv3_block5_1_relu (Activation onv3_block5_1_bn[0][0]	(None, None, None, 1	0		c
conv3_block5_2_conv (Conv2D) onv3_block5_1_relu[0][0]	(None, None, None, 3	36864		c

```
conv3_block5_concat (Concatenat (None, None, None, 2 0          c
onv3_block4_concat[0][0]
                                                               c
onv3_block5_2_conv[0][0]


conv3_block6_0_bn (BatchNormali (None, None, None, 2 1152       c
onv3_block5_concat[0][0]


conv3_block6_0_relu (Activation (None, None, None, 2 0          c
onv3_block6_0_bn[0][0]


conv3_block6_1_conv (Conv2D)    (None, None, None, 1 36864      c
onv3_block6_0_relu[0][0]


conv3_block6_1_bn (BatchNormali (None, None, None, 1 512        c
onv3_block6_1_conv[0][0]


conv3_block6_1_relu (Activation (None, None, None, 1 0          c
onv3_block6_1_bn[0][0]


conv3_block6_2_conv (Conv2D)    (None, None, None, 3 36864      c
onv3_block6_1_relu[0][0]


conv3_block6_concat (Concatenat (None, None, None, 3 0          c
onv3_block5_concat[0][0]
                                                               c
onv3_block6_2_conv[0][0]


conv3_block7_0_bn (BatchNormali (None, None, None, 3 1280       c
onv3_block6_concat[0][0]


conv3_block7_0_relu (Activation (None, None, None, 3 0          c
onv3_block7_0_bn[0][0]


conv3_block7_1_conv (Conv2D)    (None, None, None, 1 40960      c
onv3_block7_0_relu[0][0]


conv3_block7_1_bn (BatchNormali (None, None, None, 1 512        c
onv3_block7_1_conv[0][0]
```

```
conv3_block7_1_relu (Activation  (None, None, None, 1 0          c
onv3_block7_1_bn[0][0]
_____

conv3_block7_2_conv (Conv2D)     (None, None, None, 3 36864      c
onv3_block7_1_relu[0][0]
_____

conv3_block7_concat (Concatenat  (None, None, None, 3 0          c
onv3_block6_concat[0][0]
                                                                 c
onv3_block7_2_conv[0][0]
_____

conv3_block8_0_bn (BatchNormali  (None, None, None, 3 1408       c
onv3_block7_concat[0][0]
_____

conv3_block8_0_relu (Activation  (None, None, None, 3 0          c
onv3_block8_0_bn[0][0]
_____

conv3_block8_1_conv (Conv2D)     (None, None, None, 1 45056      c
onv3_block8_0_relu[0][0]
_____

conv3_block8_1_bn (BatchNormali  (None, None, None, 1 512        c
onv3_block8_1_conv[0][0]
_____

conv3_block8_1_relu (Activation  (None, None, None, 1 0          c
onv3_block8_1_bn[0][0]
_____

conv3_block8_2_conv (Conv2D)     (None, None, None, 3 36864      c
onv3_block8_1_relu[0][0]
_____

conv3_block8_concat (Concatenat  (None, None, None, 3 0          c
onv3_block7_concat[0][0]
                                                                 c
onv3_block8_2_conv[0][0]
_____

conv3_block9_0_bn (BatchNormali  (None, None, None, 3 1536       c
onv3_block8_concat[0][0]
_____

conv3_block9_0_relu (Activation  (None, None, None, 3 0          c
onv3_block9_0_bn[0][0]
_____

conv3_block9_1_conv (Conv2D)     (None, None, None, 1 49152      c
```

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                                                  onv3_block9_0_relu[0][0]
_____
conv3_block9_1_bn (BatchNormali (None, None, None, 1 512         c
onv3_block9_1_conv[0][0]
_____
conv3_block9_1_relu (Activation (None, None, None, 1 0           c
onv3_block9_1_bn[0][0]
_____
conv3_block9_2_conv (Conv2D)    (None, None, None, 3 36864       c
onv3_block9_1_relu[0][0]
_____
conv3_block9_concat (Concatenat (None, None, None, 4 0           c
onv3_block8_concat[0][0]
                                                                 c
onv3_block9_2_conv[0][0]
_____
conv3_block10_0_bn (BatchNormal (None, None, None, 4 1664        c
onv3_block9_concat[0][0]
_____
conv3_block10_0_relu (Activatio (None, None, None, 4 0           c
onv3_block10_0_bn[0][0]
_____
conv3_block10_1_conv (Conv2D)   (None, None, None, 1 53248       c
onv3_block10_0_relu[0][0]
_____
conv3_block10_1_bn (BatchNormal (None, None, None, 1 512         c
onv3_block10_1_conv[0][0]
_____
conv3_block10_1_relu (Activatio (None, None, None, 1 0           c
onv3_block10_1_bn[0][0]
_____
conv3_block10_2_conv (Conv2D)   (None, None, None, 3 36864       c
onv3_block10_1_relu[0][0]
_____
conv3_block10_concat (Concatena (None, None, None, 4 0           c
onv3_block9_concat[0][0]
                                                                 c
onv3_block10_2_conv[0][0]
_____
conv3_block11_0_bn (BatchNormal (None, None, None, 4 1792        c
onv3_block10_concat[0][0]
```

```
conv3_block11_0_relu (Activatio (None, None, None, 4 0          c
onv3_block11_0_bn[0][0]


conv3_block11_1_conv (Conv2D)   (None, None, None, 1 57344      c
onv3_block11_0_relu[0][0]


conv3_block11_1_bn (BatchNormal (None, None, None, 1 512        c
onv3_block11_1_conv[0][0]


conv3_block11_1_relu (Activatio (None, None, None, 1 0          c
onv3_block11_1_bn[0][0]


conv3_block11_2_conv (Conv2D)   (None, None, None, 3 36864      c
onv3_block11_1_relu[0][0]


conv3_block11_concat (Concatena (None, None, None, 4 0          c
onv3_block10_concat[0][0]
                                                               c
onv3_block11_2_conv[0][0]


conv3_block12_0_bn (BatchNormal (None, None, None, 4 1920       c
onv3_block11_concat[0][0]


conv3_block12_0_relu (Activatio (None, None, None, 4 0          c
onv3_block12_0_bn[0][0]


conv3_block12_1_conv (Conv2D)   (None, None, None, 1 61440      c
onv3_block12_0_relu[0][0]


conv3_block12_1_bn (BatchNormal (None, None, None, 1 512        c
onv3_block12_1_conv[0][0]


conv3_block12_1_relu (Activatio (None, None, None, 1 0          c
onv3_block12_1_bn[0][0]


conv3_block12_2_conv (Conv2D)   (None, None, None, 3 36864      c
onv3_block12_1_relu[0][0]


