

# InceptionV3-Final Working-V2

February 9, 2020

```
In [1]: import matplotlib.pyplot as plt
        from keras import applications
        from keras.preprocessing.image import ImageDataGenerator
        from keras import optimizers
        from keras.models import Sequential
        from keras.layers import Dropout, Flatten, Dense
        from keras.applications.inception_v3 import InceptionV3
        from keras.preprocessing import image
        from keras.models import Model
        from keras.layers import Dense, Flatten
        from keras import backend as K
        import numpy as np
        import pandas as pd
        import os
        from sklearn.metrics import classification_report, confusion_matrix
        import sklearn.metrics as metrics
        import sklearn
        from sklearn.metrics import roc_auc_score
        from sklearn.metrics import roc_curve
        import matplotlib.pyplot as plt
        %matplotlib inline
```

Using TensorFlow backend.

```
In [2]: # create the base pre-trained model
        # build the VGG16 network
        base_model = applications.inception_v3.InceptionV3(weights='imagenet', include_top=False,
                                                             input_shape=(150,150,3))

        print('Model loaded.')
        base_model.summary()
```

WARNING: Logging before flag parsing goes to stderr.

W0209 15:26:32.890936 139856742401856 deprecation\_wrapper.py:119] From /home/mlab/anaconda3/lib/python

W0209 15:26:32.900138 139856742401856 deprecation\_wrapper.py:119] From /home/mlab/anaconda3/lib/python

W0209 15:26:32.902187 139856742401856 deprecation\_wrapper.py:119] From /home/mlab/anaconda3/lib/python

W0209 15:26:32.916094 139856742401856 deprecation\_wrapper.py:119] From /home/mlab/anaconda3/lib/python

W0209 15:26:32.916561 139856742401856 deprecation\_wrapper.py:119] From /home/mlab/anaconda3/lib/python

W0209 15:26:33.058670 139856742401856 deprecation\_wrapper.py:119] From /home/mlab/anaconda3/lib/python

W0209 15:26:33.257560 139856742401856 deprecation\_wrapper.py:119] From /home/mlab/anaconda3/lib/python

W0209 15:26:33.691477 139856742401856 deprecation\_wrapper.py:119] From /home/mlab/anaconda3/lib/python

Model loaded.

Layer (type)	Output Shape	Param #	Connected to
input_1 (InputLayer)	(None, 150, 150, 3)	0	
conv2d_1 (Conv2D)	(None, 74, 74, 32)	864	input_1[0][0]
batch_normalization_1 (BatchNor	(None, 74, 74, 32)	96	conv2d_1[0][0]
activation_1 (Activation)	(None, 74, 74, 32)	0	batch_normalization_1[0][0]
conv2d_2 (Conv2D)	(None, 72, 72, 32)	9216	activation_1[0][0]
batch_normalization_2 (BatchNor	(None, 72, 72, 32)	96	conv2d_2[0][0]
activation_2 (Activation)	(None, 72, 72, 32)	0	batch_normalization_2[0][0]
conv2d_3 (Conv2D)	(None, 72, 72, 64)	18432	activation_2[0][0]
batch_normalization_3 (BatchNor	(None, 72, 72, 64)	192	conv2d_3[0][0]
activation_3 (Activation)	(None, 72, 72, 64)	0	batch_normalization_3[0][0]
max_pooling2d_1 (MaxPooling2D)	(None, 35, 35, 64)	0	activation_3[0][0]
conv2d_4 (Conv2D)	(None, 35, 35, 80)	5120	max_pooling2d_1[0][0]
batch_normalization_4 (BatchNor	(None, 35, 35, 80)	240	conv2d_4[0][0]
activation_4 (Activation)	(None, 35, 35, 80)	0	batch_normalization_4[0][0]
conv2d_5 (Conv2D)	(None, 33, 33, 192)	138240	activation_4[0][0]
batch_normalization_5 (BatchNor	(None, 33, 33, 192)	576	conv2d_5[0][0]

activation_5 (Activation)	(None, 33, 33, 192)	0	batch_normalization_5[0][0]
max_pooling2d_2 (MaxPooling2D)	(None, 16, 16, 192)	0	activation_5[0][0]
conv2d_9 (Conv2D)	(None, 16, 16, 64)	12288	max_pooling2d_2[0][0]
batch_normalization_9 (BatchNor	(None, 16, 16, 64)	192	conv2d_9[0][0]
activation_9 (Activation)	(None, 16, 16, 64)	0	batch_normalization_9[0][0]
conv2d_7 (Conv2D)	(None, 16, 16, 48)	9216	max_pooling2d_2[0][0]
conv2d_10 (Conv2D)	(None, 16, 16, 96)	55296	activation_9[0][0]
batch_normalization_7 (BatchNor	(None, 16, 16, 48)	144	conv2d_7[0][0]
batch_normalization_10 (BatchNo	(None, 16, 16, 96)	288	conv2d_10[0][0]
activation_7 (Activation)	(None, 16, 16, 48)	0	batch_normalization_7[0][0]
activation_10 (Activation)	(None, 16, 16, 96)	0	batch_normalization_10[0][0]
average_pooling2d_1 (AveragePoo	(None, 16, 16, 192)	0	max_pooling2d_2[0][0]
conv2d_6 (Conv2D)	(None, 16, 16, 64)	12288	max_pooling2d_2[0][0]
conv2d_8 (Conv2D)	(None, 16, 16, 64)	76800	activation_7[0][0]
conv2d_11 (Conv2D)	(None, 16, 16, 96)	82944	activation_10[0][0]
conv2d_12 (Conv2D)	(None, 16, 16, 32)	6144	average_pooling2d_1[0][0]
batch_normalization_6 (BatchNor	(None, 16, 16, 64)	192	conv2d_6[0][0]
batch_normalization_8 (BatchNor	(None, 16, 16, 64)	192	conv2d_8[0][0]
batch_normalization_11 (BatchNo	(None, 16, 16, 96)	288	conv2d_11[0][0]
batch_normalization_12 (BatchNo	(None, 16, 16, 32)	96	conv2d_12[0][0]
activation_6 (Activation)	(None, 16, 16, 64)	0	batch_normalization_6[0][0]
activation_8 (Activation)	(None, 16, 16, 64)	0	batch_normalization_8[0][0]
activation_11 (Activation)	(None, 16, 16, 96)	0	batch_normalization_11[0][0]
activation_12 (Activation)	(None, 16, 16, 32)	0	batch_normalization_12[0][0]

