DenseNet_CIFAR_resubmission

July 7, 2021

1 Implement DenseNet on CIFAR-10

1.1 Index

1. Assignment instructions
2. Assignment

- 2.1 Defining Dense Block, Transition Block and Output Block
- 2.2 Using Data Augmentation for training the DenseNet
- 2.3 Using LearningRateScheduler, ReduceLROnPlateau,CSVLogger in callbacks
- 2.4 Growth Rate(num_filter) = 36, compression = 0.7, Number of blocks = 12
- 2.5 Plotting loss and accuracy of Model 5 above

3. Conclusion

1.2 1. Assignment instructions

1. Please visit this link to access the state-of-art DenseNet code for reference - DenseNet - cifar10 notebook link
2. You need to create a copy of this and "retrain" this model to achieve 90+ test accuracy.
3. You cannot use DropOut layers.
4. You MUST use Image Augmentation Techniques.
5. You cannot use an already trained model as a beginning points, you have to initilize as your own
6. You cannot run the program for more than 300 Epochs, and it should be clear from your log, that you have only used 300 Epochs
7. You cannot use test images for training the model.
8. You cannot change the general architecture of DenseNet (which means you must use Dense Block, Transition and Output blocks as mentioned in the code)
9. You are free to change Convolution types (e.g. from 3x3 normal convolution to Depthwise Separable, etc)
10. You cannot have more than 1 Million parameters in total
11. You are free to move the code from Keras to Tensorflow, Pytorch, MXNET etc.
12. You can use any optimization algorithm you need.
13. You can checkpoint your model and retrain the model from that checkpoint so that no need of training the model from first if you lost at any epoch while training. You can directly load that model and Train from that epoch.

1.3 2. Assignment

[ ]:
```
# import keras
# from keras.datasets import cifar10
# from keras.models import Model, Sequential
# from keras.layers import Dense, Dropout, Flatten, Input, AveragePooling2D,␣
 ↪merge, Activation
# from keras.layers import Conv2D, MaxPooling2D, BatchNormalization
# from keras.layers import Concatenate
# from keras.optimizers import Adam
from tensorflow.keras import models, layers
from tensorflow.keras.models import Model
from tensorflow.keras.layers import BatchNormalization, Activation, Flatten
from tensorflow.keras.optimizers import Adam
```

[ ]:
```
# this part will prevent tensorflow to allocate all the avaliable GPU Memory
# backend
import tensorflow as tf
```

[ ]:
```
# Load CIFAR10 Data
(X_train, y_train), (X_test, y_test) = tf.keras.datasets.cifar10.load_data()
img_height, img_width, channel = X_train.shape[1],X_train.shape[2],X_train.
 ↪shape[3]

#scale the data (images) to [0,1] range
X_train = X_train.astype("float32")/255
X_test = X_test.astype("float32")/255

# convert to one hot encoding
num_classes = 10
y_train = tf.keras.utils.to_categorical(y_train, num_classes)
y_test = tf.keras.utils.to_categorical(y_test, num_classes)
```

```
Downloading data from https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz
170500096/170498071 [==============================] - 2s 0us/step
```

[ ]:
```
X_train.shape
```

[ ]:
```
(50000, 32, 32, 3)
```

[ ]:
```
X_test.shape
```

[ ]:
```
(10000, 32, 32, 3)
```

1.3.1 2.1 Defining Dense Block, Transition Block and Output Layer

[ ]:
```
# Dense Block
def denseblock(input, num_filter = 12, dropout_rate = 0.2):
    global compression
    temp = input
    for _ in range(l):
        BatchNorm = layers.BatchNormalization()(temp)
        relu = layers.Activation('relu')(BatchNorm)
        Conv2D_1_1 = layers.Conv2D(int(num_filter*compression),␣
 ↪(1,1),use_bias=False,padding='same')(relu)
        BatchNorm1 = layers.BatchNormalization()(Conv2D_1_1)
        relu1 = layers.Activation('relu')(BatchNorm1)
        Conv2D_3_3 = layers.Conv2D(int(num_filter*compression), (3,3),␣
 ↪use_bias=False ,padding='same')(relu1)
        if dropout_rate>0:
            Conv2D_3_3 = layers.Dropout(dropout_rate)(Conv2D_3_3)
        concat = layers.Concatenate(axis=-1)([temp,Conv2D_3_3])

        temp = concat

    return temp

## transition Block
def transition(input, num_filter = 12, dropout_rate = 0.2):
    global compression
    BatchNorm = layers.BatchNormalization()(input)
    relu = layers.Activation('relu')(BatchNorm)
    Conv2D_BottleNeck = layers.Conv2D(int(num_filter*compression), (1,1),␣
 ↪use_bias=False ,padding='same')(relu)
    if dropout_rate>0:
         Conv2D_BottleNeck = layers.Dropout(dropout_rate)(Conv2D_BottleNeck)
    avg = layers.AveragePooling2D(pool_size=(2,2))(Conv2D_BottleNeck)
    return avg

#output layer
def output_layer(input):
    global compression
    BatchNorm = layers.BatchNormalization()(input)
    relu = layers.Activation('relu')(BatchNorm)
    AvgPooling = layers.AveragePooling2D(pool_size=(2,2))(relu)
    flat = layers.Flatten()(AvgPooling)
    output = layers.Dense(num_classes, activation='softmax')(flat)
    return output
```

1.3.2 2.2 Using Data Augmentation for training the DenseNet

[ ]:
```
#https://www.pyimagesearch.com/2018/12/24/
 ↪how-to-use-keras-fit-and-fit_generator-a-hands-on-tutorial/
from tensorflow.keras.preprocessing.image import ImageDataGenerator
#creating a training image generator for data augmentation
aug = ImageDataGenerator(rotation_range=0.20,width_shift_range=0.
 ↪20,height_shift_range=0.15,shear_range=0.15,
                         zoom_range=0.30,horizontal_flip=True)
```

1.3.3 2.3 Using LearningRateScheduler, ReduceLROnPlateau,CSVLogger in callbacks

[ ]:
```
#https://keras.io/api/callbacks/reduce_lr_on_plateau/
from tensorflow.keras.callbacks import ReduceLROnPlateau

reduce_lr = ReduceLROnPlateau(monitor='val_loss', factor=0.2, patience=5,␣
 ↪min_lr=0.001)
```

[ ]:
```
#https://keras.io/api/callbacks/learning_rate_scheduler/
from tensorflow.keras.callbacks import LearningRateScheduler
lr_list = [0.01,0.001,0.0001]
def scheduler(epoch,lr):
  if epoch<25:
    return lr_list[0]
  if epoch>=25 and epoch<50:
    return lr_list[1]
  else:
    return lr_list[2]


lr_scheduler = LearningRateScheduler(scheduler)
```

[ ]:
```
#https://keras.io/api/callbacks/csv_logger/
from tensorflow.keras.callbacks import CSVLogger

csv_logger = CSVLogger('training.log')
```

[ ]:
```
#https://keras.io/api/callbacks/early_stopping/
from tensorflow.keras.callbacks import EarlyStopping

early_stop = EarlyStopping(monitor='loss',patience=10)
```

1.3.4 2.4 Growth Rate(num_filter) = 36, compression = 0.7, Number of blocks = 12

[ ]:
```
# Hyperparameters
batch_size = 64
num_classes = 10
nb_epoch = 100
l = 12
num_filter = 36
compression = 0.7
dropout_rate = 0
```