conv3_block12_concat (Concatena (None, None, None, 5 0          c
```

```
onv3_block11_concat[0][0]
                                                                                    c
onv3_block12_2_conv[0][0]
```

| pool3_bn (BatchNormalization) | (None, None, None, 5 2048 | c |
| onv3_block12_concat[0][0] | | |

| pool3_relu (Activation) | (None, None, None, 5 0 | p |
| ool3_bn[0][0] | | |

| pool3_conv (Conv2D) | (None, None, None, 2 131072 | p |
| ool3_relu[0][0] | | |

| pool3_pool (AveragePooling2D) | (None, None, None, 2 0 | p |
| ool3_conv[0][0] | | |

| conv4_block1_0_bn (BatchNormali | (None, None, None, 2 1024 | p |
| ool3_pool[0][0] | | |

| conv4_block1_0_relu (Activation | (None, None, None, 2 0 | c |
| onv4_block1_0_bn[0][0] | | |

| conv4_block1_1_conv (Conv2D) | (None, None, None, 1 32768 | c |
| onv4_block1_0_relu[0][0] | | |

| conv4_block1_1_bn (BatchNormali | (None, None, None, 1 512 | c |
| onv4_block1_1_conv[0][0] | | |

| conv4_block1_1_relu (Activation | (None, None, None, 1 0 | c |
| onv4_block1_1_bn[0][0] | | |

| conv4_block1_2_conv (Conv2D) | (None, None, None, 3 36864 | c |
| onv4_block1_1_relu[0][0] | | |

conv4_block1_concat (Concatenat	(None, None, None, 2 0	p
ool3_pool[0][0]		
		c
onv4_block1_2_conv[0][0]		

| conv4_block2_0_bn (BatchNormali | (None, None, None, 2 1152 | c |
| onv4_block1_concat[0][0] | | |

conv4_block2_0_relu (Activation onv4_block2_0_bn[0][0]	(None, None, None, 2	0	c
conv4_block2_1_conv (Conv2D) onv4_block2_0_relu[0][0]	(None, None, None, 1	36864	c
conv4_block2_1_bn (BatchNormali onv4_block2_1_conv[0][0]	(None, None, None, 1	512	c
conv4_block2_1_relu (Activation onv4_block2_1_bn[0][0]	(None, None, None, 1	0	c
conv4_block2_2_conv (Conv2D) onv4_block2_1_relu[0][0]	(None, None, None, 3	36864	c
conv4_block2_concat (Concatenat onv4_block1_concat[0][0]	(None, None, None, 3	0	c
onv4_block2_2_conv[0][0]			c
conv4_block3_0_bn (BatchNormali onv4_block2_concat[0][0]	(None, None, None, 3	1280	c
conv4_block3_0_relu (Activation onv4_block3_0_bn[0][0]	(None, None, None, 3	0	c
conv4_block3_1_conv (Conv2D) onv4_block3_0_relu[0][0]	(None, None, None, 1	40960	c
conv4_block3_1_bn (BatchNormali onv4_block3_1_conv[0][0]	(None, None, None, 1	512	c
conv4_block3_1_relu (Activation onv4_block3_1_bn[0][0]	(None, None, None, 1	0	c
conv4_block3_2_conv (Conv2D) onv4_block3_1_relu[0][0]	(None, None, None, 3	36864	c
conv4_block3_concat (Concatenat	(None, None, None, 3	0	c

```
                                                                                                c
onv4_block2_concat[0][0]

onv4_block3_2_conv[0][0]
_____

conv4_block4_0_bn (BatchNormali  (None, None, None, 3 1408        c
onv4_block3_concat[0][0]
_____

conv4_block4_0_relu (Activation  (None, None, None, 3 0          c
onv4_block4_0_bn[0][0]
_____

conv4_block4_1_conv (Conv2D)     (None, None, None, 1 45056      c
onv4_block4_0_relu[0][0]
_____

conv4_block4_1_bn (BatchNormali  (None, None, None, 1 512        c
onv4_block4_1_conv[0][0]
_____

conv4_block4_1_relu (Activation  (None, None, None, 1 0          c
onv4_block4_1_bn[0][0]
_____

conv4_block4_2_conv (Conv2D)     (None, None, None, 3 36864      c
onv4_block4_1_relu[0][0]
_____

conv4_block4_concat (Concatenat  (None, None, None, 3 0          c
onv4_block3_concat[0][0]
                                                                                                c
onv4_block4_2_conv[0][0]
_____

conv4_block5_0_bn (BatchNormali  (None, None, None, 3 1536        c
onv4_block4_concat[0][0]
_____

conv4_block5_0_relu (Activation  (None, None, None, 3 0          c
onv4_block5_0_bn[0][0]
_____

conv4_block5_1_conv (Conv2D)     (None, None, None, 1 49152      c
onv4_block5_0_relu[0][0]
_____

conv4_block5_1_bn (BatchNormali  (None, None, None, 1 512        c
onv4_block5_1_conv[0][0]
_____

conv4_block5_1_relu (Activation  (None, None, None, 1 0          c
onv4_block5_1_bn[0][0]
```

| conv4_block5_2_conv (Conv2D) | (None, None, None, 3 | 36864 | c |
| onv4_block5_1_relu[0][0] | | | |

conv4_block5_concat (Concatenat	(None, None, None, 4	0	c
onv4_block4_concat[0][0]			
			c
onv4_block5_2_conv[0][0]			

| conv4_block6_0_bn (BatchNormali | (None, None, None, 4 | 1664 | c |
| onv4_block5_concat[0][0] | | | |

| conv4_block6_0_relu (Activation | (None, None, None, 4 | 0 | c |
| onv4_block6_0_bn[0][0] | | | |

| conv4_block6_1_conv (Conv2D) | (None, None, None, 1 | 53248 | c |
| onv4_block6_0_relu[0][0] | | | |

| conv4_block6_1_bn (BatchNormali | (None, None, None, 1 | 512 | c |
| onv4_block6_1_conv[0][0] | | | |

| conv4_block6_1_relu (Activation | (None, None, None, 1 | 0 | c |
| onv4_block6_1_bn[0][0] | | | |

| conv4_block6_2_conv (Conv2D) | (None, None, None, 3 | 36864 | c |
| onv4_block6_1_relu[0][0] | | | |

conv4_block6_concat (Concatenat	(None, None, None, 4	0	c
onv4_block5_concat[0][0]			
			c
onv4_block6_2_conv[0][0]			

| conv4_block7_0_bn (BatchNormali | (None, None, None, 4 | 1792 | c |
| onv4_block6_concat[0][0] | | | |

| conv4_block7_0_relu (Activation | (None, None, None, 4 | 0 | c |
| onv4_block7_0_bn[0][0] | | | |

| conv4_block7_1_conv (Conv2D) | (None, None, None, 1 | 57344 | c |
| onv4_block7_0_relu[0][0] | | | |

```
conv4_block7_1_bn (BatchNormali  (None, None, None, 1 512                    c
onv4_block7_1_conv[0][0]
```

```
conv4_block7_1_relu (Activation  (None, None, None, 1 0                      c
onv4_block7_1_bn[0][0]
```

```
conv4_block7_2_conv (Conv2D)     (None, None, None, 3 36864                  c
onv4_block7_1_relu[0][0]
```

```
conv4_block7_concat (Concatenat  (None, None, None, 4 0                      c
onv4_block6_concat[0][0]
                                                                            c
onv4_block7_2_conv[0][0]
```

```
conv4_block8_0_bn (BatchNormali  (None, None, None, 4 1920                   c
onv4_block7_concat[0][0]
```

```
conv4_block8_0_relu (Activation  (None, None, None, 4 0                      c
onv4_block8_0_bn[0][0]
```

```
conv4_block8_1_conv (Conv2D)     (None, None, None, 1 61440                  c
onv4_block8_0_relu[0][0]
```

```
conv4_block8_1_bn (BatchNormali  (None, None, None, 1 512                    c
onv4_block8_1_conv[0][0]
```

```
conv4_block8_1_relu (Activation  (None, None, None, 1 0                      c
onv4_block8_1_bn[0][0]
```