mixed0 (Concatenate)	(None, 16, 16, 256)	0	activation_6[0][0] activation_8[0][0] activation_11[0][0] activation_12[0][0]
conv2d_16 (Conv2D)	(None, 16, 16, 64)	16384	mixed0[0][0]
batch_normalization_16 (Batch Normalization)	(None, 16, 16, 64)	192	conv2d_16[0][0]
activation_16 (Activation)	(None, 16, 16, 64)	0	batch_normalization_16[0][0]
conv2d_14 (Conv2D)	(None, 16, 16, 48)	12288	mixed0[0][0]
conv2d_17 (Conv2D)	(None, 16, 16, 96)	55296	activation_16[0][0]
batch_normalization_14 (Batch Normalization)	(None, 16, 16, 48)	144	conv2d_14[0][0]
batch_normalization_17 (Batch Normalization)	(None, 16, 16, 96)	288	conv2d_17[0][0]
activation_14 (Activation)	(None, 16, 16, 48)	0	batch_normalization_14[0][0]
activation_17 (Activation)	(None, 16, 16, 96)	0	batch_normalization_17[0][0]
average_pooling2d_2 (Average Pooling)	(None, 16, 16, 256)	0	mixed0[0][0]
conv2d_13 (Conv2D)	(None, 16, 16, 64)	16384	mixed0[0][0]
conv2d_15 (Conv2D)	(None, 16, 16, 64)	76800	activation_14[0][0]
conv2d_18 (Conv2D)	(None, 16, 16, 96)	82944	activation_17[0][0]
conv2d_19 (Conv2D)	(None, 16, 16, 64)	16384	average_pooling2d_2[0][0]
batch_normalization_13 (Batch Normalization)	(None, 16, 16, 64)	192	conv2d_13[0][0]
batch_normalization_15 (Batch Normalization)	(None, 16, 16, 64)	192	conv2d_15[0][0]
batch_normalization_18 (Batch Normalization)	(None, 16, 16, 96)	288	conv2d_18[0][0]
batch_normalization_19 (Batch Normalization)	(None, 16, 16, 64)	192	conv2d_19[0][0]
activation_13 (Activation)	(None, 16, 16, 64)	0	batch_normalization_13[0][0]
activation_15 (Activation)	(None, 16, 16, 64)	0	batch_normalization_15[0][0]
activation_18 (Activation)	(None, 16, 16, 96)	0	batch_normalization_18[0][0]

activation_19 (Activation)	(None, 16, 16, 64)	0	batch_normalization_19[0][0]
mixed1 (Concatenate)	(None, 16, 16, 288)	0	activation_13[0][0] activation_15[0][0] activation_18[0][0] activation_19[0][0]
conv2d_23 (Conv2D)	(None, 16, 16, 64)	18432	mixed1[0][0]
batch_normalization_23 (BatchNo	(None, 16, 16, 64)	192	conv2d_23[0][0]
activation_23 (Activation)	(None, 16, 16, 64)	0	batch_normalization_23[0][0]
conv2d_21 (Conv2D)	(None, 16, 16, 48)	13824	mixed1[0][0]
conv2d_24 (Conv2D)	(None, 16, 16, 96)	55296	activation_23[0][0]
batch_normalization_21 (BatchNo	(None, 16, 16, 48)	144	conv2d_21[0][0]
batch_normalization_24 (BatchNo	(None, 16, 16, 96)	288	conv2d_24[0][0]
activation_21 (Activation)	(None, 16, 16, 48)	0	batch_normalization_21[0][0]
activation_24 (Activation)	(None, 16, 16, 96)	0	batch_normalization_24[0][0]
average_pooling2d_3 (AveragePoo	(None, 16, 16, 288)	0	mixed1[0][0]
conv2d_20 (Conv2D)	(None, 16, 16, 64)	18432	mixed1[0][0]
conv2d_22 (Conv2D)	(None, 16, 16, 64)	76800	activation_21[0][0]
conv2d_25 (Conv2D)	(None, 16, 16, 96)	82944	activation_24[0][0]
conv2d_26 (Conv2D)	(None, 16, 16, 64)	18432	average_pooling2d_3[0][0]
batch_normalization_20 (BatchNo	(None, 16, 16, 64)	192	conv2d_20[0][0]
batch_normalization_22 (BatchNo	(None, 16, 16, 64)	192	conv2d_22[0][0]
batch_normalization_25 (BatchNo	(None, 16, 16, 96)	288	conv2d_25[0][0]
batch_normalization_26 (BatchNo	(None, 16, 16, 64)	192	conv2d_26[0][0]
activation_20 (Activation)	(None, 16, 16, 64)	0	batch_normalization_20[0][0]
activation_22 (Activation)	(None, 16, 16, 64)	0	batch_normalization_22[0][0]
activation_25 (Activation)	(None, 16, 16, 96)	0	batch_normalization_25[0][0]

activation_26 (Activation)	(None, 16, 16, 64)	0	batch_normalization_26[0][0]
mixed2 (Concatenate)	(None, 16, 16, 288)	0	activation_20[0][0] activation_22[0][0] activation_25[0][0] activation_26[0][0]
conv2d_28 (Conv2D)	(None, 16, 16, 64)	18432	mixed2[0][0]
batch_normalization_28 (BatchNo	(None, 16, 16, 64)	192	conv2d_28[0][0]
activation_28 (Activation)	(None, 16, 16, 64)	0	batch_normalization_28[0][0]
conv2d_29 (Conv2D)	(None, 16, 16, 96)	55296	activation_28[0][0]
batch_normalization_29 (BatchNo	(None, 16, 16, 96)	288	conv2d_29[0][0]
activation_29 (Activation)	(None, 16, 16, 96)	0	batch_normalization_29[0][0]
conv2d_27 (Conv2D)	(None, 7, 7, 384)	995328	mixed2[0][0]
conv2d_30 (Conv2D)	(None, 7, 7, 96)	82944	activation_29[0][0]
batch_normalization_27 (BatchNo	(None, 7, 7, 384)	1152	conv2d_27[0][0]
batch_normalization_30 (BatchNo	(None, 7, 7, 96)	288	conv2d_30[0][0]
activation_27 (Activation)	(None, 7, 7, 384)	0	batch_normalization_27[0][0]
activation_30 (Activation)	(None, 7, 7, 96)	0	batch_normalization_30[0][0]
max_pooling2d_3 (MaxPooling2D)	(None, 7, 7, 288)	0	mixed2[0][0]
mixed3 (Concatenate)	(None, 7, 7, 768)	0	activation_27[0][0] activation_30[0][0] max_pooling2d_3[0][0]
conv2d_35 (Conv2D)	(None, 7, 7, 128)	98304	mixed3[0][0]
batch_normalization_35 (BatchNo	(None, 7, 7, 128)	384	conv2d_35[0][0]
activation_35 (Activation)	(None, 7, 7, 128)	0	batch_normalization_35[0][0]
conv2d_36 (Conv2D)	(None, 7, 7, 128)	114688	activation_35[0][0]
batch_normalization_36 (BatchNo	(None, 7, 7, 128)	384	conv2d_36[0][0]