[ ]:
```
from tensorflow.keras.callbacks import ModelCheckpoint
#https://machinelearningmastery.com/check-point-deep-learning-models-keras/
filepath="model5_weights.best.hdf5"
model_checkpoint =␣
↪ModelCheckpoint(filepath,monitor='val_accuracy',save_best_only=True,verbose=1)
```

[ ]:
```
input = layers.Input(shape=(img_height, img_width, channel,))
First_Conv2D = layers.Conv2D(num_filter, (3,3), use_bias=False␣
↪,padding='same')(input)

First_Block = denseblock(First_Conv2D, num_filter, dropout_rate)
First_Transition = transition(First_Block, num_filter, dropout_rate)

Second_Block = denseblock(First_Transition, num_filter, dropout_rate)
Second_Transition = transition(Second_Block, num_filter, dropout_rate)

Third_Block = denseblock(Second_Transition, num_filter, dropout_rate)
Third_Transition = transition(Third_Block, num_filter, dropout_rate)

Last_Block = denseblock(Third_Transition,  num_filter, dropout_rate)
output = output_layer(Last_Block)
```

[16]:
```
model5 = Model(inputs = [input], outputs = [output])
model5.summary()
```

```
Model: "model"
__________________________________________________________________________________
__________________
Layer (type)                    Output Shape         Param #     Connected to
==================================================================================
==================
input_1 (InputLayer)            [(None, 32, 32, 3)]  0
__________________________________________________________________________________
__________________
conv2d (Conv2D)                 (None, 32, 32, 36)   972         input_1[0][0]
__________________________________________________________________________________
```

```
------------------
batch_normalization (BatchNorma (None, 32, 32, 36)   144         conv2d[0][0]
____________________________________________________________________________
------------------
activation (Activation)         (None, 32, 32, 36)   0
batch_normalization[0][0]
____________________________________________________________________________
------------------
conv2d_1 (Conv2D)               (None, 32, 32, 25)   900
activation[0][0]
____________________________________________________________________________
------------------
batch_normalization_1 (BatchNor (None, 32, 32, 25)   100         conv2d_1[0][0]
____________________________________________________________________________
------------------
activation_1 (Activation)       (None, 32, 32, 25)   0
batch_normalization_1[0][0]
____________________________________________________________________________
------------------
conv2d_2 (Conv2D)               (None, 32, 32, 25)   5625
activation_1[0][0]
____________________________________________________________________________
------------------
concatenate (Concatenate)       (None, 32, 32, 61)   0           conv2d[0][0]
                                                                 conv2d_2[0][0]
____________________________________________________________________________
------------------
batch_normalization_2 (BatchNor (None, 32, 32, 61)   244
concatenate[0][0]
____________________________________________________________________________
------------------
activation_2 (Activation)       (None, 32, 32, 61)   0
batch_normalization_2[0][0]
____________________________________________________________________________
------------------
conv2d_3 (Conv2D)               (None, 32, 32, 25)   1525
activation_2[0][0]
____________________________________________________________________________
------------------
batch_normalization_3 (BatchNor (None, 32, 32, 25)   100         conv2d_3[0][0]
____________________________________________________________________________
------------------
activation_3 (Activation)       (None, 32, 32, 25)   0
batch_normalization_3[0][0]
____________________________________________________________________________
------------------
conv2d_4 (Conv2D)               (None, 32, 32, 25)   5625
activation_3[0][0]
```

```
__________________________________________________________________________________
__________________
concatenate_1 (Concatenate)     (None, 32, 32, 86)   0
concatenate[0][0]
                                                                 conv2d_4[0][0]
__________________________________________________________________________________
__________________
batch_normalization_4 (BatchNor (None, 32, 32, 86)   344
concatenate_1[0][0]
__________________________________________________________________________________
__________________
activation_4 (Activation)       (None, 32, 32, 86)   0
batch_normalization_4[0][0]
__________________________________________________________________________________
__________________
conv2d_5 (Conv2D)               (None, 32, 32, 25)   2150
activation_4[0][0]
__________________________________________________________________________________
__________________
batch_normalization_5 (BatchNor (None, 32, 32, 25)   100         conv2d_5[0][0]
__________________________________________________________________________________
__________________
activation_5 (Activation)       (None, 32, 32, 25)   0
batch_normalization_5[0][0]
__________________________________________________________________________________
__________________
conv2d_6 (Conv2D)               (None, 32, 32, 25)   5625
activation_5[0][0]
__________________________________________________________________________________
__________________
concatenate_2 (Concatenate)     (None, 32, 32, 111)  0
concatenate_1[0][0]
                                                                 conv2d_6[0][0]
__________________________________________________________________________________
__________________
batch_normalization_6 (BatchNor (None, 32, 32, 111)  444
concatenate_2[0][0]
__________________________________________________________________________________
__________________
activation_6 (Activation)       (None, 32, 32, 111)  0
batch_normalization_6[0][0]
__________________________________________________________________________________
__________________
conv2d_7 (Conv2D)               (None, 32, 32, 25)   2775
activation_6[0][0]
__________________________________________________________________________________
__________________
batch_normalization_7 (BatchNor (None, 32, 32, 25)   100         conv2d_7[0][0]
```

```
____________________________________________________________________________
__________________
activation_7 (Activation)       (None, 32, 32, 25)   0
batch_normalization_7[0][0]
____________________________________________________________________________
__________________
conv2d_8 (Conv2D)               (None, 32, 32, 25)   5625
activation_7[0][0]
____________________________________________________________________________
__________________
concatenate_3 (Concatenate)     (None, 32, 32, 136)  0
concatenate_2[0][0]
                                                                 conv2d_8[0][0]
____________________________________________________________________________
__________________
batch_normalization_8 (BatchNor (None, 32, 32, 136)  544
concatenate_3[0][0]
____________________________________________________________________________
__________________
activation_8 (Activation)       (None, 32, 32, 136)  0
batch_normalization_8[0][0]
____________________________________________________________________________
__________________
conv2d_9 (Conv2D)               (None, 32, 32, 25)   3400
activation_8[0][0]
____________________________________________________________________________
__________________
batch_normalization_9 (BatchNor (None, 32, 32, 25)   100         conv2d_9[0][0]
____________________________________________________________________________
__________________
activation_9 (Activation)       (None, 32, 32, 25)   0
batch_normalization_9[0][0]
____________________________________________________________________________
__________________
conv2d_10 (Conv2D)              (None, 32, 32, 25)   5625
activation_9[0][0]
____________________________________________________________________________
__________________
concatenate_4 (Concatenate)     (None, 32, 32, 161)  0
concatenate_3[0][0]
                                                                 conv2d_10[0][0]
____________________________________________________________________________
__________________
batch_normalization_10 (BatchNo (None, 32, 32, 161)  644
concatenate_4[0][0]
____________________________________________________________________________
__________________
activation_10 (Activation)      (None, 32, 32, 161)  0
```

```
batch_normalization_10[0][0]
__________________________________________________________________________________________________
conv2d_11 (Conv2D)              (None, 32, 32, 25)   4025
activation_10[0][0]
__________________________________________________________________________________________________
batch_normalization_11 (BatchNo (None, 32, 32, 25)   100         conv2d_11[0][0]
__________________________________________________________________________________________________
activation_11 (Activation)      (None, 32, 32, 25)   0
batch_normalization_11[0][0]
__________________________________________________________________________________________________
conv2d_12 (Conv2D)              (None, 32, 32, 25)   5625
activation_11[0][0]
__________________________________________________________________________________________________
concatenate_5 (Concatenate)     (None, 32, 32, 186)  0
concatenate_4[0][0]
                                                     conv2d_12[0][0]
__________________________________________________________________________________________________
batch_normalization_12 (BatchNo (None, 32, 32, 186)  744
concatenate_5[0][0]
__________________________________________________________________________________________________
activation_12 (Activation)      (None, 32, 32, 186)  0
batch_normalization_12[0][0]
__________________________________________________________________________________________________
conv2d_13 (Conv2D)              (None, 32, 32, 25)   4650
activation_12[0][0]
__________________________________________________________________________________________________
batch_normalization_13 (BatchNo (None, 32, 32, 25)   100         conv2d_13[0][0]
__________________________________________________________________________________________________
activation_13 (Activation)      (None, 32, 32, 25)   0
batch_normalization_13[0][0]
__________________________________________________________________________________________________
conv2d_14 (Conv2D)              (None, 32, 32, 25)   5625
activation_13[0][0]
__________________________________________________________________________________________________
concatenate_6 (Concatenate)     (None, 32, 32, 211)  0
concatenate_5[0][0]
```

```
                                                                    conv2d_14[0][0]
__________________________________________________________________________________
__________________
batch_normalization_14 (BatchNo (None, 32, 32, 211)  844
concatenate_6[0][0]
__________________________________________________________________________________
__________________
activation_14 (Activation)      (None, 32, 32, 211)  0
batch_normalization_14[0][0]
__________________________________________________________________________________
__________________
conv2d_15 (Conv2D)              (None, 32, 32, 25)   5275
activation_14[0][0]
__________________________________________________________________________________
__________________
batch_normalization_15 (BatchNo (None, 32, 32, 25)   100         conv2d_15[0][0]
__________________________________________________________________________________
__________________
activation_15 (Activation)      (None, 32, 32, 25)   0
batch_normalization_15[0][0]
__________________________________________________________________________________
__________________
conv2d_16 (Conv2D)              (None, 32, 32, 25)   5625
activation_15[0][0]
__________________________________________________________________________________
__________________
concatenate_7 (Concatenate)     (None, 32, 32, 236)  0
concatenate_6[0][0]
                                                                    conv2d_16[0][0]
__________________________________________________________________________________
__________________
batch_normalization_16 (BatchNo (None, 32, 32, 236)  944
concatenate_7[0][0]
__________________________________________________________________________________
__________________
activation_16 (Activation)      (None, 32, 32, 236)  0
batch_normalization_16[0][0]
__________________________________________________________________________________
__________________
conv2d_17 (Conv2D)              (None, 32, 32, 25)   5900
activation_16[0][0]
__________________________________________________________________________________
__________________
batch_normalization_17 (BatchNo (None, 32, 32, 25)   100         conv2d_17[0][0]
__________________________________________________________________________________
__________________
activation_17 (Activation)      (None, 32, 32, 25)   0
batch_normalization_17[0][0]
```

```
__________________________________________________________________________________
__________________
conv2d_18 (Conv2D)              (None, 32, 32, 25)   5625
activation_17[0][0]
__________________________________________________________________________________
__________________
concatenate_8 (Concatenate)     (None, 32, 32, 261)  0
concatenate_7[0][0]
                                                                  conv2d_18[0][0]
__________________________________________________________________________________
__________________
batch_normalization_18 (BatchNo (None, 32, 32, 261)  1044
concatenate_8[0][0]
__________________________________________________________________________________
__________________
activation_18 (Activation)      (None, 32, 32, 261)  0
batch_normalization_18[0][0]
__________________________________________________________________________________
__________________
conv2d_19 (Conv2D)              (None, 32, 32, 25)   6525
activation_18[0][0]
__________________________________________________________________________________
__________________
batch_normalization_19 (BatchNo (None, 32, 32, 25)   100          conv2d_19[0][0]
__________________________________________________________________________________
__________________
activation_19 (Activation)      (None, 32, 32, 25)   0
batch_normalization_19[0][0]
__________________________________________________________________________________
__________________
conv2d_20 (Conv2D)              (None, 32, 32, 25)   5625
activation_19[0][0]
__________________________________________________________________________________
__________________
concatenate_9 (Concatenate)     (None, 32, 32, 286)  0
concatenate_8[0][0]
                                                                  conv2d_20[0][0]
__________________________________________________________________________________
__________________
batch_normalization_20 (BatchNo (None, 32, 32, 286)  1144
concatenate_9[0][0]
__________________________________________________________________________________
__________________
activation_20 (Activation)      (None, 32, 32, 286)  0
batch_normalization_20[0][0]
__________________________________________________________________________________
__________________
conv2d_21 (Conv2D)              (None, 32, 32, 25)   7150
```

```
activation_20[0][0]
__________________________________________________________________________________________________
batch_normalization_21 (BatchNo (None, 32, 32, 25)   100         conv2d_21[0][0]
__________________________________________________________________________________________________
activation_21 (Activation)      (None, 32, 32, 25)   0
batch_normalization_21[0][0]
__________________________________________________________________________________________________
conv2d_22 (Conv2D)              (None, 32, 32, 25)   5625
activation_21[0][0]
__________________________________________________________________________________________________
concatenate_10 (Concatenate)    (None, 32, 32, 311)  0
concatenate_9[0][0]
                                                                 conv2d_22[0][0]
__________________________________________________________________________________________________
batch_normalization_22 (BatchNo (None, 32, 32, 311)  1244
concatenate_10[0][0]
__________________________________________________________________________________________________
activation_22 (Activation)      (None, 32, 32, 311)  0
batch_normalization_22[0][0]
__________________________________________________________________________________________________
conv2d_23 (Conv2D)              (None, 32, 32, 25)   7775
activation_22[0][0]
__________________________________________________________________________________________________
batch_normalization_23 (BatchNo (None, 32, 32, 25)   100         conv2d_23[0][0]
__________________________________________________________________________________________________
activation_23 (Activation)      (None, 32, 32, 25)   0
batch_normalization_23[0][0]
__________________________________________________________________________________________________
conv2d_24 (Conv2D)              (None, 32, 32, 25)   5625
activation_23[0][0]
__________________________________________________________________________________________________
concatenate_11 (Concatenate)    (None, 32, 32, 336)  0
concatenate_10[0][0]
                                                                 conv2d_24[0][0]
__________________________________________________________________________________________________
batch_normalization_24 (BatchNo (None, 32, 32, 336)  1344
```

```
concatenate_11[0][0]
__________________________________________________________________________________
__________________
activation_24 (Activation)      (None, 32, 32, 336)  0
batch_normalization_24[0][0]
__________________________________________________________________________________
__________________
conv2d_25 (Conv2D)              (None, 32, 32, 25)   8400
activation_24[0][0]
__________________________________________________________________________________
__________________
average_pooling2d (AveragePooli (None, 16, 16, 25)   0           conv2d_25[0][0]
__________________________________________________________________________________
__________________
batch_normalization_25 (BatchNo (None, 16, 16, 25)   100
average_pooling2d[0][0]
__________________________________________________________________________________
__________________
activation_25 (Activation)      (None, 16, 16, 25)   0
batch_normalization_25[0][0]
__________________________________________________________________________________
__________________
conv2d_26 (Conv2D)              (None, 16, 16, 25)   625
activation_25[0][0]
__________________________________________________________________________________
__________________
batch_normalization_26 (BatchNo (None, 16, 16, 25)   100         conv2d_26[0][0]
__________________________________________________________________________________
__________________
activation_26 (Activation)      (None, 16, 16, 25)   0
batch_normalization_26[0][0]
__________________________________________________________________________________
__________________
conv2d_27 (Conv2D)              (None, 16, 16, 25)   5625
activation_26[0][0]
__________________________________________________________________________________
__________________
concatenate_12 (Concatenate)    (None, 16, 16, 50)   0
average_pooling2d[0][0]
                                                                 conv2d_27[0][0]
__________________________________________________________________________________
__________________
batch_normalization_27 (BatchNo (None, 16, 16, 50)   200
concatenate_12[0][0]
__________________________________________________________________________________
__________________
activation_27 (Activation)      (None, 16, 16, 50)   0
batch_normalization_27[0][0]
```

```
____________________________________________________________________________________________________
conv2d_28 (Conv2D)              (None, 16, 16, 25)   1250
activation_27[0][0]
____________________________________________________________________________________________________
batch_normalization_28 (BatchNo (None, 16, 16, 25)   100         conv2d_28[0][0]
____________________________________________________________________________________________________
activation_28 (Activation)      (None, 16, 16, 25)   0
batch_normalization_28[0][0]
____________________________________________________________________________________________________
conv2d_29 (Conv2D)              (None, 16, 16, 25)   5625
activation_28[0][0]
____________________________________________________________________________________________________
concatenate_13 (Concatenate)    (None, 16, 16, 75)   0
concatenate_12[0][0]
                                                                 conv2d_29[0][0]
____________________________________________________________________________________________________
batch_normalization_29 (BatchNo (None, 16, 16, 75)   300
concatenate_13[0][0]
____________________________________________________________________________________________________
activation_29 (Activation)      (None, 16, 16, 75)   0
batch_normalization_29[0][0]
____________________________________________________________________________________________________
conv2d_30 (Conv2D)              (None, 16, 16, 25)   1875
activation_29[0][0]