```
conv4_block8_2_conv (Conv2D)     (None, None, None, 3 36864                  c
onv4_block8_1_relu[0][0]
```

```
conv4_block8_concat (Concatenat  (None, None, None, 5 0                      c
onv4_block7_concat[0][0]
                                                                            c
onv4_block8_2_conv[0][0]
```

```
conv4_block9_0_bn (BatchNormali  (None, None, None, 5 2048                   c
onv4_block8_concat[0][0]
```

conv4_block9_0_relu (Activation onv4_block9_0_bn[0][0]	(None, None, None, 5	0	c

conv4_block9_1_conv (Conv2D) onv4_block9_0_relu[0][0]	(None, None, None, 1	65536	c

conv4_block9_1_bn (BatchNormali onv4_block9_1_conv[0][0]	(None, None, None, 1	512	c

conv4_block9_1_relu (Activation onv4_block9_1_bn[0][0]	(None, None, None, 1	0	c

conv4_block9_2_conv (Conv2D) onv4_block9_1_relu[0][0]	(None, None, None, 3	36864	c

conv4_block9_concat (Concatenat onv4_block8_concat[0][0] onv4_block9_2_conv[0][0]	(None, None, None, 5	0	c c

conv4_block10_0_bn (BatchNormal onv4_block9_concat[0][0]	(None, None, None, 5	2176	c

conv4_block10_0_relu (Activatio onv4_block10_0_bn[0][0]	(None, None, None, 5	0	c

conv4_block10_1_conv (Conv2D) onv4_block10_0_relu[0][0]	(None, None, None, 1	69632	c

conv4_block10_1_bn (BatchNormal onv4_block10_1_conv[0][0]	(None, None, None, 1	512	c

conv4_block10_1_relu (Activatio onv4_block10_1_bn[0][0]	(None, None, None, 1	0	c

conv4_block10_2_conv (Conv2D) onv4_block10_1_relu[0][0]	(None, None, None, 3	36864	c

conv4_block10_concat (Concatena onv4_block9_concat[0][0]	(None, None, None, 5	0	c c

```
                                                   onv4_block10_2_conv[0][0]


conv4_block11_0_bn (BatchNormal (None, None, None, 5 2304              c
onv4_block10_concat[0][0]


conv4_block11_0_relu (Activatio (None, None, None, 5 0                 c
onv4_block11_0_bn[0][0]


conv4_block11_1_conv (Conv2D)   (None, None, None, 1 73728             c
onv4_block11_0_relu[0][0]


conv4_block11_1_bn (BatchNormal (None, None, None, 1 512               c
onv4_block11_1_conv[0][0]


conv4_block11_1_relu (Activatio (None, None, None, 1 0                 c
onv4_block11_1_bn[0][0]


conv4_block11_2_conv (Conv2D)   (None, None, None, 3 36864             c
onv4_block11_1_relu[0][0]


conv4_block11_concat (Concatena (None, None, None, 6 0                 c
onv4_block10_concat[0][0]
                                                                      c
onv4_block11_2_conv[0][0]


conv4_block12_0_bn (BatchNormal (None, None, None, 6 2432              c
onv4_block11_concat[0][0]


conv4_block12_0_relu (Activatio (None, None, None, 6 0                 c
onv4_block12_0_bn[0][0]


conv4_block12_1_conv (Conv2D)   (None, None, None, 1 77824             c
onv4_block12_0_relu[0][0]


conv4_block12_1_bn (BatchNormal (None, None, None, 1 512               c
onv4_block12_1_conv[0][0]


conv4_block12_1_relu (Activatio (None, None, None, 1 0                 c
onv4_block12_1_bn[0][0]
```

```
conv4_block12_2_conv (Conv2D)     (None, None, None, 3 36864        c
onv4_block12_1_relu[0][0]
```

```
conv4_block12_concat (Concatena (None, None, None, 6 0            c
onv4_block11_concat[0][0]
                                                                c
onv4_block12_2_conv[0][0]
```

```
conv4_block13_0_bn (BatchNormal (None, None, None, 6 2560         c
onv4_block12_concat[0][0]
```

```
conv4_block13_0_relu (Activatio (None, None, None, 6 0            c
onv4_block13_0_bn[0][0]
```

```
conv4_block13_1_conv (Conv2D)     (None, None, None, 1 81920       c
onv4_block13_0_relu[0][0]
```

```
conv4_block13_1_bn (BatchNormal (None, None, None, 1 512          c
onv4_block13_1_conv[0][0]
```

```
conv4_block13_1_relu (Activatio (None, None, None, 1 0            c
onv4_block13_1_bn[0][0]
```

```
conv4_block13_2_conv (Conv2D)     (None, None, None, 3 36864       c
onv4_block13_1_relu[0][0]
```

```
conv4_block13_concat (Concatena (None, None, None, 6 0            c
onv4_block12_concat[0][0]
                                                                c
onv4_block13_2_conv[0][0]
```

```
conv4_block14_0_bn (BatchNormal (None, None, None, 6 2688         c
onv4_block13_concat[0][0]
```

```
conv4_block14_0_relu (Activatio (None, None, None, 6 0            c
onv4_block14_0_bn[0][0]
```

```
conv4_block14_1_conv (Conv2D)     (None, None, None, 1 86016       c
onv4_block14_0_relu[0][0]
```

