AI4M_C1_W1_lecture_ex_03

July 16, 2020

0.1 AI for Medicine Course 1 Week 1 lecture exercises

Densenet

In this week's assignment, you'll be using a pre-trained Densenet model for image classification.

Densenet is a convolutional network where each layer is connected to all other layers that are deeper in the network - The first layer is connected to the 3rd, 4th etc. - The second layer is connected to the 3rd, 4th, 5th etc.

Like this:

For a detailed explanation of Densenet, check out the source of the image above, a paper by Gao Huang et al. 2018 called Densely Connected Convolutional Networks.

The cells below are set up to provide an exploration of the Keras densenet implementation that you'll be using in the assignment. Run these cells to gain some insight into the network architecture.

```
In [1]: # Import Densenet from Keras
        from keras.applications.densenet import DenseNet121
        from keras.layers import Dense, GlobalAveragePooling2D
        from keras.models import Model
        from keras import backend as K
```

Using TensorFlow backend.

For your work in the assignment, you'll be loading a set of pre-trained weights to reduce training time.

```
In [2]: # Create the base pre-trained model
        base_model = DenseNet121(weights='./nih/densenet.hdf5', include_top=False);
```

WARNING:tensorflow:From /opt/conda/lib/python3.6/site-packages/tensorflow_core/python/ops/resou
Instructions for updating:
If using Keras pass *_constraint arguments to layers.
WARNING:tensorflow:From /opt/conda/lib/python3.6/site-packages/keras/backend/tensorflow_backend

WARNING:tensorflow:From /opt/conda/lib/python3.6/site-packages/keras/backend/tensorflow_backend

View a summary of the model

```
In [3]: # Print the model summary
        base_model.summary()
```

Model: "densenet121"

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]
```

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                                                            conv2_block5_2_conv[0][0]
_____
conv2_block6_0_bn (BatchNormali (None, None, None, 2 896        conv2_block5_concat[0][0]
_____
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]
_____
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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]
_____
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]
```

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----------------------------------------------------------------------------------------------------
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]
```

Layer	Output Shape	Param #	Connected to
conv3_block9_0_bn (BatchNormali	(None, None, None, 3	1536	conv3_block8_concat[0][0]
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]
_____
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]
_____
```

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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]
_____
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]
--------------------------------------------------------------------------------------------------
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]
_____
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]
```

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-----------------------------------------------------------------------------------------------
conv4_block15_2_conv (Conv2D)    (None, None, None, 3 36864      conv4_block15_1_relu[0][0]
-----------------------------------------------------------------------------------------------
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]
_____
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]
_____
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]
```

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----------------------------------------------------------------------------------------------------
pool4_conv (Conv2D)            (None, None, None, 5 524288      pool4_relu[0][0]
----------------------------------------------------------------------------------------------------
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]
```

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                                                                  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]
```

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```
--------------------------------------------------------------------------------------------------
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]

--------------------------------------------------------------------------------------------------
relu (Activation)                (None, None, None, 1 0        bn[0][0]
==================================================================================================
Total params: 7,037,504
Trainable params: 6,953,856
Non-trainable params: 83,648

--------------------------------------------------------------------------------------------------
```

```python
In [4]: # Print out the first five layers
        layers_l = base_model.layers

        print("First 5 layers")
        layers_l[0:5]
```

First 5 layers

```
Out[4]: [<keras.engine.input_layer.InputLayer at 0x7f431b854278>,
         <keras.layers.convolutional.ZeroPadding2D at 0x7f431b854550>,
         <keras.layers.convolutional.Conv2D at 0x7f431b854668>,
         <keras.layers.normalization.BatchNormalization at 0x7f431b854c50>,
         <keras.layers.core.Activation at 0x7f431b854fd0>]
```

```python
In [5]: # Print out the last five layers
        print("Last 5 layers")
        layers_l[-6:-1]
```

Last 5 layers

```
Out[5]: [<keras.layers.normalization.BatchNormalization at 0x7f41a40b29e8>,
         <keras.layers.core.Activation at 0x7f41a40b2b00>,
         <keras.layers.convolutional.Conv2D at 0x7f41a4044be0>,
         <keras.layers.merge.Concatenate at 0x7f41a406d668>,
         <keras.layers.normalization.BatchNormalization at 0x7f41a406d780>]
```

```python
In [6]: # Get the convolutional layers and print the first 5
        conv2D_layers = [layer for layer in base_model.layers
                         if str(type(layer)).find('Conv2D') > -1]
        print("The first five conv2D layers")
        conv2D_layers[0:5]
```

The first five conv2D layers

```
Out[6]: [<keras.layers.convolutional.Conv2D at 0x7f431b854668>,
         <keras.layers.convolutional.Conv2D at 0x7f43195cde80>,
         <keras.layers.convolutional.Conv2D at 0x7f431957df60>,
         <keras.layers.convolutional.Conv2D at 0x7f4319539c50>,
         <keras.layers.convolutional.Conv2D at 0x7f43194f0860>]
```

```
In [7]: # Print out the total number of convolutional layers
        print(f"There are {len(conv2D_layers)} convolutional layers")
```

There are 120 convolutional layers

```
In [8]: # Print the number of channels in the input
        print("The input has 3 channels")
        base_model.input
```

The input has 3 channels

```
Out[8]: <tf.Tensor 'input_1:0' shape=(?, ?, ?, 3) dtype=float32>
```

```
In [9]: # Print the number of output channels
        print("The output has 1024 channels")
        x = base_model.output
        x
```

The output has 1024 channels

```
Out[9]: <tf.Tensor 'relu/Relu:0' shape=(?, ?, ?, 1024) dtype=float32>
```

```
In [10]: # Add a global spatial average pooling layer
         x_pool = GlobalAveragePooling2D()(x)
         x_pool
```

```
Out[10]: <tf.Tensor 'global_average_pooling2d_1/Mean:0' shape=(?, 1024) dtype=float32>
```

```
In [11]: # Define a set of five class labels to use as an example
         labels = ['Emphysema',
                   'Hernia',
                   'Mass',
                   'Pneumonia',
                   'Edema']
         n_classes = len(labels)
         print(f"In this example, you want your model to identify {n_classes} classes")
```

In this example, you want your model to identify 5 classes

```
In [12]: # Add a logistic layer the same size as the number of classes you're trying to predic
         predictions = Dense(n_classes, activation="sigmoid")(x_pool)
         print(f"Predictions have {n_classes} units, one for each class")
         predictions

Predictions have 5 units, one for each class


Out[12]: <tf.Tensor 'dense_1/Sigmoid:0' shape=(?, 5) dtype=float32>

In [13]: # Create an updated model
         model = Model(inputs=base_model.input, outputs=predictions)

In [14]: # Compile the model
         model.compile(optimizer='adam',
                       loss='categorical_crossentropy')
         # (You'll customize the loss function in the assignment!)
```

This has been a brief exploration of the Densenet architecture you'll use in this week's graded assignment!