____________________________________________________________________________________________________
batch_normalization_30 (BatchNo (None, 16, 16, 25)   100         conv2d_30[0][0]
____________________________________________________________________________________________________
activation_30 (Activation)      (None, 16, 16, 25)   0
batch_normalization_30[0][0]
____________________________________________________________________________________________________
conv2d_31 (Conv2D)              (None, 16, 16, 25)   5625
activation_30[0][0]
____________________________________________________________________________________________________
concatenate_14 (Concatenate)    (None, 16, 16, 100)  0
concatenate_13[0][0]
                                                                 conv2d_31[0][0]
```

```
__________________________________________________________________________________
__________________
batch_normalization_31 (BatchNo (None, 16, 16, 100)  400
concatenate_14[0][0]
__________________________________________________________________________________
__________________
activation_31 (Activation)      (None, 16, 16, 100)  0
batch_normalization_31[0][0]
__________________________________________________________________________________
__________________
conv2d_32 (Conv2D)              (None, 16, 16, 25)   2500
activation_31[0][0]
__________________________________________________________________________________
__________________
batch_normalization_32 (BatchNo (None, 16, 16, 25)   100         conv2d_32[0][0]
__________________________________________________________________________________
__________________
activation_32 (Activation)      (None, 16, 16, 25)   0
batch_normalization_32[0][0]
__________________________________________________________________________________
__________________
conv2d_33 (Conv2D)              (None, 16, 16, 25)   5625
activation_32[0][0]
__________________________________________________________________________________
__________________
concatenate_15 (Concatenate)    (None, 16, 16, 125)  0
concatenate_14[0][0]
                                                                 conv2d_33[0][0]
__________________________________________________________________________________
__________________
batch_normalization_33 (BatchNo (None, 16, 16, 125)  500
concatenate_15[0][0]
__________________________________________________________________________________
__________________
activation_33 (Activation)      (None, 16, 16, 125)  0
batch_normalization_33[0][0]
__________________________________________________________________________________
__________________
conv2d_34 (Conv2D)              (None, 16, 16, 25)   3125
activation_33[0][0]
__________________________________________________________________________________
__________________
batch_normalization_34 (BatchNo (None, 16, 16, 25)   100         conv2d_34[0][0]
__________________________________________________________________________________
__________________
activation_34 (Activation)      (None, 16, 16, 25)   0
batch_normalization_34[0][0]
__________________________________________________________________________________
```

```
__________________
conv2d_35 (Conv2D)              (None, 16, 16, 25)   5625
activation_34[0][0]
__________________________________________________________________________________
__________________
concatenate_16 (Concatenate)    (None, 16, 16, 150)  0
concatenate_15[0][0]
                                                                 conv2d_35[0][0]
__________________________________________________________________________________
__________________
batch_normalization_35 (BatchNo (None, 16, 16, 150)  600
concatenate_16[0][0]
__________________________________________________________________________________
__________________
activation_35 (Activation)      (None, 16, 16, 150)  0
batch_normalization_35[0][0]
__________________________________________________________________________________
__________________
conv2d_36 (Conv2D)              (None, 16, 16, 25)   3750
activation_35[0][0]
__________________________________________________________________________________
__________________
batch_normalization_36 (BatchNo (None, 16, 16, 25)   100         conv2d_36[0][0]
__________________________________________________________________________________
__________________
activation_36 (Activation)      (None, 16, 16, 25)   0
batch_normalization_36[0][0]
__________________________________________________________________________________
__________________
conv2d_37 (Conv2D)              (None, 16, 16, 25)   5625
activation_36[0][0]
__________________________________________________________________________________
__________________
concatenate_17 (Concatenate)    (None, 16, 16, 175)  0
concatenate_16[0][0]
                                                                 conv2d_37[0][0]
__________________________________________________________________________________
__________________
batch_normalization_37 (BatchNo (None, 16, 16, 175)  700
concatenate_17[0][0]
__________________________________________________________________________________
__________________
activation_37 (Activation)      (None, 16, 16, 175)  0
batch_normalization_37[0][0]
__________________________________________________________________________________
__________________
conv2d_38 (Conv2D)              (None, 16, 16, 25)   4375
activation_37[0][0]
```

```
__________________________________________________________________________________
__________________
batch_normalization_38 (BatchNo (None, 16, 16, 25)   100         conv2d_38[0][0]
__________________________________________________________________________________
__________________
activation_38 (Activation)      (None, 16, 16, 25)   0
batch_normalization_38[0][0]
__________________________________________________________________________________
__________________
conv2d_39 (Conv2D)              (None, 16, 16, 25)   5625
activation_38[0][0]
__________________________________________________________________________________
__________________
concatenate_18 (Concatenate)    (None, 16, 16, 200)  0
concatenate_17[0][0]
                                                                 conv2d_39[0][0]
__________________________________________________________________________________
__________________
batch_normalization_39 (BatchNo (None, 16, 16, 200)  800
concatenate_18[0][0]
__________________________________________________________________________________
__________________
activation_39 (Activation)      (None, 16, 16, 200)  0
batch_normalization_39[0][0]
__________________________________________________________________________________
__________________
conv2d_40 (Conv2D)              (None, 16, 16, 25)   5000
activation_39[0][0]
__________________________________________________________________________________
__________________
batch_normalization_40 (BatchNo (None, 16, 16, 25)   100         conv2d_40[0][0]
__________________________________________________________________________________
__________________
activation_40 (Activation)      (None, 16, 16, 25)   0
batch_normalization_40[0][0]
__________________________________________________________________________________
__________________
conv2d_41 (Conv2D)              (None, 16, 16, 25)   5625
activation_40[0][0]
__________________________________________________________________________________
__________________
concatenate_19 (Concatenate)    (None, 16, 16, 225)  0
concatenate_18[0][0]
                                                                 conv2d_41[0][0]
__________________________________________________________________________________
__________________
batch_normalization_41 (BatchNo (None, 16, 16, 225)  900
concatenate_19[0][0]
```

```
__________________________________________________________________________________
__________________
activation_41 (Activation)      (None, 16, 16, 225)  0
batch_normalization_41[0][0]
__________________________________________________________________________________
__________________
conv2d_42 (Conv2D)              (None, 16, 16, 25)   5625
activation_41[0][0]
__________________________________________________________________________________
__________________
batch_normalization_42 (BatchNo (None, 16, 16, 25)   100         conv2d_42[0][0]
__________________________________________________________________________________
__________________
activation_42 (Activation)      (None, 16, 16, 25)   0
batch_normalization_42[0][0]
__________________________________________________________________________________
__________________
conv2d_43 (Conv2D)              (None, 16, 16, 25)   5625
activation_42[0][0]
__________________________________________________________________________________
__________________
concatenate_20 (Concatenate)    (None, 16, 16, 250)  0
concatenate_19[0][0]
                                                                 conv2d_43[0][0]
__________________________________________________________________________________
__________________
batch_normalization_43 (BatchNo (None, 16, 16, 250)  1000
concatenate_20[0][0]
__________________________________________________________________________________
__________________
activation_43 (Activation)      (None, 16, 16, 250)  0
batch_normalization_43[0][0]
__________________________________________________________________________________
__________________
conv2d_44 (Conv2D)              (None, 16, 16, 25)   6250
activation_43[0][0]
__________________________________________________________________________________
__________________
batch_normalization_44 (BatchNo (None, 16, 16, 25)   100         conv2d_44[0][0]
__________________________________________________________________________________
__________________
activation_44 (Activation)      (None, 16, 16, 25)   0
batch_normalization_44[0][0]
__________________________________________________________________________________
__________________
conv2d_45 (Conv2D)              (None, 16, 16, 25)   5625
activation_44[0][0]
__________________________________________________________________________________
```

```
------------------
concatenate_21 (Concatenate)    (None, 16, 16, 275)  0
concatenate_20[0][0]
                                                                  conv2d_45[0][0]
------------------------------------------------------------------------------------
------------------
batch_normalization_45 (BatchNo (None, 16, 16, 275)  1100
concatenate_21[0][0]
------------------------------------------------------------------------------------
------------------
activation_45 (Activation)      (None, 16, 16, 275)  0
batch_normalization_45[0][0]
------------------------------------------------------------------------------------
------------------
conv2d_46 (Conv2D)              (None, 16, 16, 25)   6875
activation_45[0][0]
------------------------------------------------------------------------------------
------------------
batch_normalization_46 (BatchNo (None, 16, 16, 25)   100         conv2d_46[0][0]
------------------------------------------------------------------------------------
------------------
activation_46 (Activation)      (None, 16, 16, 25)   0
batch_normalization_46[0][0]
------------------------------------------------------------------------------------
------------------
conv2d_47 (Conv2D)              (None, 16, 16, 25)   5625
activation_46[0][0]
------------------------------------------------------------------------------------
------------------
concatenate_22 (Concatenate)    (None, 16, 16, 300)  0
concatenate_21[0][0]
                                                                  conv2d_47[0][0]
------------------------------------------------------------------------------------
------------------
batch_normalization_47 (BatchNo (None, 16, 16, 300)  1200
concatenate_22[0][0]
------------------------------------------------------------------------------------
------------------
activation_47 (Activation)      (None, 16, 16, 300)  0
batch_normalization_47[0][0]
------------------------------------------------------------------------------------
------------------
conv2d_48 (Conv2D)              (None, 16, 16, 25)   7500
activation_47[0][0]
------------------------------------------------------------------------------------
------------------
batch_normalization_48 (BatchNo (None, 16, 16, 25)   100         conv2d_48[0][0]
------------------------------------------------------------------------------------
```

```
__________________
activation_48 (Activation)      (None, 16, 16, 25)   0
batch_normalization_48[0][0]

____________________________________________________________________________
__________________
conv2d_49 (Conv2D)              (None, 16, 16, 25)   5625
activation_48[0][0]

____________________________________________________________________________
__________________
concatenate_23 (Concatenate)    (None, 16, 16, 325)  0
concatenate_22[0][0]
                                                                 conv2d_49[0][0]

____________________________________________________________________________
__________________
batch_normalization_49 (BatchNo (None, 16, 16, 325)  1300
concatenate_23[0][0]

____________________________________________________________________________
__________________
activation_49 (Activation)      (None, 16, 16, 325)  0
batch_normalization_49[0][0]

____________________________________________________________________________
__________________
conv2d_50 (Conv2D)              (None, 16, 16, 25)   8125
activation_49[0][0]

____________________________________________________________________________
__________________
average_pooling2d_1 (AveragePoo (None, 8, 8, 25)     0           conv2d_50[0][0]

____________________________________________________________________________
__________________
batch_normalization_50 (BatchNo (None, 8, 8, 25)     100
average_pooling2d_1[0][0]

____________________________________________________________________________
__________________
activation_50 (Activation)      (None, 8, 8, 25)     0
batch_normalization_50[0][0]

____________________________________________________________________________
__________________
conv2d_51 (Conv2D)              (None, 8, 8, 25)     625
activation_50[0][0]

____________________________________________________________________________
__________________
batch_normalization_51 (BatchNo (None, 8, 8, 25)     100         conv2d_51[0][0]

____________________________________________________________________________
__________________
activation_51 (Activation)      (None, 8, 8, 25)     0
batch_normalization_51[0][0]

____________________________________________________________________________
__________________
```

```
conv2d_52 (Conv2D)              (None, 8, 8, 25)     5625
activation_51[0][0]
__________________________________________________________________________________
__________________
concatenate_24 (Concatenate)    (None, 8, 8, 50)     0
average_pooling2d_1[0][0]
                                                                  conv2d_52[0][0]
__________________________________________________________________________________
__________________
batch_normalization_52 (BatchNo (None, 8, 8, 50)     200
concatenate_24[0][0]
__________________________________________________________________________________
__________________
activation_52 (Activation)      (None, 8, 8, 50)     0
batch_normalization_52[0][0]
__________________________________________________________________________________
__________________
conv2d_53 (Conv2D)              (None, 8, 8, 25)     1250
activation_52[0][0]
__________________________________________________________________________________
__________________
batch_normalization_53 (BatchNo (None, 8, 8, 25)     100         conv2d_53[0][0]
__________________________________________________________________________________
__________________
activation_53 (Activation)      (None, 8, 8, 25)     0
batch_normalization_53[0][0]
__________________________________________________________________________________
__________________
conv2d_54 (Conv2D)              (None, 8, 8, 25)     5625
activation_53[0][0]
__________________________________________________________________________________
__________________
concatenate_25 (Concatenate)    (None, 8, 8, 75)     0
concatenate_24[0][0]
                                                                  conv2d_54[0][0]
__________________________________________________________________________________
__________________
batch_normalization_54 (BatchNo (None, 8, 8, 75)     300
concatenate_25[0][0]
__________________________________________________________________________________
__________________
activation_54 (Activation)      (None, 8, 8, 75)     0
batch_normalization_54[0][0]
__________________________________________________________________________________
__________________
conv2d_55 (Conv2D)              (None, 8, 8, 25)     1875
activation_54[0][0]
__________________________________________________________________________________
```

```
------------------
batch_normalization_55 (BatchNo (None, 8, 8, 25)     100         conv2d_55[0][0]
--------------------------------------------------------------------------------
------------------
activation_55 (Activation)      (None, 8, 8, 25)     0
batch_normalization_55[0][0]
--------------------------------------------------------------------------------
------------------
conv2d_56 (Conv2D)              (None, 8, 8, 25)     5625
activation_55[0][0]
--------------------------------------------------------------------------------
------------------
concatenate_26 (Concatenate)    (None, 8, 8, 100)    0
concatenate_25[0][0]
                                                                 conv2d_56[0][0]
--------------------------------------------------------------------------------
------------------
batch_normalization_56 (BatchNo (None, 8, 8, 100)    400
concatenate_26[0][0]
--------------------------------------------------------------------------------
------------------
activation_56 (Activation)      (None, 8, 8, 100)    0
batch_normalization_56[0][0]
--------------------------------------------------------------------------------
------------------
conv2d_57 (Conv2D)              (None, 8, 8, 25)     2500
activation_56[0][0]
--------------------------------------------------------------------------------
------------------
batch_normalization_57 (BatchNo (None, 8, 8, 25)     100         conv2d_57[0][0]
--------------------------------------------------------------------------------
------------------
activation_57 (Activation)      (None, 8, 8, 25)     0
batch_normalization_57[0][0]
--------------------------------------------------------------------------------
------------------
conv2d_58 (Conv2D)              (None, 8, 8, 25)     5625
activation_57[0][0]
--------------------------------------------------------------------------------
------------------
concatenate_27 (Concatenate)    (None, 8, 8, 125)    0
concatenate_26[0][0]
                                                                 conv2d_58[0][0]
--------------------------------------------------------------------------------
------------------
batch_normalization_58 (BatchNo (None, 8, 8, 125)    500
concatenate_27[0][0]
--------------------------------------------------------------------------------
```

```
------------------
activation_58 (Activation)      (None, 8, 8, 125)    0
batch_normalization_58[0][0]

------------------------------------------------------------------------------
------------------
conv2d_59 (Conv2D)              (None, 8, 8, 25)     3125
activation_58[0][0]

------------------------------------------------------------------------------
------------------
batch_normalization_59 (BatchNo (None, 8, 8, 25)     100         conv2d_59[0][0]

------------------------------------------------------------------------------
------------------
activation_59 (Activation)      (None, 8, 8, 25)     0
batch_normalization_59[0][0]

------------------------------------------------------------------------------
------------------
conv2d_60 (Conv2D)              (None, 8, 8, 25)     5625
activation_59[0][0]

------------------------------------------------------------------------------
------------------
concatenate_28 (Concatenate)    (None, 8, 8, 150)    0
concatenate_27[0][0]
                                                     conv2d_60[0][0]

------------------------------------------------------------------------------
------------------
batch_normalization_60 (BatchNo (None, 8, 8, 150)    600
concatenate_28[0][0]

------------------------------------------------------------------------------
------------------
activation_60 (Activation)      (None, 8, 8, 150)    0
batch_normalization_60[0][0]

------------------------------------------------------------------------------
------------------
conv2d_61 (Conv2D)              (None, 8, 8, 25)     3750
activation_60[0][0]

------------------------------------------------------------------------------
------------------
batch_normalization_61 (BatchNo (None, 8, 8, 25)     100         conv2d_61[0][0]

------------------------------------------------------------------------------
------------------
activation_61 (Activation)      (None, 8, 8, 25)     0
batch_normalization_61[0][0]

------------------------------------------------------------------------------
------------------
conv2d_62 (Conv2D)              (None, 8, 8, 25)     5625
activation_61[0][0]

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