```
conv4_block14_1_bn (BatchNormal (None, None, None, 1 512          c
```

onv4_block14_1_conv[0][0]

_____

conv4_block14_1_relu (Activatio (None, None, None, 1 0   c
onv4_block14_1_bn[0][0]

_____

conv4_block14_2_conv (Conv2D)   (None, None, None, 3 36864   c
onv4_block14_1_relu[0][0]

_____

conv4_block14_concat (Concatena (None, None, None, 7 0   c
onv4_block13_concat[0][0]
                                                                  c

onv4_block14_2_conv[0][0]

_____

conv4_block15_0_bn (BatchNormal (None, None, None, 7 2816   c
onv4_block14_concat[0][0]

_____

conv4_block15_0_relu (Activatio (None, None, None, 7 0   c
onv4_block15_0_bn[0][0]

_____

conv4_block15_1_conv (Conv2D)   (None, None, None, 1 90112   c
onv4_block15_0_relu[0][0]

_____

conv4_block15_1_bn (BatchNormal (None, None, None, 1 512   c
onv4_block15_1_conv[0][0]

_____

conv4_block15_1_relu (Activatio (None, None, None, 1 0   c
onv4_block15_1_bn[0][0]

_____

conv4_block15_2_conv (Conv2D)   (None, None, None, 3 36864   c
onv4_block15_1_relu[0][0]

_____

conv4_block15_concat (Concatena (None, None, None, 7 0   c
onv4_block14_concat[0][0]
                                                                  c

onv4_block15_2_conv[0][0]

_____

conv4_block16_0_bn (BatchNormal (None, None, None, 7 2944   c
onv4_block15_concat[0][0]

_____

conv4_block16_0_relu (Activatio (None, None, None, 7 0   c
onv4_block16_0_bn[0][0]

conv4_block16_1_conv (Conv2D) onv4_block16_0_relu[0][0]	(None, None, None, 1 94208	c
conv4_block16_1_bn (BatchNormal onv4_block16_1_conv[0][0]	(None, None, None, 1 512	c
conv4_block16_1_relu (Activatio onv4_block16_1_bn[0][0]	(None, None, None, 1 0	c
conv4_block16_2_conv (Conv2D) onv4_block16_1_relu[0][0]	(None, None, None, 3 36864	c
conv4_block16_concat (Concatena onv4_block15_concat[0][0] onv4_block16_2_conv[0][0]	(None, None, None, 7 0	c c
conv4_block17_0_bn (BatchNormal onv4_block16_concat[0][0]	(None, None, None, 7 3072	c
conv4_block17_0_relu (Activatio onv4_block17_0_bn[0][0]	(None, None, None, 7 0	c
conv4_block17_1_conv (Conv2D) onv4_block17_0_relu[0][0]	(None, None, None, 1 98304	c
conv4_block17_1_bn (BatchNormal onv4_block17_1_conv[0][0]	(None, None, None, 1 512	c
conv4_block17_1_relu (Activatio onv4_block17_1_bn[0][0]	(None, None, None, 1 0	c
conv4_block17_2_conv (Conv2D) onv4_block17_1_relu[0][0]	(None, None, None, 3 36864	c
conv4_block17_concat (Concatena onv4_block16_concat[0][0] onv4_block17_2_conv[0][0]	(None, None, None, 8 0	c c

conv4_block18_0_bn (BatchNormal onv4_block17_concat[0][0]	(None, None, None, 8	3200	c
conv4_block18_0_relu (Activatio onv4_block18_0_bn[0][0]	(None, None, None, 8	0	c
conv4_block18_1_conv (Conv2D) onv4_block18_0_relu[0][0]	(None, None, None, 1	102400	c
conv4_block18_1_bn (BatchNormal onv4_block18_1_conv[0][0]	(None, None, None, 1	512	c
conv4_block18_1_relu (Activatio onv4_block18_1_bn[0][0]	(None, None, None, 1	0	c
conv4_block18_2_conv (Conv2D) onv4_block18_1_relu[0][0]	(None, None, None, 3	36864	c
conv4_block18_concat (Concatena onv4_block17_concat[0][0] onv4_block18_2_conv[0][0]	(None, None, None, 8	0	c c
conv4_block19_0_bn (BatchNormal onv4_block18_concat[0][0]	(None, None, None, 8	3328	c
conv4_block19_0_relu (Activatio onv4_block19_0_bn[0][0]	(None, None, None, 8	0	c
conv4_block19_1_conv (Conv2D) onv4_block19_0_relu[0][0]	(None, None, None, 1	106496	c
conv4_block19_1_bn (BatchNormal onv4_block19_1_conv[0][0]	(None, None, None, 1	512	c
conv4_block19_1_relu (Activatio onv4_block19_1_bn[0][0]	(None, None, None, 1	0	c
conv4_block19_2_conv (Conv2D) onv4_block19_1_relu[0][0]	(None, None, None, 3	36864	c

```
conv4_block19_concat (Concatena (None, None, None, 8 0          c
onv4_block18_concat[0][0]

                                                               c
onv4_block19_2_conv[0][0]
```

```
conv4_block20_0_bn (BatchNormal (None, None, None, 8 3456       c
onv4_block19_concat[0][0]
```

```
conv4_block20_0_relu (Activatio (None, None, None, 8 0          c
onv4_block20_0_bn[0][0]
```

```
conv4_block20_1_conv (Conv2D)   (None, None, None, 1 110592     c
onv4_block20_0_relu[0][0]
```

```
conv4_block20_1_bn (BatchNormal (None, None, None, 1 512        c
onv4_block20_1_conv[0][0]
```

```
conv4_block20_1_relu (Activatio (None, None, None, 1 0          c
onv4_block20_1_bn[0][0]
```

```
conv4_block20_2_conv (Conv2D)   (None, None, None, 3 36864      c
onv4_block20_1_relu[0][0]
```

```
conv4_block20_concat (Concatena (None, None, None, 8 0          c
onv4_block19_concat[0][0]

                                                               c
onv4_block20_2_conv[0][0]
```

```
conv4_block21_0_bn (BatchNormal (None, None, None, 8 3584       c
onv4_block20_concat[0][0]
```

```
conv4_block21_0_relu (Activatio (None, None, None, 8 0          c
onv4_block21_0_bn[0][0]
```

```
conv4_block21_1_conv (Conv2D)   (None, None, None, 1 114688     c
onv4_block21_0_relu[0][0]
```

```
conv4_block21_1_bn (BatchNormal (None, None, None, 1 512        c
onv4_block21_1_conv[0][0]
```

conv4_block21_1_relu (Activatio onv4_block21_1_bn[0][0]	(None, None, None, 1	0	c
conv4_block21_2_conv (Conv2D) onv4_block21_1_relu[0][0]	(None, None, None, 3	36864	c
conv4_block21_concat (Concatena onv4_block20_concat[0][0] onv4_block21_2_conv[0][0]	(None, None, None, 9	0	c c
conv4_block22_0_bn (BatchNormal onv4_block21_concat[0][0]	(None, None, None, 9	3712	c
conv4_block22_0_relu (Activatio onv4_block22_0_bn[0][0]	(None, None, None, 9	0	c
conv4_block22_1_conv (Conv2D) onv4_block22_0_relu[0][0]	(None, None, None, 1	118784	c
conv4_block22_1_bn (BatchNormal onv4_block22_1_conv[0][0]	(None, None, None, 1	512	c
conv4_block22_1_relu (Activatio onv4_block22_1_bn[0][0]	(None, None, None, 1	0	c
conv4_block22_2_conv (Conv2D) onv4_block22_1_relu[0][0]	(None, None, None, 3	36864	c
conv4_block22_concat (Concatena onv4_block21_concat[0][0] onv4_block22_2_conv[0][0]	(None, None, None, 9	0	c c
conv4_block23_0_bn (BatchNormal onv4_block22_concat[0][0]	(None, None, None, 9	3840	c
conv4_block23_0_relu (Activatio onv4_block23_0_bn[0][0]	(None, None, None, 9	0	c

conv4_block23_1_conv (Conv2D) onv4_block23_0_relu[0][0]	(None, None, None, 1 122880	c
conv4_block23_1_bn (BatchNormal onv4_block23_1_conv[0][0]	(None, None, None, 1 512	c
conv4_block23_1_relu (Activatio onv4_block23_1_bn[0][0]	(None, None, None, 1 0	c
conv4_block23_2_conv (Conv2D) onv4_block23_1_relu[0][0]	(None, None, None, 3 36864	c
conv4_block23_concat (Concatena onv4_block22_concat[0][0] onv4_block23_2_conv[0][0]	(None, None, None, 9 0	c c
conv4_block24_0_bn (BatchNormal onv4_block23_concat[0][0]	(None, None, None, 9 3968	c
conv4_block24_0_relu (Activatio onv4_block24_0_bn[0][0]	(None, None, None, 9 0	c
conv4_block24_1_conv (Conv2D) onv4_block24_0_relu[0][0]	(None, None, None, 1 126976	c
conv4_block24_1_bn (BatchNormal onv4_block24_1_conv[0][0]	(None, None, None, 1 512	c
conv4_block24_1_relu (Activatio onv4_block24_1_bn[0][0]	(None, None, None, 1 0	c
conv4_block24_2_conv (Conv2D) onv4_block24_1_relu[0][0]	(None, None, None, 3 36864	c
conv4_block24_concat (Concatena onv4_block23_concat[0][0] onv4_block24_2_conv[0][0]	(None, None, None, 1 0	c c
pool4_bn (BatchNormalization)	(None, None, None, 1 4096	c