activation_36 (Activation)	(None, 7, 7, 128)	0	batch_normalization_36[0][0]
conv2d_32 (Conv2D)	(None, 7, 7, 128)	98304	mixed3[0][0]
conv2d_37 (Conv2D)	(None, 7, 7, 128)	114688	activation_36[0][0]
batch_normalization_32 (BatchNo	(None, 7, 7, 128)	384	conv2d_32[0][0]
batch_normalization_37 (BatchNo	(None, 7, 7, 128)	384	conv2d_37[0][0]
activation_32 (Activation)	(None, 7, 7, 128)	0	batch_normalization_32[0][0]
activation_37 (Activation)	(None, 7, 7, 128)	0	batch_normalization_37[0][0]
conv2d_33 (Conv2D)	(None, 7, 7, 128)	114688	activation_32[0][0]
conv2d_38 (Conv2D)	(None, 7, 7, 128)	114688	activation_37[0][0]
batch_normalization_33 (BatchNo	(None, 7, 7, 128)	384	conv2d_33[0][0]
batch_normalization_38 (BatchNo	(None, 7, 7, 128)	384	conv2d_38[0][0]
activation_33 (Activation)	(None, 7, 7, 128)	0	batch_normalization_33[0][0]
activation_38 (Activation)	(None, 7, 7, 128)	0	batch_normalization_38[0][0]
average_pooling2d_4 (AveragePoo	(None, 7, 7, 768)	0	mixed3[0][0]
conv2d_31 (Conv2D)	(None, 7, 7, 192)	147456	mixed3[0][0]
conv2d_34 (Conv2D)	(None, 7, 7, 192)	172032	activation_33[0][0]
conv2d_39 (Conv2D)	(None, 7, 7, 192)	172032	activation_38[0][0]
conv2d_40 (Conv2D)	(None, 7, 7, 192)	147456	average_pooling2d_4[0][0]
batch_normalization_31 (BatchNo	(None, 7, 7, 192)	576	conv2d_31[0][0]
batch_normalization_34 (BatchNo	(None, 7, 7, 192)	576	conv2d_34[0][0]
batch_normalization_39 (BatchNo	(None, 7, 7, 192)	576	conv2d_39[0][0]
batch_normalization_40 (BatchNo	(None, 7, 7, 192)	576	conv2d_40[0][0]
activation_31 (Activation)	(None, 7, 7, 192)	0	batch_normalization_31[0][0]
activation_34 (Activation)	(None, 7, 7, 192)	0	batch_normalization_34[0][0]

activation_39 (Activation)	(None, 7, 7, 192)	0	batch_normalization_39[0][0]
activation_40 (Activation)	(None, 7, 7, 192)	0	batch_normalization_40[0][0]
mixed4 (Concatenate)	(None, 7, 7, 768)	0	activation_31[0][0] activation_34[0][0] activation_39[0][0] activation_40[0][0]
conv2d_45 (Conv2D)	(None, 7, 7, 160)	122880	mixed4[0][0]
batch_normalization_45 (BatchNo	(None, 7, 7, 160)	480	conv2d_45[0][0]
activation_45 (Activation)	(None, 7, 7, 160)	0	batch_normalization_45[0][0]
conv2d_46 (Conv2D)	(None, 7, 7, 160)	179200	activation_45[0][0]
batch_normalization_46 (BatchNo	(None, 7, 7, 160)	480	conv2d_46[0][0]
activation_46 (Activation)	(None, 7, 7, 160)	0	batch_normalization_46[0][0]
conv2d_42 (Conv2D)	(None, 7, 7, 160)	122880	mixed4[0][0]
conv2d_47 (Conv2D)	(None, 7, 7, 160)	179200	activation_46[0][0]
batch_normalization_42 (BatchNo	(None, 7, 7, 160)	480	conv2d_42[0][0]
batch_normalization_47 (BatchNo	(None, 7, 7, 160)	480	conv2d_47[0][0]
activation_42 (Activation)	(None, 7, 7, 160)	0	batch_normalization_42[0][0]
activation_47 (Activation)	(None, 7, 7, 160)	0	batch_normalization_47[0][0]
conv2d_43 (Conv2D)	(None, 7, 7, 160)	179200	activation_42[0][0]
conv2d_48 (Conv2D)	(None, 7, 7, 160)	179200	activation_47[0][0]
batch_normalization_43 (BatchNo	(None, 7, 7, 160)	480	conv2d_43[0][0]
batch_normalization_48 (BatchNo	(None, 7, 7, 160)	480	conv2d_48[0][0]
activation_43 (Activation)	(None, 7, 7, 160)	0	batch_normalization_43[0][0]
activation_48 (Activation)	(None, 7, 7, 160)	0	batch_normalization_48[0][0]
average_pooling2d_5 (AveragePoo	(None, 7, 7, 768)	0	mixed4[0][0]
conv2d_41 (Conv2D)	(None, 7, 7, 192)	147456	mixed4[0][0]



conv2d_44 (Conv2D)	(None, 7, 7, 192)	215040	activation_43[0][0]
conv2d_49 (Conv2D)	(None, 7, 7, 192)	215040	activation_48[0][0]
conv2d_50 (Conv2D)	(None, 7, 7, 192)	147456	average_pooling2d_5[0][0]
batch_normalization_41 (BatchNo	(None, 7, 7, 192)	576	conv2d_41[0][0]
batch_normalization_44 (BatchNo	(None, 7, 7, 192)	576	conv2d_44[0][0]
batch_normalization_49 (BatchNo	(None, 7, 7, 192)	576	conv2d_49[0][0]
batch_normalization_50 (BatchNo	(None, 7, 7, 192)	576	conv2d_50[0][0]
activation_41 (Activation)	(None, 7, 7, 192)	0	batch_normalization_41[0][0]
activation_44 (Activation)	(None, 7, 7, 192)	0	batch_normalization_44[0][0]
activation_49 (Activation)	(None, 7, 7, 192)	0	batch_normalization_49[0][0]
activation_50 (Activation)	(None, 7, 7, 192)	0	batch_normalization_50[0][0]
mixed5 (Concatenate)	(None, 7, 7, 768)	0	activation_41[0][0]
			activation_44[0][0]
			activation_49[0][0]
			activation_50[0][0]
conv2d_55 (Conv2D)	(None, 7, 7, 160)	122880	mixed5[0][0]
batch_normalization_55 (BatchNo	(None, 7, 7, 160)	480	conv2d_55[0][0]
activation_55 (Activation)	(None, 7, 7, 160)	0	batch_normalization_55[0][0]
conv2d_56 (Conv2D)	(None, 7, 7, 160)	179200	activation_55[0][0]
batch_normalization_56 (BatchNo	(None, 7, 7, 160)	480	conv2d_56[0][0]
activation_56 (Activation)	(None, 7, 7, 160)	0	batch_normalization_56[0][0]
conv2d_52 (Conv2D)	(None, 7, 7, 160)	122880	mixed5[0][0]
conv2d_57 (Conv2D)	(None, 7, 7, 160)	179200	activation_56[0][0]
batch_normalization_52 (BatchNo	(None, 7, 7, 160)	480	conv2d_52[0][0]
batch_normalization_57 (BatchNo	(None, 7, 7, 160)	480	conv2d_57[0][0]