```
concatenate_29 (Concatenate)    (None, 8, 8, 175)    0
concatenate_28[0][0]
                                                                 conv2d_62[0][0]
__________________________________________________________________________________
__________________
batch_normalization_62 (BatchNo (None, 8, 8, 175)    700
concatenate_29[0][0]
__________________________________________________________________________________
__________________
activation_62 (Activation)      (None, 8, 8, 175)    0
batch_normalization_62[0][0]
__________________________________________________________________________________
__________________
conv2d_63 (Conv2D)              (None, 8, 8, 25)     4375
activation_62[0][0]
__________________________________________________________________________________
__________________
batch_normalization_63 (BatchNo (None, 8, 8, 25)     100          conv2d_63[0][0]
__________________________________________________________________________________
__________________
activation_63 (Activation)      (None, 8, 8, 25)     0
batch_normalization_63[0][0]
__________________________________________________________________________________
__________________
conv2d_64 (Conv2D)              (None, 8, 8, 25)     5625
activation_63[0][0]
__________________________________________________________________________________
__________________
concatenate_30 (Concatenate)    (None, 8, 8, 200)    0
concatenate_29[0][0]
                                                                 conv2d_64[0][0]
__________________________________________________________________________________
__________________
batch_normalization_64 (BatchNo (None, 8, 8, 200)    800
concatenate_30[0][0]
__________________________________________________________________________________
__________________
activation_64 (Activation)      (None, 8, 8, 200)    0
batch_normalization_64[0][0]
__________________________________________________________________________________
__________________
conv2d_65 (Conv2D)              (None, 8, 8, 25)     5000
activation_64[0][0]
__________________________________________________________________________________
__________________
batch_normalization_65 (BatchNo (None, 8, 8, 25)     100          conv2d_65[0][0]
__________________________________________________________________________________
__________________
```