```
                                             onv4_block24_concat[0][0]


pool4_relu (Activation)          (None, None, None, 1 0                  p
ool4_bn[0][0]


pool4_conv (Conv2D)              (None, None, None, 5 524288             p
ool4_relu[0][0]


pool4_pool (AveragePooling2D)    (None, None, None, 5 0                  p
ool4_conv[0][0]


conv5_block1_0_bn (BatchNormali  (None, None, None, 5 2048               p
ool4_pool[0][0]


conv5_block1_0_relu (Activation  (None, None, None, 5 0                  c
onv5_block1_0_bn[0][0]


conv5_block1_1_conv (Conv2D)     (None, None, None, 1 65536              c
onv5_block1_0_relu[0][0]


conv5_block1_1_bn (BatchNormali  (None, None, None, 1 512                c
onv5_block1_1_conv[0][0]


conv5_block1_1_relu (Activation  (None, None, None, 1 0                  c
onv5_block1_1_bn[0][0]


conv5_block1_2_conv (Conv2D)     (None, None, None, 3 36864              c
onv5_block1_1_relu[0][0]


conv5_block1_concat (Concatenat  (None, None, None, 5 0                  p
ool4_pool[0][0]
                                                                         c
onv5_block1_2_conv[0][0]


conv5_block2_0_bn (BatchNormali  (None, None, None, 5 2176               c
onv5_block1_concat[0][0]


conv5_block2_0_relu (Activation  (None, None, None, 5 0                  c
onv5_block2_0_bn[0][0]
```

```
conv5_block2_1_conv (Conv2D)     (None, None, None, 1 69632           c
onv5_block2_0_relu[0][0]
_____

conv5_block2_1_bn (BatchNormali (None, None, None, 1 512             c
onv5_block2_1_conv[0][0]
_____

conv5_block2_1_relu (Activation (None, None, None, 1 0               c
onv5_block2_1_bn[0][0]
_____

conv5_block2_2_conv (Conv2D)     (None, None, None, 3 36864          c
onv5_block2_1_relu[0][0]
_____

conv5_block2_concat (Concatenat (None, None, None, 5 0               c
onv5_block1_concat[0][0]
                                                                     c
onv5_block2_2_conv[0][0]
_____

conv5_block3_0_bn (BatchNormali (None, None, None, 5 2304            c
onv5_block2_concat[0][0]
_____

conv5_block3_0_relu (Activation (None, None, None, 5 0               c
onv5_block3_0_bn[0][0]
_____

conv5_block3_1_conv (Conv2D)     (None, None, None, 1 73728          c
onv5_block3_0_relu[0][0]
_____

conv5_block3_1_bn (BatchNormali (None, None, None, 1 512             c
onv5_block3_1_conv[0][0]
_____

conv5_block3_1_relu (Activation (None, None, None, 1 0               c
onv5_block3_1_bn[0][0]
_____

conv5_block3_2_conv (Conv2D)     (None, None, None, 3 36864          c
onv5_block3_1_relu[0][0]
_____

conv5_block3_concat (Concatenat (None, None, None, 6 0               c
onv5_block2_concat[0][0]
                                                                     c
onv5_block3_2_conv[0][0]
_____

conv5_block4_0_bn (BatchNormali (None, None, None, 6 2432            c
```

onv5_block3_concat[0][0]

_____

conv5_block4_0_relu (Activation (None, None, None, 6 0   c
onv5_block4_0_bn[0][0]

_____

conv5_block4_1_conv (Conv2D)   (None, None, None, 1 77824   c
onv5_block4_0_relu[0][0]

_____

conv5_block4_1_bn (BatchNormali (None, None, None, 1 512   c
onv5_block4_1_conv[0][0]

_____

conv5_block4_1_relu (Activation (None, None, None, 1 0   c
onv5_block4_1_bn[0][0]

_____

conv5_block4_2_conv (Conv2D)   (None, None, None, 3 36864   c
onv5_block4_1_relu[0][0]

_____

conv5_block4_concat (Concatenat (None, None, None, 6 0   c
onv5_block3_concat[0][0]

                                                                     c
onv5_block4_2_conv[0][0]

_____

conv5_block5_0_bn (BatchNormali (None, None, None, 6 2560   c
onv5_block4_concat[0][0]

_____

conv5_block5_0_relu (Activation (None, None, None, 6 0   c
onv5_block5_0_bn[0][0]

_____

conv5_block5_1_conv (Conv2D)   (None, None, None, 1 81920   c
onv5_block5_0_relu[0][0]

_____

conv5_block5_1_bn (BatchNormali (None, None, None, 1 512   c
onv5_block5_1_conv[0][0]

_____

conv5_block5_1_relu (Activation (None, None, None, 1 0   c
onv5_block5_1_bn[0][0]

_____

conv5_block5_2_conv (Conv2D)   (None, None, None, 3 36864   c
onv5_block5_1_relu[0][0]

_____

```
conv5_block5_concat (Concatenat (None, None, None, 6 0          c
onv5_block4_concat[0][0]

                                                               c

onv5_block5_2_conv[0][0]
_____

_____
conv5_block6_0_bn (BatchNormali (None, None, None, 6 2688       c
onv5_block5_concat[0][0]
_____

_____
conv5_block6_0_relu (Activation (None, None, None, 6 0          c
onv5_block6_0_bn[0][0]
_____

_____
conv5_block6_1_conv (Conv2D)    (None, None, None, 1 86016      c
onv5_block6_0_relu[0][0]
_____

_____
conv5_block6_1_bn (BatchNormali (None, None, None, 1 512        c
onv5_block6_1_conv[0][0]
_____

_____
conv5_block6_1_relu (Activation (None, None, None, 1 0          c
onv5_block6_1_bn[0][0]
_____

_____
conv5_block6_2_conv (Conv2D)    (None, None, None, 3 36864      c
onv5_block6_1_relu[0][0]
_____

_____
conv5_block6_concat (Concatenat (None, None, None, 7 0          c
onv5_block5_concat[0][0]

                                                               c

onv5_block6_2_conv[0][0]
_____

_____
conv5_block7_0_bn (BatchNormali (None, None, None, 7 2816       c
onv5_block6_concat[0][0]
_____

_____
conv5_block7_0_relu (Activation (None, None, None, 7 0          c
onv5_block7_0_bn[0][0]
_____

_____
conv5_block7_1_conv (Conv2D)    (None, None, None, 1 90112      c
onv5_block7_0_relu[0][0]
_____

_____
conv5_block7_1_bn (BatchNormali (None, None, None, 1 512        c
onv5_block7_1_conv[0][0]
_____

_____
conv5_block7_1_relu (Activation (None, None, None, 1 0          c
```

onv5_block7_1_bn[0][0]

---

conv5_block7_2_conv (Conv2D)   (None, None, None, 3 36864   c
onv5_block7_1_relu[0][0]

---

conv5_block7_concat (Concatenat (None, None, None, 7 0   c
onv5_block6_concat[0][0]
                                                                  c
onv5_block7_2_conv[0][0]

---

conv5_block8_0_bn (BatchNormali (None, None, None, 7 2944   c
onv5_block7_concat[0][0]

---

conv5_block8_0_relu (Activation (None, None, None, 7 0   c
onv5_block8_0_bn[0][0]

---

conv5_block8_1_conv (Conv2D)   (None, None, None, 1 94208   c
onv5_block8_0_relu[0][0]

---

conv5_block8_1_bn (BatchNormali (None, None, None, 1 512   c
onv5_block8_1_conv[0][0]

---

conv5_block8_1_relu (Activation (None, None, None, 1 0   c
onv5_block8_1_bn[0][0]

---

conv5_block8_2_conv (Conv2D)   (None, None, None, 3 36864   c
onv5_block8_1_relu[0][0]

---

conv5_block8_concat (Concatenat (None, None, None, 7 0   c
onv5_block7_concat[0][0]
                                                                  c
onv5_block8_2_conv[0][0]

---

conv5_block9_0_bn (BatchNormali (None, None, None, 7 3072   c
onv5_block8_concat[0][0]

---

conv5_block9_0_relu (Activation (None, None, None, 7 0   c
onv5_block9_0_bn[0][0]

---

conv5_block9_1_conv (Conv2D)   (None, None, None, 1 98304   c
onv5_block9_0_relu[0][0]