activation_52 (Activation)	(None, 7, 7, 160)	0	batch_normalization_52[0][0]
activation_57 (Activation)	(None, 7, 7, 160)	0	batch_normalization_57[0][0]
conv2d_53 (Conv2D)	(None, 7, 7, 160)	179200	activation_52[0][0]
conv2d_58 (Conv2D)	(None, 7, 7, 160)	179200	activation_57[0][0]
batch_normalization_53 (BatchNo	(None, 7, 7, 160)	480	conv2d_53[0][0]
batch_normalization_58 (BatchNo	(None, 7, 7, 160)	480	conv2d_58[0][0]
activation_53 (Activation)	(None, 7, 7, 160)	0	batch_normalization_53[0][0]
activation_58 (Activation)	(None, 7, 7, 160)	0	batch_normalization_58[0][0]
average_pooling2d_6 (AveragePoo	(None, 7, 7, 768)	0	mixed5[0][0]
conv2d_51 (Conv2D)	(None, 7, 7, 192)	147456	mixed5[0][0]
conv2d_54 (Conv2D)	(None, 7, 7, 192)	215040	activation_53[0][0]
conv2d_59 (Conv2D)	(None, 7, 7, 192)	215040	activation_58[0][0]
conv2d_60 (Conv2D)	(None, 7, 7, 192)	147456	average_pooling2d_6[0][0]
batch_normalization_51 (BatchNo	(None, 7, 7, 192)	576	conv2d_51[0][0]
batch_normalization_54 (BatchNo	(None, 7, 7, 192)	576	conv2d_54[0][0]
batch_normalization_59 (BatchNo	(None, 7, 7, 192)	576	conv2d_59[0][0]
batch_normalization_60 (BatchNo	(None, 7, 7, 192)	576	conv2d_60[0][0]
activation_51 (Activation)	(None, 7, 7, 192)	0	batch_normalization_51[0][0]
activation_54 (Activation)	(None, 7, 7, 192)	0	batch_normalization_54[0][0]
activation_59 (Activation)	(None, 7, 7, 192)	0	batch_normalization_59[0][0]
activation_60 (Activation)	(None, 7, 7, 192)	0	batch_normalization_60[0][0]
mixed6 (Concatenate)	(None, 7, 7, 768)	0	activation_51[0][0] activation_54[0][0] activation_59[0][0] activation_60[0][0]
conv2d_65 (Conv2D)	(None, 7, 7, 192)	147456	mixed6[0][0]

batch_normalization_65 (BatchNo	(None, 7, 7, 192)	576	conv2d_65[0][0]
activation_65 (Activation)	(None, 7, 7, 192)	0	batch_normalization_65[0][0]
conv2d_66 (Conv2D)	(None, 7, 7, 192)	258048	activation_65[0][0]
batch_normalization_66 (BatchNo	(None, 7, 7, 192)	576	conv2d_66[0][0]
activation_66 (Activation)	(None, 7, 7, 192)	0	batch_normalization_66[0][0]
conv2d_62 (Conv2D)	(None, 7, 7, 192)	147456	mixed6[0][0]
conv2d_67 (Conv2D)	(None, 7, 7, 192)	258048	activation_66[0][0]
batch_normalization_62 (BatchNo	(None, 7, 7, 192)	576	conv2d_62[0][0]
batch_normalization_67 (BatchNo	(None, 7, 7, 192)	576	conv2d_67[0][0]
activation_62 (Activation)	(None, 7, 7, 192)	0	batch_normalization_62[0][0]
activation_67 (Activation)	(None, 7, 7, 192)	0	batch_normalization_67[0][0]
conv2d_63 (Conv2D)	(None, 7, 7, 192)	258048	activation_62[0][0]
conv2d_68 (Conv2D)	(None, 7, 7, 192)	258048	activation_67[0][0]
batch_normalization_63 (BatchNo	(None, 7, 7, 192)	576	conv2d_63[0][0]
batch_normalization_68 (BatchNo	(None, 7, 7, 192)	576	conv2d_68[0][0]
activation_63 (Activation)	(None, 7, 7, 192)	0	batch_normalization_63[0][0]
activation_68 (Activation)	(None, 7, 7, 192)	0	batch_normalization_68[0][0]
average_pooling2d_7 (AveragePoo	(None, 7, 7, 768)	0	mixed6[0][0]
conv2d_61 (Conv2D)	(None, 7, 7, 192)	147456	mixed6[0][0]
conv2d_64 (Conv2D)	(None, 7, 7, 192)	258048	activation_63[0][0]
conv2d_69 (Conv2D)	(None, 7, 7, 192)	258048	activation_68[0][0]
conv2d_70 (Conv2D)	(None, 7, 7, 192)	147456	average_pooling2d_7[0][0]
batch_normalization_61 (BatchNo	(None, 7, 7, 192)	576	conv2d_61[0][0]
batch_normalization_64 (BatchNo	(None, 7, 7, 192)	576	conv2d_64[0][0]