```
activation_65 (Activation)      (None, 8, 8, 25)     0
batch_normalization_65[0][0]
__________________________________________________________________________________
__________________
conv2d_66 (Conv2D)              (None, 8, 8, 25)     5625
activation_65[0][0]
__________________________________________________________________________________
__________________
concatenate_31 (Concatenate)    (None, 8, 8, 225)    0
concatenate_30[0][0]
                                                                    conv2d_66[0][0]
__________________________________________________________________________________
__________________
batch_normalization_66 (BatchNo (None, 8, 8, 225)    900
concatenate_31[0][0]
__________________________________________________________________________________
__________________
activation_66 (Activation)      (None, 8, 8, 225)    0
batch_normalization_66[0][0]
__________________________________________________________________________________
__________________
conv2d_67 (Conv2D)              (None, 8, 8, 25)     5625
activation_66[0][0]
__________________________________________________________________________________
__________________
batch_normalization_67 (BatchNo (None, 8, 8, 25)     100         conv2d_67[0][0]
__________________________________________________________________________________
__________________
activation_67 (Activation)      (None, 8, 8, 25)     0
batch_normalization_67[0][0]
__________________________________________________________________________________
__________________
conv2d_68 (Conv2D)              (None, 8, 8, 25)     5625
activation_67[0][0]
__________________________________________________________________________________
__________________
concatenate_32 (Concatenate)    (None, 8, 8, 250)    0
concatenate_31[0][0]
                                                                    conv2d_68[0][0]
__________________________________________________________________________________
__________________
batch_normalization_68 (BatchNo (None, 8, 8, 250)    1000
concatenate_32[0][0]
__________________________________________________________________________________
__________________
activation_68 (Activation)      (None, 8, 8, 250)    0
batch_normalization_68[0][0]
__________________________________________________________________________________
```