```
conv5_block9_1_bn (BatchNormali   (None, None, None, 1 512              c
onv5_block9_1_conv[0][0]


conv5_block9_1_relu (Activation   (None, None, None, 1 0               c
onv5_block9_1_bn[0][0]


conv5_block9_2_conv (Conv2D)      (None, None, None, 3 36864           c
onv5_block9_1_relu[0][0]


conv5_block9_concat (Concatenat   (None, None, None, 8 0               c
onv5_block8_concat[0][0]
                                                                      c

onv5_block9_2_conv[0][0]


conv5_block10_0_bn (BatchNormal   (None, None, None, 8 3200            c
onv5_block9_concat[0][0]


conv5_block10_0_relu (Activatio   (None, None, None, 8 0               c
onv5_block10_0_bn[0][0]


conv5_block10_1_conv (Conv2D)     (None, None, None, 1 102400          c
onv5_block10_0_relu[0][0]


conv5_block10_1_bn (BatchNormal   (None, None, None, 1 512             c
onv5_block10_1_conv[0][0]


conv5_block10_1_relu (Activatio   (None, None, None, 1 0               c
onv5_block10_1_bn[0][0]


conv5_block10_2_conv (Conv2D)     (None, None, None, 3 36864           c
onv5_block10_1_relu[0][0]


conv5_block10_concat (Concatena   (None, None, None, 8 0               c
onv5_block9_concat[0][0]
                                                                      c

onv5_block10_2_conv[0][0]


conv5_block11_0_bn (BatchNormal   (None, None, None, 8 3328            c
onv5_block10_concat[0][0]
```

conv5_block11_0_relu (Activatio onv5_block11_0_bn[0][0]	(None, None, None, 8	0	c
conv5_block11_1_conv (Conv2D) onv5_block11_0_relu[0][0]	(None, None, None, 1	106496	c
conv5_block11_1_bn (BatchNormal onv5_block11_1_conv[0][0]	(None, None, None, 1	512	c
conv5_block11_1_relu (Activatio onv5_block11_1_bn[0][0]	(None, None, None, 1	0	c
conv5_block11_2_conv (Conv2D) onv5_block11_1_relu[0][0]	(None, None, None, 3	36864	c
conv5_block11_concat (Concatena onv5_block10_concat[0][0]	(None, None, None, 8	0	c
onv5_block11_2_conv[0][0]			c
conv5_block12_0_bn (BatchNormal onv5_block11_concat[0][0]	(None, None, None, 8	3456	c
conv5_block12_0_relu (Activatio onv5_block12_0_bn[0][0]	(None, None, None, 8	0	c
conv5_block12_1_conv (Conv2D) onv5_block12_0_relu[0][0]	(None, None, None, 1	110592	c
conv5_block12_1_bn (BatchNormal onv5_block12_1_conv[0][0]	(None, None, None, 1	512	c
conv5_block12_1_relu (Activatio onv5_block12_1_bn[0][0]	(None, None, None, 1	0	c
conv5_block12_2_conv (Conv2D) onv5_block12_1_relu[0][0]	(None, None, None, 3	36864	c
conv5_block12_concat (Concatena onv5_block11_concat[0][0]	(None, None, None, 8	0	c

```
                                                                                          c
onv5_block12_2_conv[0][0]
_____

_____
conv5_block13_0_bn (BatchNormal  (None, None, None, 8  3584          c
onv5_block12_concat[0][0]
_____

_____
conv5_block13_0_relu (Activatio  (None, None, None, 8  0             c
onv5_block13_0_bn[0][0]
_____

_____
conv5_block13_1_conv (Conv2D)    (None, None, None, 1  114688        c
onv5_block13_0_relu[0][0]
_____

_____
conv5_block13_1_bn (BatchNormal  (None, None, None, 1  512           c
onv5_block13_1_conv[0][0]
_____

_____
conv5_block13_1_relu (Activatio  (None, None, None, 1  0             c
onv5_block13_1_bn[0][0]
_____

_____
conv5_block13_2_conv (Conv2D)    (None, None, None, 3  36864         c
onv5_block13_1_relu[0][0]
_____

_____
conv5_block13_concat (Concatena  (None, None, None, 9  0             c
onv5_block12_concat[0][0]
                                                                                          c
onv5_block13_2_conv[0][0]
_____

_____
conv5_block14_0_bn (BatchNormal  (None, None, None, 9  3712          c
onv5_block13_concat[0][0]
_____

_____
conv5_block14_0_relu (Activatio  (None, None, None, 9  0             c
onv5_block14_0_bn[0][0]
_____

_____
conv5_block14_1_conv (Conv2D)    (None, None, None, 1  118784        c
onv5_block14_0_relu[0][0]
_____

_____
conv5_block14_1_bn (BatchNormal  (None, None, None, 1  512           c
onv5_block14_1_conv[0][0]
_____

_____
conv5_block14_1_relu (Activatio  (None, None, None, 1  0             c
onv5_block14_1_bn[0][0]
_____
```

conv5_block14_2_conv (Conv2D) onv5_block14_1_relu[0][0]	(None, None, None, 3	36864	c

conv5_block14_concat (Concatena onv5_block13_concat[0][0]	(None, None, None, 9	0	c
onv5_block14_2_conv[0][0]			c

conv5_block15_0_bn (BatchNormal onv5_block14_concat[0][0]	(None, None, None, 9	3840	c

conv5_block15_0_relu (Activatio onv5_block15_0_bn[0][0]	(None, None, None, 9	0	c

conv5_block15_1_conv (Conv2D) onv5_block15_0_relu[0][0]	(None, None, None, 1	122880	c

conv5_block15_1_bn (BatchNormal onv5_block15_1_conv[0][0]	(None, None, None, 1	512	c

conv5_block15_1_relu (Activatio onv5_block15_1_bn[0][0]	(None, None, None, 1	0	c

conv5_block15_2_conv (Conv2D) onv5_block15_1_relu[0][0]	(None, None, None, 3	36864	c

conv5_block15_concat (Concatena onv5_block14_concat[0][0]	(None, None, None, 9	0	c
onv5_block15_2_conv[0][0]			c

conv5_block16_0_bn (BatchNormal onv5_block15_concat[0][0]	(None, None, None, 9	3968	c

conv5_block16_0_relu (Activatio onv5_block16_0_bn[0][0]	(None, None, None, 9	0	c

conv5_block16_1_conv (Conv2D) onv5_block16_0_relu[0][0]	(None, None, None, 1	126976	c