batch_normalization_69 (BatchNo	(None, 7, 7, 192)	576	conv2d_69[0][0]
batch_normalization_70 (BatchNo	(None, 7, 7, 192)	576	conv2d_70[0][0]
activation_61 (Activation)	(None, 7, 7, 192)	0	batch_normalization_61[0][0]
activation_64 (Activation)	(None, 7, 7, 192)	0	batch_normalization_64[0][0]
activation_69 (Activation)	(None, 7, 7, 192)	0	batch_normalization_69[0][0]
activation_70 (Activation)	(None, 7, 7, 192)	0	batch_normalization_70[0][0]
mixed7 (Concatenate)	(None, 7, 7, 768)	0	activation_61[0][0]
			activation_64[0][0]
			activation_69[0][0]
			activation_70[0][0]
conv2d_73 (Conv2D)	(None, 7, 7, 192)	147456	mixed7[0][0]
batch_normalization_73 (BatchNo	(None, 7, 7, 192)	576	conv2d_73[0][0]
activation_73 (Activation)	(None, 7, 7, 192)	0	batch_normalization_73[0][0]
conv2d_74 (Conv2D)	(None, 7, 7, 192)	258048	activation_73[0][0]
batch_normalization_74 (BatchNo	(None, 7, 7, 192)	576	conv2d_74[0][0]
activation_74 (Activation)	(None, 7, 7, 192)	0	batch_normalization_74[0][0]
conv2d_71 (Conv2D)	(None, 7, 7, 192)	147456	mixed7[0][0]
conv2d_75 (Conv2D)	(None, 7, 7, 192)	258048	activation_74[0][0]
batch_normalization_71 (BatchNo	(None, 7, 7, 192)	576	conv2d_71[0][0]
batch_normalization_75 (BatchNo	(None, 7, 7, 192)	576	conv2d_75[0][0]
activation_71 (Activation)	(None, 7, 7, 192)	0	batch_normalization_71[0][0]
activation_75 (Activation)	(None, 7, 7, 192)	0	batch_normalization_75[0][0]
conv2d_72 (Conv2D)	(None, 3, 3, 320)	552960	activation_71[0][0]
conv2d_76 (Conv2D)	(None, 3, 3, 192)	331776	activation_75[0][0]
batch_normalization_72 (BatchNo	(None, 3, 3, 320)	960	conv2d_72[0][0]

batch_normalization_76 (BatchNo	(None, 3, 3, 192)	576	conv2d_76[0][0]
activation_72 (Activation)	(None, 3, 3, 320)	0	batch_normalization_72[0][0]
activation_76 (Activation)	(None, 3, 3, 192)	0	batch_normalization_76[0][0]
max_pooling2d_4 (MaxPooling2D)	(None, 3, 3, 768)	0	mixed7[0][0]
mixed8 (Concatenate)	(None, 3, 3, 1280)	0	activation_72[0][0] activation_76[0][0] max_pooling2d_4[0][0]
conv2d_81 (Conv2D)	(None, 3, 3, 448)	573440	mixed8[0][0]
batch_normalization_81 (BatchNo	(None, 3, 3, 448)	1344	conv2d_81[0][0]
activation_81 (Activation)	(None, 3, 3, 448)	0	batch_normalization_81[0][0]
conv2d_78 (Conv2D)	(None, 3, 3, 384)	491520	mixed8[0][0]
conv2d_82 (Conv2D)	(None, 3, 3, 384)	1548288	activation_81[0][0]
batch_normalization_78 (BatchNo	(None, 3, 3, 384)	1152	conv2d_78[0][0]
batch_normalization_82 (BatchNo	(None, 3, 3, 384)	1152	conv2d_82[0][0]
activation_78 (Activation)	(None, 3, 3, 384)	0	batch_normalization_78[0][0]
activation_82 (Activation)	(None, 3, 3, 384)	0	batch_normalization_82[0][0]
conv2d_79 (Conv2D)	(None, 3, 3, 384)	442368	activation_78[0][0]
conv2d_80 (Conv2D)	(None, 3, 3, 384)	442368	activation_78[0][0]
conv2d_83 (Conv2D)	(None, 3, 3, 384)	442368	activation_82[0][0]
conv2d_84 (Conv2D)	(None, 3, 3, 384)	442368	activation_82[0][0]
average_pooling2d_8 (AveragePoo	(None, 3, 3, 1280)	0	mixed8[0][0]
conv2d_77 (Conv2D)	(None, 3, 3, 320)	409600	mixed8[0][0]
batch_normalization_79 (BatchNo	(None, 3, 3, 384)	1152	conv2d_79[0][0]
batch_normalization_80 (BatchNo	(None, 3, 3, 384)	1152	conv2d_80[0][0]
batch_normalization_83 (BatchNo	(None, 3, 3, 384)	1152	conv2d_83[0][0]

batch_normalization_84 (BatchNo	(None, 3, 3, 384)	1152	conv2d_84[0][0]
conv2d_85 (Conv2D)	(None, 3, 3, 192)	245760	average_pooling2d_8[0][0]
batch_normalization_77 (BatchNo	(None, 3, 3, 320)	960	conv2d_77[0][0]
activation_79 (Activation)	(None, 3, 3, 384)	0	batch_normalization_79[0][0]
activation_80 (Activation)	(None, 3, 3, 384)	0	batch_normalization_80[0][0]
activation_83 (Activation)	(None, 3, 3, 384)	0	batch_normalization_83[0][0]
activation_84 (Activation)	(None, 3, 3, 384)	0	batch_normalization_84[0][0]
batch_normalization_85 (BatchNo	(None, 3, 3, 192)	576	conv2d_85[0][0]
activation_77 (Activation)	(None, 3, 3, 320)	0	batch_normalization_77[0][0]
mixed9_0 (Concatenate)	(None, 3, 3, 768)	0	activation_79[0][0] activation_80[0][0]
concatenate_1 (Concatenate)	(None, 3, 3, 768)	0	activation_83[0][0] activation_84[0][0]
activation_85 (Activation)	(None, 3, 3, 192)	0	batch_normalization_85[0][0]
mixed9 (Concatenate)	(None, 3, 3, 2048)	0	activation_77[0][0] mixed9_0[0][0] concatenate_1[0][0] activation_85[0][0]
conv2d_90 (Conv2D)	(None, 3, 3, 448)	917504	mixed9[0][0]
batch_normalization_90 (BatchNo	(None, 3, 3, 448)	1344	conv2d_90[0][0]
activation_90 (Activation)	(None, 3, 3, 448)	0	batch_normalization_90[0][0]
conv2d_87 (Conv2D)	(None, 3, 3, 384)	786432	mixed9[0][0]
conv2d_91 (Conv2D)	(None, 3, 3, 384)	1548288	activation_90[0][0]
batch_normalization_87 (BatchNo	(None, 3, 3, 384)	1152	conv2d_87[0][0]
batch_normalization_91 (BatchNo	(None, 3, 3, 384)	1152	conv2d_91[0][0]
activation_87 (Activation)	(None, 3, 3, 384)	0	batch_normalization_87[0][0]
activation_91 (Activation)	(None, 3, 3, 384)	0	batch_normalization_91[0][0]