```
__________________
conv2d_69 (Conv2D)              (None, 8, 8, 25)     6250
activation_68[0][0]
__________________________________________________________________________________
__________________
batch_normalization_69 (BatchNo (None, 8, 8, 25)     100         conv2d_69[0][0]
__________________________________________________________________________________
__________________
activation_69 (Activation)      (None, 8, 8, 25)     0
batch_normalization_69[0][0]
__________________________________________________________________________________
__________________
conv2d_70 (Conv2D)              (None, 8, 8, 25)     5625
activation_69[0][0]
__________________________________________________________________________________
__________________
concatenate_33 (Concatenate)    (None, 8, 8, 275)    0
concatenate_32[0][0]
                                                     conv2d_70[0][0]
__________________________________________________________________________________
__________________
batch_normalization_70 (BatchNo (None, 8, 8, 275)    1100
concatenate_33[0][0]
__________________________________________________________________________________
__________________
activation_70 (Activation)      (None, 8, 8, 275)    0
batch_normalization_70[0][0]
__________________________________________________________________________________
__________________
conv2d_71 (Conv2D)              (None, 8, 8, 25)     6875
activation_70[0][0]
__________________________________________________________________________________
__________________
batch_normalization_71 (BatchNo (None, 8, 8, 25)     100         conv2d_71[0][0]
__________________________________________________________________________________
__________________
activation_71 (Activation)      (None, 8, 8, 25)     0
batch_normalization_71[0][0]
__________________________________________________________________________________
__________________
conv2d_72 (Conv2D)              (None, 8, 8, 25)     5625
activation_71[0][0]
__________________________________________________________________________________
__________________
concatenate_34 (Concatenate)    (None, 8, 8, 300)    0
concatenate_33[0][0]
                                                     conv2d_72[0][0]
__________________________________________________________________________________
```