```
conv5_block16_1_bn (BatchNormal  (None, None, None, 1 512        c
onv5_block16_1_conv[0][0]
_____

conv5_block16_1_relu (Activatio  (None, None, None, 1 0          c
onv5_block16_1_bn[0][0]
_____

conv5_block16_2_conv (Conv2D)    (None, None, None, 3 36864      c
onv5_block16_1_relu[0][0]
_____

conv5_block16_concat (Concatena  (None, None, None, 1 0          c
onv5_block15_concat[0][0]
                                                                 c
onv5_block16_2_conv[0][0]
_____

bn (BatchNormalization)          (None, None, None, 1 4096       c
onv5_block16_concat[0][0]
_____

global_average_pooling2d_1 (Glo  (None, 1024)         0          b
n[0][0]
_____

dense_1 (Dense)                  (None, 14)           14350      g
lobal_average_pooling2d_1[0][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 [4]:   # 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__', '__ge__', '__getattribute__', '__
gt__', '__hash__', '__init__', '__init_subclass__', '__le__', '__l
t__', '__module__', '__ne__', '__new__', '__reduce__', '__reduce_e
x__', '__repr__', '__setattr__', '__sizeof__', '__str__', '__subcl
asshook__', '__weakref__', '_add_inbound_node', '_built', '_check_
num_samples', '_check_trainable_weights_consistency', '_collected_
trainable_weights', '_container_nodes', '_feed_input_names', '_fee
d_input_shapes', '_feed_inputs', '_feed_loss_fns', '_feed_output_n
ames', '_feed_output_shapes', '_feed_outputs', '_feed_sample_weigh
t_modes', '_feed_sample_weights', '_feed_targets', '_fit_loop', '_
function_kwargs', '_get_node_attribute_at_index', '_inbound_nodes'
, '_internal_input_shapes', '_internal_output_shapes', '_make_pred
ict_function', '_make_test_function', '_make_train_function', '_no
de_key', '_nodes_by_depth', '_outbound_nodes', '_output_mask_cache
', '_output_shape_cache', '_output_tensor_cache', '_per_input_loss
es', '_per_input_updates', '_predict_loop', '_standardize_user_dat
a', '_test_loop', '_updated_config', 'add_loss', 'add_update', 'ad
d_weight', 'assert_input_compatibility', 'build', 'built', 'call',
'compile', 'compute_mask', 'compute_output_shape', 'count_params',
'evaluate', 'evaluate_generator', 'fit', 'fit_generator', 'from_co
nfig', 'get_config', 'get_input_at', 'get_input_mask_at', 'get_inp
ut_shape_at', 'get_layer', 'get_losses_for', 'get_output_at', 'get
_output_mask_at', 'get_output_shape_at', 'get_updates_for', 'get_w
eights', 'input', 'input_layers', 'input_layers_node_indices', 'in
put_layers_tensor_indices', 'input_mask', 'input_names', 'input_sh
ape', 'input_spec', 'inputs', 'layers', 'layers_by_depth', 'load_w
eights', 'loss', 'loss_functions', 'loss_weights', 'losses', 'metr
ics', 'metrics_names', 'metrics_tensors', 'metrics_updates', 'name
', 'non_trainable_weights', 'optimizer', 'output', 'output_layers'
, 'output_layers_node_indices', 'output_layers_tensor_indices', 'o
utput_mask', 'output_names', 'output_shape', 'outputs', 'predict',
'predict_function', 'predict_generator', 'predict_on_batch', 'rese
t_states', 'run_internal_graph', 'sample_weight_mode', 'sample_wei
ght_modes', 'sample_weights', 'save', 'save_weights', 'set_weights
', 'state_updates', 'stateful', 'stateful_metric_functions', 'stat
eful_metric_names', 'summary', 'supports_masking', 'targets', 'tes
t_function', 'test_on_batch', 'to_json', 'to_yaml', 'total_loss',
'train_function', 'train_on_batch', 'trainable', 'trainable_weight
s', 'updates', 'uses_learning_phase', 'weighted_metrics', 'weights
']
```

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 [5]:
```python
# Check the type of the model's layers
type(model.layers)
```

Out[5]: list

In [6]:
```python
# 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 0x7f57f3873160>
With name: input_1

Layer number 1:
<keras.layers.convolutional.ZeroPadding2D object at 0x7f57f35c2c18
>
With name: zero_padding2d_1

Layer number 2:
<keras.layers.convolutional.Conv2D object at 0x7f57f3873668>
With name: conv1/conv

Layer number 3:
<keras.layers.normalization.BatchNormalization object at 0x7f57f35
eb7f0>
With name: conv1/bn

Layer number 4:
<keras.layers.core.Activation object at 0x7f57f3581908>
With name: conv1/relu
```

Let's check how many layers our model has:

In [7]:
```python
# 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 [8]:   # Number of layers that are of type "Convolutional" or "Concatenate
          "
          len([l for l in model.layers if ("conv" in str(type(l))) or ("Conca
          tenate" in str(type(l)))])
```

```
Out[8]:   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 [9]:   # Save the desired layer in a variable
          layer = model.layers[424]

          # Print layer
          layer
```

```
Out[9]:   <keras.layers.merge.Concatenate at 0x7f570778cd68>
```

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

          # Print layer
          layer
```

```
Out[10]:  <keras.layers.merge.Concatenate at 0x7f570778cd68>
```

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

```
In [11]:   # 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__', '__ge__', '__getattribute__', '__
gt__', '__hash__', '__init__', '__init_subclass__', '__le__', '__l
t__', '__module__', '__ne__', '__new__', '__reduce__', '__reduce_e
x__', '__repr__', '__setattr__', '__sizeof__', '__str__', '__subcl
asshook__', '__weakref__', '_add_inbound_node', '_built', '_comput
e_elemwise_op_output_shape', '_get_node_attribute_at_index', '_inb
ound_nodes', '_initial_weights', '_losses', '_merge_function', '_n
ode_key', '_non_trainable_weights', '_outbound_nodes', '_per_input
_losses', '_per_input_updates', '_reshape_required', '_trainable_w
eights', '_updates', 'add_loss', 'add_update', 'add_weight', 'asse
rt_input_compatibility', 'axis', 'build', 'built', 'call', 'comput
e_mask', 'compute_output_shape', 'count_params', 'from_config', 'g
et_config', 'get_input_at', 'get_input_mask_at', 'get_input_shape_
at', 'get_losses_for', 'get_output_at', 'get_output_mask_at', 'get
_output_shape_at', 'get_updates_for', 'get_weights', 'input', 'inp
ut_mask', 'input_shape', 'input_spec', 'losses', 'name', 'non_trai
nable_weights', 'output', 'output_mask', 'output_shape', 'set_weig
hts', 'stateful', 'supports_masking', 'trainable', 'trainable_weig
hts', 'updates', 'weights']
```

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 [12]:   # Print layer's output
           layer.output
```

```
Out[12]:   <tf.Tensor 'conv5_block16_concat/concat:0' shape=(?, ?, ?, 1024) d
           type=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 [13]:   # Print model's input tensor placeholder
           model.input
```

```
Out[13]:   <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 [14]:   # Instantiate the function to compute the activations of the last c
           onvolutional layer
           last_layer_activations_function = K.function([model.input], [layer.
           output])