conv2d_88 (Conv2D)	(None, 3, 3, 384)	442368	activation_87[0][0]
conv2d_89 (Conv2D)	(None, 3, 3, 384)	442368	activation_87[0][0]
conv2d_92 (Conv2D)	(None, 3, 3, 384)	442368	activation_91[0][0]
conv2d_93 (Conv2D)	(None, 3, 3, 384)	442368	activation_91[0][0]
average_pooling2d_9 (AveragePoo	(None, 3, 3, 2048)	0	mixed9[0][0]
conv2d_86 (Conv2D)	(None, 3, 3, 320)	655360	mixed9[0][0]
batch_normalization_88 (BatchNo	(None, 3, 3, 384)	1152	conv2d_88[0][0]
batch_normalization_89 (BatchNo	(None, 3, 3, 384)	1152	conv2d_89[0][0]
batch_normalization_92 (BatchNo	(None, 3, 3, 384)	1152	conv2d_92[0][0]
batch_normalization_93 (BatchNo	(None, 3, 3, 384)	1152	conv2d_93[0][0]
conv2d_94 (Conv2D)	(None, 3, 3, 192)	393216	average_pooling2d_9[0][0]
batch_normalization_86 (BatchNo	(None, 3, 3, 320)	960	conv2d_86[0][0]
activation_88 (Activation)	(None, 3, 3, 384)	0	batch_normalization_88[0][0]
activation_89 (Activation)	(None, 3, 3, 384)	0	batch_normalization_89[0][0]
activation_92 (Activation)	(None, 3, 3, 384)	0	batch_normalization_92[0][0]
activation_93 (Activation)	(None, 3, 3, 384)	0	batch_normalization_93[0][0]
batch_normalization_94 (BatchNo	(None, 3, 3, 192)	576	conv2d_94[0][0]
activation_86 (Activation)	(None, 3, 3, 320)	0	batch_normalization_86[0][0]
mixed9_1 (Concatenate)	(None, 3, 3, 768)	0	activation_88[0][0] activation_89[0][0]
concatenate_2 (Concatenate)	(None, 3, 3, 768)	0	activation_92[0][0] activation_93[0][0]
activation_94 (Activation)	(None, 3, 3, 192)	0	batch_normalization_94[0][0]
mixed10 (Concatenate)	(None, 3, 3, 2048)	0	activation_86[0][0] mixed9_1[0][0] concatenate_2[0][0]

activation\_94[0][0]

```
=====  
Total params: 21,802,784  
Trainable params: 21,768,352  
Non-trainable params: 34,432  
-----
```

```
In [3]: # this is the model we will train  
        model = Sequential()  
        model.add(base_model)  
        model.add(Flatten())  
        model.add(Dense(256,activation='relu'))  
        model.add(Dense(1, activation='sigmoid'))  
  
        model.summary()
```

```
-----  
Layer (type)             Output Shape          Param #  
=====
```

inception_v3 (Model)	(None, 3, 3, 2048)	21802784
flatten_1 (Flatten)	(None, 18432)	0
dense_1 (Dense)	(None, 256)	4718848
dense_2 (Dense)	(None, 1)	257

```
=====
```

```
Total params: 26,521,889  
Trainable params: 26,487,457  
Non-trainable params: 34,432  
-----
```

```
In [4]: print('Number of trainable weights before freezing: ', len(model.trainable_weights))  
        ## to freeze all convolutional layers in pretrained network method 1  
        # base_model.trainable=False
```

Number of trainable weights before freezing: 192

```
In [5]: # def recall_m(y_true, y_pred):  
        #     true_positives = K.sum(K.round(K.clip(y_true * y_pred,0,1)))  
        #     possible_positives = K.sum(K.round(K.clip(y_true,0,1)))  
        #     recall = true_positives / (possible_positives + K.epsilon())  
        #     return recall  
        # def precision_m(y_true, y_pred):  
        #     true_positives = K.sum(K.round(K.clip(y_true * y_pred,0,1)))  
        #     predicted_positives = K.sum(K.round(K.clip(y_pred,0,1)))
```



```

# precision = true_positives/(predicted_positives+K.epsilon())
# return precision

# first: train only the top layers (which were randomly initialized)
# i.e. freeze all convolutional pretrained layers method 2
for layer in base_model.layers:
    layer.trainable = False
print('After freezing: ', len(model.trainable_weights))
# compile the model (should be done *after* setting layers to non-trainable)
model.compile(optimizer=optimizers.Adam(lr=1e-4), metrics=['acc'], loss='binary_crossentropy')

```

W0209 15:26:46.548356 139856742401856 deprecation\_wrapper.py:119] From /home/mlab/anaconda3/lib/python

W0209 15:26:46.554069 139856742401856 deprecation.py:323] From /home/mlab/anaconda3/lib/python3.7/site-p

Instructions for updating:

Use tf.where in 2.0, which has the same broadcast rule as np.where

After freezing: 4

```

In [6]: train_data_dir = '/home/mlab/Documents/brats_hl_data/train'
        validation_data_dir = '/home/mlab/Documents/brats_hl_data/val'
        # 44938
        # 5616
        nb_train_samples = 44938
        nb_validation_samples = 5616
        epochs = 8
        batch_size = 128
        # prepare data augmentation configuration
        train_datagen = ImageDataGenerator(
            rescale=1. / 255,
            shear_range=0.2,
            zoom_range=0.2,
            horizontal_flip=True)

        test_datagen = ImageDataGenerator(rescale=1. / 255)

        train_generator = train_datagen.flow_from_directory(
            train_data_dir,
            target_size=(150, 150),
            batch_size=batch_size,
            class_mode='binary')

        validation_generator = test_datagen.flow_from_directory(
            validation_data_dir,
            target_size=(150, 150),
            batch_size=batch_size,
            class_mode='binary')