```
__________________
batch_normalization_72 (BatchNo (None, 8, 8, 300)    1200
concatenate_34[0][0]
__________________________________________________________________________________
__________________
activation_72 (Activation)      (None, 8, 8, 300)    0
batch_normalization_72[0][0]
__________________________________________________________________________________
__________________
conv2d_73 (Conv2D)              (None, 8, 8, 25)     7500
activation_72[0][0]
__________________________________________________________________________________
__________________
batch_normalization_73 (BatchNo (None, 8, 8, 25)     100          conv2d_73[0][0]
__________________________________________________________________________________
__________________
activation_73 (Activation)      (None, 8, 8, 25)     0
batch_normalization_73[0][0]
__________________________________________________________________________________
__________________
conv2d_74 (Conv2D)              (None, 8, 8, 25)     5625
activation_73[0][0]
__________________________________________________________________________________
__________________
concatenate_35 (Concatenate)    (None, 8, 8, 325)    0
concatenate_34[0][0]
                                                                 conv2d_74[0][0]
__________________________________________________________________________________
__________________
batch_normalization_74 (BatchNo (None, 8, 8, 325)    1300
concatenate_35[0][0]
__________________________________________________________________________________
__________________
activation_74 (Activation)      (None, 8, 8, 325)    0
batch_normalization_74[0][0]
__________________________________________________________________________________
__________________
conv2d_75 (Conv2D)              (None, 8, 8, 25)     8125
activation_74[0][0]
__________________________________________________________________________________
__________________
average_pooling2d_2 (AveragePoo (None, 4, 4, 25)     0            conv2d_75[0][0]
__________________________________________________________________________________
__________________
batch_normalization_75 (BatchNo (None, 4, 4, 25)     100
average_pooling2d_2[0][0]
__________________________________________________________________________________
__________________
```

```
activation_75 (Activation)      (None, 4, 4, 25)     0
batch_normalization_75[0][0]
__________________________________________________________________________________
__________________
conv2d_76 (Conv2D)              (None, 4, 4, 25)     625
activation_75[0][0]
__________________________________________________________________________________
__________________
batch_normalization_76 (BatchNo (None, 4, 4, 25)     100         conv2d_76[0][0]
__________________________________________________________________________________
__________________
activation_76 (Activation)      (None, 4, 4, 25)     0
batch_normalization_76[0][0]
__________________________________________________________________________________
__________________
conv2d_77 (Conv2D)              (None, 4, 4, 25)     5625
activation_76[0][0]
__________________________________________________________________________________
__________________
concatenate_36 (Concatenate)    (None, 4, 4, 50)     0
average_pooling2d_2[0][0]
                                                                 conv2d_77[0][0]
__________________________________________________________________________________
__________________
batch_normalization_77 (BatchNo (None, 4, 4, 50)     200
concatenate_36[0][0]
__________________________________________________________________________________
__________________
activation_77 (Activation)      (None, 4, 4, 50)     0
batch_normalization_77[0][0]
__________________________________________________________________________________
__________________
conv2d_78 (Conv2D)              (None, 4, 4, 25)     1250
activation_77[0][0]
__________________________________________________________________________________
__________________
batch_normalization_78 (BatchNo (None, 4, 4, 25)     100         conv2d_78[0][0]
__________________________________________________________________________________
__________________
activation_78 (Activation)      (None, 4, 4, 25)     0
batch_normalization_78[0][0]
__________________________________________________________________________________
__________________
conv2d_79 (Conv2D)              (None, 4, 4, 25)     5625
activation_78[0][0]
__________________________________________________________________________________
__________________
concatenate_37 (Concatenate)    (None, 4, 4, 75)     0
```