           # Print the Keras function
           last_layer_activations_function
```

```
Out[14]:   <keras.backend.tensorflow_backend.Function at 0x7f56fe4e6b38>
```

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 [15]:   # Load dataframe that contains information about the dataset of ima
           ges
           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()
```
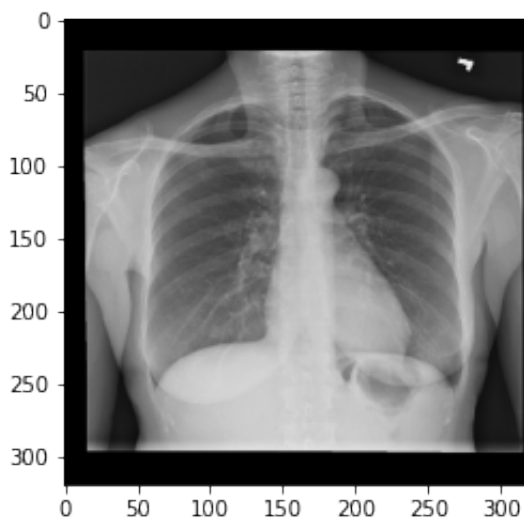

We should normalize this image before going forward, this has also been taken care of:

```
In [16]:   # 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)
```

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

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

```
In [19]:    # 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[19]:   array([[[-2.34528378e-01,  1.03888601e-01, -1.02932416e-01, ...,
                      1.95436418e-01, -7.53498077e-02,  2.19688460e-01],
                    [-3.57181996e-01, -5.06232321e-01, -9.07948315e-01, ...,
                      2.82368094e-01, -8.69844109e-02,  3.30677748e-01],
                    [-2.64806449e-01, -2.77638644e-01, -9.12588179e-01, ...,
                      2.36321479e-01, -7.62053505e-02,  2.71659851e-01],
                    ...,
                    [-3.64358276e-01, -3.05198252e-01, -8.99509788e-01, ...,
                      1.32572979e-01, -8.87970179e-02,  1.68741941e-01],
                    [-2.63873279e-01, -7.16017410e-02, -5.18461406e-01, ...,
                      2.81986654e-01, -1.17035367e-01,  3.22839558e-01],
                    [-2.43374333e-01,  2.20213965e-01, -8.40832591e-02, ...,
                      1.46577284e-01, -7.16667622e-02,  2.15044528e-01]],

                   [[-3.85911673e-01,  3.94917391e-02, -4.89642799e-01, ...,
                      2.48766661e-01, -1.19054504e-01,  3.17032784e-01],
                    [-1.75690576e-01, -4.20813233e-01, -2.65263885e-01, ...,
                      4.28565294e-01, -1.49629205e-01,  4.95896250e-01],
                    [-4.91427928e-01, -5.02470613e-01, -4.33604479e-01, ...,
                      2.54681349e-01, -1.14488915e-01,  3.30634028e-01],
                    ...,
                    [-3.48210931e-01, -6.88572645e-01, -5.79565823e-01, ...,
                      1.57981083e-01, -1.03492454e-01,  1.86690331e-01],
                    [-5.49307585e-01, -1.02473652e+00, -5.52783251e-01, ...,
                      3.22046787e-01, -1.36609375e-01,  3.27671915e-01],
                    [-5.58423519e-01, -2.21409231e-01,  1.06662512e-03, ...,
                      1.82196707e-01, -6.83000088e-02,  2.14448273e-01]],

                   [[-4.71532464e-01, -2.07039714e-02, -4.41627920e-01, ...,
                      2.74705708e-01, -1.13615274e-01,  2.43266091e-01],
                    [-1.25446916e+00, -1.07412672e+00, -2.99405575e-01, ...,
                      4.57139075e-01, -1.50618494e-01,  3.55173171e-01],
                    [-8.81016254e-01, -6.38861358e-01, -5.44111133e-01, ...,
                      2.96926886e-01, -9.45852175e-02,  2.02520594e-01],
                    ...,
                    [-1.35452890e+00,  1.39726698e-01,  2.32537150e-01, ...,
                      6.18949272e-02, -5.50149716e-02,  8.78603086e-02],
                    [-8.59520912e-01, -2.54668146e-02,  1.16123629e+00, ...,
                      1.92437738e-01, -6.40552044e-02,  1.55031338e-01],
                    [-7.34347522e-01, -1.96773887e-01,  9.74288881e-01, ...,
                      8.12446550e-02, -2.90456042e-02,  8.25736523e-02]],
```

```
       ...,

       [[-5.93337536e-01, -1.82666220e-02,  1.42468229e-01, ...,
          3.61059010e-01, -1.51442572e-01,  4.83031034e-01],
        [-3.63586664e-01,  7.16439605e-01, -3.02047431e-02, ...,
          4.02755529e-01, -1.18740864e-01,  7.14342237e-01],
        [-2.05164719e+00, -1.17773581e+00, -7.96093047e-01, ...,
          1.89675331e-01,  1.75441876e-01,  8.65436077e-01],
        ...,
        [-2.01013637e+00, -7.83838212e-01, -5.93690693e-01, ...,
         -5.11500984e-03,  1.18342265e-01,  1.41481924e+00],
        [-1.60671687e+00,  1.13282204e-01, -5.64168513e-01, ...,
          1.52177155e-01, -6.78298026e-02,  1.50779235e+00],
        [-8.80541980e-01,  7.00929314e-02,  3.32438052e-01, ...,
         -1.33873001e-01,  1.02796428e-01,  1.05246699e+00]],

       [[-6.13768876e-01, -3.93467359e-02, -4.98745412e-01, ...,
          2.92770028e-01, -1.57525450e-01,  4.59775925e-01],
        [-5.27344882e-01,  1.30507693e-01, -4.39863145e-01, ...,
          4.43635941e-01, -2.30797246e-01,  6.37336552e-01],
        [-4.47706252e-01,  6.52831733e-01, -1.53416073e+00, ...,
          3.40943336e-01, -1.47531837e-01,  5.14184713e-01],
        ...,
        [-7.80842781e-01, -4.47639078e-02, -1.02739370e+00, ...,
          7.32436106e-02, -7.68425167e-02,  7.55837739e-01],
        [-2.56010771e-01,  4.37092394e-01, -9.21702981e-01, ...,
          2.91409433e-01, -2.16206715e-01,  8.89219224e-01],
        [-5.01822472e-01, -1.27244368e-01, -5.96898496e-01, ...,
          3.73074859e-02, -8.50129500e-02,  7.00261950e-01]],

       [[-8.94521356e-01,  2.00330630e-01,  4.90441620e-01, ...,
          2.61645913e-01, -1.10321872e-01,  2.45080888e-01],
        [-9.90234494e-01, -1.79898918e-01,  3.64397943e-01, ...,
          3.40280712e-01, -1.21333607e-01,  3.34408909e-01],
        [-6.39139056e-01,  2.23485455e-02, -2.95223475e-01, ...,
          2.67534673e-01, -9.55819562e-02,  2.79736072e-01],
        ...,
        [-5.00944674e-01,  7.57797956e-01, -8.73069167e-02, ...,
          1.57085389e-01, -8.08104724e-02,  2.48510525e-01],
        [-5.79098403e-01,  3.12583297e-01,  2.19042763e-01, ...,
          2.47366339e-01, -1.15144797e-01,  3.04065764e-01],
        [-6.10948980e-01,  2.20546141e-01,  5.39675653e-01, ...,
          1.70019135e-01, -5.60478754e-02,  2.50791490e-01]]],
      dtype=float32)
```

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!