```

Found 44938 images belonging to 2 classes.  
Found 5616 images belonging to 2 classes.

```
In [7]: true_classes = train_generator.classes
        print(true_classes)
        class_labels = list(train_generator.class_indices.keys())
        print(class_labels)
```

```
[0 0 0 ... 1 1 1]
['high', 'low']
```

```
In [8]: # train the model on the new data for a few epochs
        history = model.fit_generator(train_generator,
                                     steps_per_epoch=nb_train_samples//batch_size,
                                     epochs=epochs,
                                     validation_data=validation_generator,
                                     validation_steps=nb_validation_samples//batch_size)
```

```
Epoch 1/8
351/351 [=====] - 475s 1s/step - loss: 0.6253 - acc: 0.6408 - val_loss: 0.5528
Epoch 2/8
351/351 [=====] - 457s 1s/step - loss: 0.5528 - acc: 0.6988 - val_loss: 0.5225
Epoch 3/8
351/351 [=====] - 458s 1s/step - loss: 0.5225 - acc: 0.7221 - val_loss: 0.4977
Epoch 4/8
351/351 [=====] - 458s 1s/step - loss: 0.4977 - acc: 0.7406 - val_loss: 0.4816
Epoch 5/8
351/351 [=====] - 458s 1s/step - loss: 0.4816 - acc: 0.7513 - val_loss: 0.4634
Epoch 6/8
351/351 [=====] - 456s 1s/step - loss: 0.4634 - acc: 0.7641 - val_loss: 0.4598
Epoch 7/8
351/351 [=====] - 457s 1s/step - loss: 0.4598 - acc: 0.7647 - val_loss: 0.4486
Epoch 8/8
351/351 [=====] - 459s 1s/step - loss: 0.4486 - acc: 0.7740 - val_loss: 0.4486
```

```
In [9]: true_classes_1 = validation_generator.classes
        print(true_classes)
        class_labels_1 = list(validation_generator.class_indices.keys())
        print(class_labels_1)
```

```
[0 0 0 ... 1 1 1]
['high', 'low']
```

```
In [10]: #Confution Matrix and Classification Report
         Y_pred = model.predict_generator(validation_generator, nb_validation_samples // batch_size+1)
```

```

In [11]: # y_pred = np.argmax(Y_pred, axis=1)
        y_pred = (Y_pred<0.475).astype(np.int)

        # print('Confusion Matrix')
        # print(confusion_matrix(true_classes_1, y_pred))
        # print('Classification Report')
        # print(classification_report(validation_generator.classes, y_pred,
        #                             target_names=class_labels_1))

In [12]: # print(validation_generator.classes)

In [13]: confusion_matrix = metrics.confusion_matrix(true_classes_1,y_pred)
        print(confusion_matrix)

[[1643 1132]
 [1704 1137]]

In [14]: report= sklearn.metrics.classification_report(true_classes_1, y_pred,
        target_names = class_labels_1)

        print(report)

              precision    recall  f1-score   support

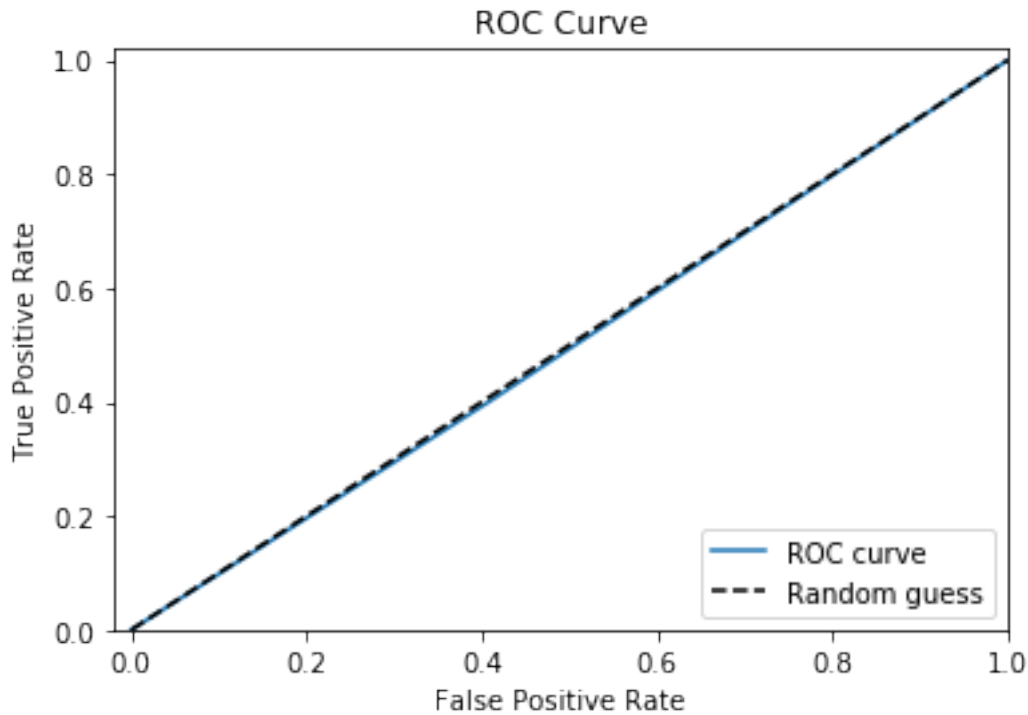
    high         0.49         0.59         0.54         2775
    low          0.50         0.40         0.45         2841

 micro avg         0.50         0.50         0.50         5616
 macro avg         0.50         0.50         0.49         5616
weighted avg         0.50         0.50         0.49         5616


In [15]: fpr, tpr, thresholds = roc_curve(validation_generator.classes, y_pred)

        # create plot
        plt.plot(fpr, tpr, label='ROC curve')
        plt.plot([0, 1], [0, 1], 'k--', label='Random guess')
        _ = plt.xlabel('False Positive Rate')
        _ = plt.ylabel('True Positive Rate')
        _ = plt.title('ROC Curve')
        _ = plt.xlim([-0.02, 1])
        _ = plt.ylim([0, 1.02])
        _ = plt.legend(loc="lower right")

```



```
In [16]: roc_auc_score(validation_generator.classes, y_pred)
```

```
Out[16]: 0.4961416326569441
```

```
In [17]: batchX, batchy = train_generator.next()
_, accuracy = model.evaluate(batchX, batchy)
print('Accuracy training: %.2f' % (accuracy*100))
batchXv, batchyv = validation_generator.next()
_, accuracy = model.evaluate(batchXv, batchyv)
print('Accuracy val: %.2f' % (accuracy*100))
```

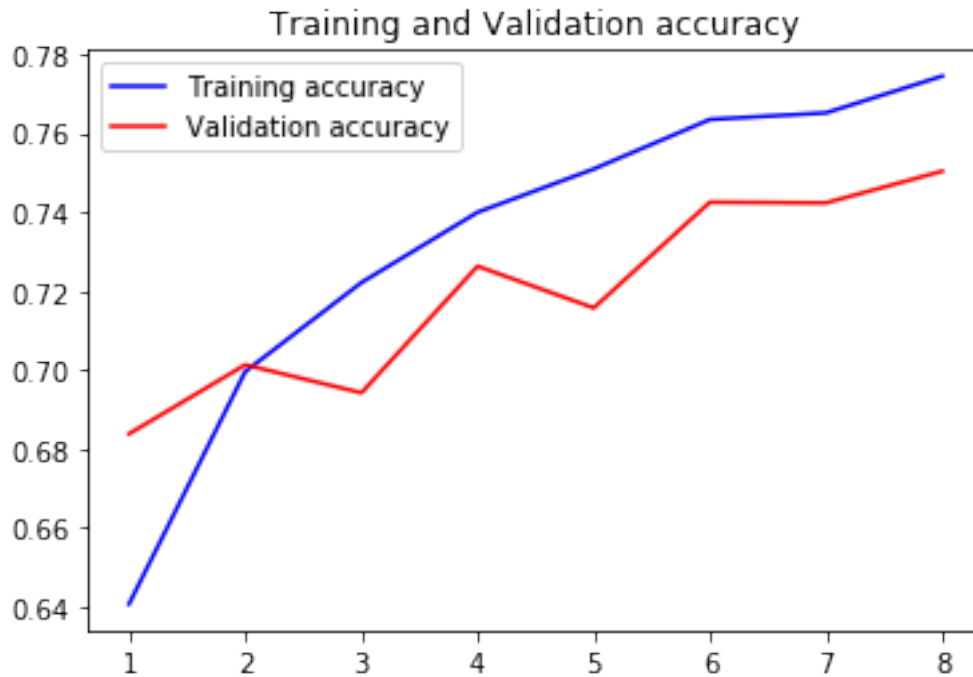
```
128/128 [=====] - 1s 9ms/step
Accuracy training: 82.81
128/128 [=====] - 1s 10ms/step
Accuracy val: 81.25
```

```
In [18]: #plot the train and val curve
#get the details from the history object
acc = history.history['acc']
val_acc=history.history['val_acc']
loss = history.history['loss']
val_loss = history.history['val_loss']
```

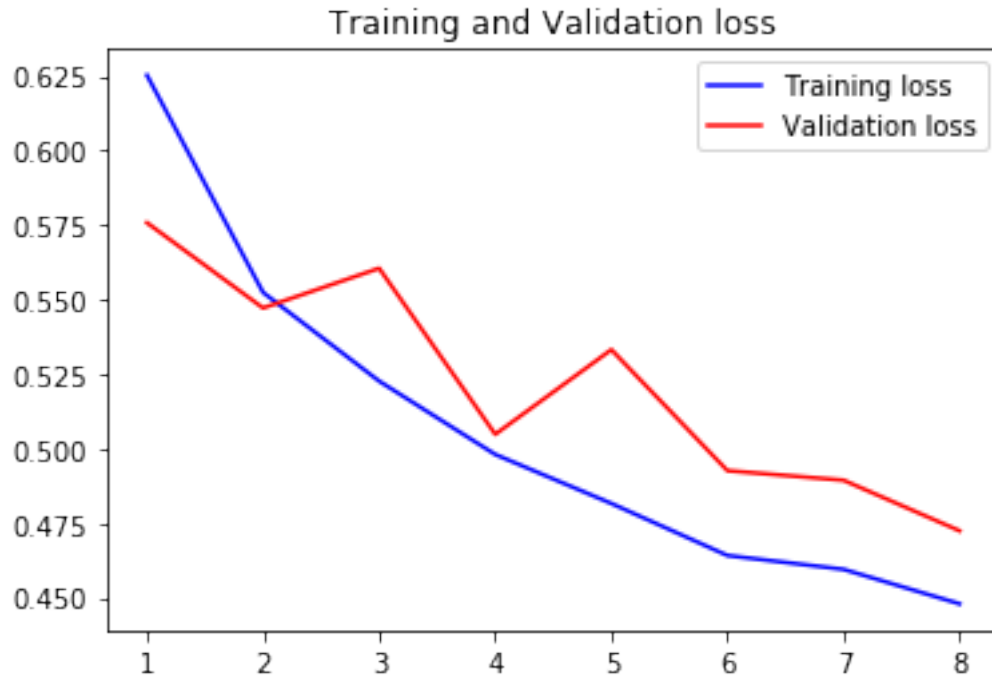
```
epochs = range(1,len(acc)+1)

#train and validation accuracy
plt.plot(epochs,acc,'b',label='Training accuracy')
plt.plot(epochs,val_acc,'r',label='Validation accuracy')
plt.title('Training and Validation accuracy')
plt.legend()
```

Out[18]: <matplotlib.legend.Legend at 0x7f31bd1ce4e0>



```
In [19]: #train and validation loss
plt.plot(epochs, loss, 'b',label='Training loss')
plt.plot(epochs, val_loss, 'r',label='Validation loss')
plt.title('Training and Validation loss')
plt.legend()
plt.show()
```



```
In [20]: test_generator = test_datagen.flow_from_directory('/home/mlab/Documents/brats_hl_data/test',
class_mode='binary',
batch_size=batch_size,
target_size=(150,150))
scores = model.evaluate_generator(test_generator, steps=nb_validation_samples//batch_size)
```

Found 5619 images belonging to 2 classes.

```
In [21]: print("%s: %.2f%%" % (model.metrics_names[1], scores[1]*100))
```

acc: 74.26%

```
In [22]: #Confution Matrix and Classification Report
# Y_pred = model.predict_generator(val_generator, 5616 // batch_size)
nb_test_samples=5619
Y_pred1 = model.predict_generator(test_generator,nb_test_samples//batch_size+1)
# y_pred = np.argmax(Y_pred,axis=1)
```

```
In [23]: true_classes_2 = test_generator.classes
print(true_classes_2)
class_labels_2 = list(test_generator.class_indices.keys())
print(class_labels_2)
```

```
[0 0 0 ... 1 1 1]
['high', 'low']
```

```
In [24]: # y_pred1 = (Y_pred1<0.5).astype(np.int)
        y_pred1 = (Y_pred1 < 0.475).astype(np.int)
        # print(y_pred)
        # print('Confusion Matrix')
        # print(confusion_matrix(true_classes_2, y_pred1))
        # print('Classification Report')
        # print(classification_report(true_classes_2, y_pred1, target_names=class_labels_2))
```

```
In [25]: confusion_matrix1 = metrics.confusion_matrix(true_classes_2,y_pred1)
        print(confusion_matrix1)
```

```
[[1619 1157]
 [1746 1097]]
```

```
In [26]: report1= sklearn.metrics.classification_report(true_classes_2, y_pred1,
        target_names = class_labels_2)
        print(report1)
```

	precision	recall	f1-score	support
high	0.48	0.58	0.53	2776
low	0.49	0.39	0.43	2843
micro avg	0.48	0.48	0.48	5619
macro avg	0.48	0.48	0.48	5619
weighted avg	0.48	0.48	0.48	5619

```
In [27]: print(" Loss: ", scores[0],"\n","Accuracy: ", scores[1])
```

```
Loss: 0.4889762325342311
Accuracy: 0.7425508720930233
```