```
concatenate_36[0][0]
                                                                    conv2d_79[0][0]
__________________________________________________________________________________
__________________
batch_normalization_79 (BatchNo (None, 4, 4, 75)     300
concatenate_37[0][0]
__________________________________________________________________________________
__________________
activation_79 (Activation)      (None, 4, 4, 75)     0
batch_normalization_79[0][0]
__________________________________________________________________________________
__________________
conv2d_80 (Conv2D)              (None, 4, 4, 25)     1875
activation_79[0][0]
__________________________________________________________________________________
__________________
batch_normalization_80 (BatchNo (None, 4, 4, 25)     100         conv2d_80[0][0]
__________________________________________________________________________________
__________________
activation_80 (Activation)      (None, 4, 4, 25)     0
batch_normalization_80[0][0]
__________________________________________________________________________________
__________________
conv2d_81 (Conv2D)              (None, 4, 4, 25)     5625
activation_80[0][0]
__________________________________________________________________________________
__________________
concatenate_38 (Concatenate)    (None, 4, 4, 100)    0
concatenate_37[0][0]
                                                                    conv2d_81[0][0]
__________________________________________________________________________________
__________________
batch_normalization_81 (BatchNo (None, 4, 4, 100)    400
concatenate_38[0][0]
__________________________________________________________________________________
__________________
activation_81 (Activation)      (None, 4, 4, 100)    0
batch_normalization_81[0][0]
__________________________________________________________________________________
__________________
conv2d_82 (Conv2D)              (None, 4, 4, 25)     2500
activation_81[0][0]
__________________________________________________________________________________
__________________
batch_normalization_82 (BatchNo (None, 4, 4, 25)     100         conv2d_82[0][0]
__________________________________________________________________________________
__________________
activation_82 (Activation)      (None, 4, 4, 25)     0
```

```
batch_normalization_82[0][0]
__________________________________________________________________________________________________
conv2d_83 (Conv2D)              (None, 4, 4, 25)     5625
activation_82[0][0]
__________________________________________________________________________________________________
concatenate_39 (Concatenate)    (None, 4, 4, 125)    0
concatenate_38[0][0]
                                                                 conv2d_83[0][0]
__________________________________________________________________________________________________
batch_normalization_83 (BatchNo (None, 4, 4, 125)    500
concatenate_39[0][0]
__________________________________________________________________________________________________
activation_83 (Activation)      (None, 4, 4, 125)    0
batch_normalization_83[0][0]
__________________________________________________________________________________________________
conv2d_84 (Conv2D)              (None, 4, 4, 25)     3125
activation_83[0][0]
__________________________________________________________________________________________________
batch_normalization_84 (BatchNo (None, 4, 4, 25)     100         conv2d_84[0][0]
__________________________________________________________________________________________________
activation_84 (Activation)      (None, 4, 4, 25)     0
batch_normalization_84[0][0]
__________________________________________________________________________________________________
conv2d_85 (Conv2D)              (None, 4, 4, 25)     5625
activation_84[0][0]
__________________________________________________________________________________________________
concatenate_40 (Concatenate)    (None, 4, 4, 150)    0
concatenate_39[0][0]
                                                                 conv2d_85[0][0]
__________________________________________________________________________________________________
batch_normalization_85 (BatchNo (None, 4, 4, 150)    600
concatenate_40[0][0]
__________________________________________________________________________________________________
activation_85 (Activation)      (None, 4, 4, 150)    0
batch_normalization_85[0][0]
__________________________________________________________________________________________________
```

```
conv2d_86 (Conv2D)              (None, 4, 4, 25)     3750
activation_85[0][0]
__________________________________________________________________________________
__________________
batch_normalization_86 (BatchNo (None, 4, 4, 25)     100         conv2d_86[0][0]
__________________________________________________________________________________
__________________
activation_86 (Activation)      (None, 4, 4, 25)     0
batch_normalization_86[0][0]
__________________________________________________________________________________
__________________
conv2d_87 (Conv2D)              (None, 4, 4, 25)     5625
activation_86[0][0]
__________________________________________________________________________________
__________________
concatenate_41 (Concatenate)    (None, 4, 4, 175)    0
concatenate_40[0][0]
                                                                 conv2d_87[0][0]
__________________________________________________________________________________
__________________
batch_normalization_87 (BatchNo (None, 4, 4, 175)    700
concatenate_41[0][0]
__________________________________________________________________________________
__________________
activation_87 (Activation)      (None, 4, 4, 175)    0
batch_normalization_87[0][0]
__________________________________________________________________________________
__________________
conv2d_88 (Conv2D)              (None, 4, 4, 25)     4375
activation_87[0][0]
__________________________________________________________________________________
__________________
batch_normalization_88 (BatchNo (None, 4, 4, 25)     100         conv2d_88[0][0]
__________________________________________________________________________________
__________________
activation_88 (Activation)      (None, 4, 4, 25)     0
batch_normalization_88[0][0]
__________________________________________________________________________________
__________________
conv2d_89 (Conv2D)              (None, 4, 4, 25)     5625
activation_88[0][0]
__________________________________________________________________________________
__________________
concatenate_42 (Concatenate)    (None, 4, 4, 200)    0
concatenate_41[0][0]
                                                                 conv2d_89[0][0]
__________________________________________________________________________________
__________________
```

```
batch_normalization_89 (BatchNo (None, 4, 4, 200)    800
concatenate_42[0][0]
__________________________________________________________________________________
__________________
activation_89 (Activation)      (None, 4, 4, 200)    0
batch_normalization_89[0][0]
__________________________________________________________________________________
__________________
conv2d_90 (Conv2D)              (None, 4, 4, 25)     5000
activation_89[0][0]
__________________________________________________________________________________
__________________
batch_normalization_90 (BatchNo (None, 4, 4, 25)     100          conv2d_90[0][0]
__________________________________________________________________________________
__________________
activation_90 (Activation)      (None, 4, 4, 25)     0
batch_normalization_90[0][0]
__________________________________________________________________________________
__________________
conv2d_91 (Conv2D)              (None, 4, 4, 25)     5625
activation_90[0][0]
__________________________________________________________________________________
__________________
concatenate_43 (Concatenate)    (None, 4, 4, 225)    0
concatenate_42[0][0]
                                                                  conv2d_91[0][0]
__________________________________________________________________________________
__________________
batch_normalization_91 (BatchNo (None, 4, 4, 225)    900
concatenate_43[0][0]
__________________________________________________________________________________
__________________
activation_91 (Activation)      (None, 4, 4, 225)    0
batch_normalization_91[0][0]
__________________________________________________________________________________
__________________
conv2d_92 (Conv2D)              (None, 4, 4, 25)     5625
activation_91[0][0]
__________________________________________________________________________________
__________________
batch_normalization_92 (BatchNo (None, 4, 4, 25)     100          conv2d_92[0][0]
__________________________________________________________________________________
__________________
activation_92 (Activation)      (None, 4, 4, 25)     0
batch_normalization_92[0][0]
__________________________________________________________________________________
__________________
conv2d_93 (Conv2D)              (None, 4, 4, 25)     5625
```

```
activation_92[0][0]
__________________________________________________________________________________________________
concatenate_44 (Concatenate)    (None, 4, 4, 250)    0
concatenate_43[0][0]
                                                                 conv2d_93[0][0]
__________________________________________________________________________________________________
batch_normalization_93 (BatchNo (None, 4, 4, 250)    1000
concatenate_44[0][0]
__________________________________________________________________________________________________
activation_93 (Activation)      (None, 4, 4, 250)    0
batch_normalization_93[0][0]
__________________________________________________________________________________________________
conv2d_94 (Conv2D)              (None, 4, 4, 25)     6250
activation_93[0][0]
__________________________________________________________________________________________________
batch_normalization_94 (BatchNo (None, 4, 4, 25)     100         conv2d_94[0][0]
__________________________________________________________________________________________________
activation_94 (Activation)      (None, 4, 4, 25)     0
batch_normalization_94[0][0]
__________________________________________________________________________________________________
conv2d_95 (Conv2D)              (None, 4, 4, 25)     5625
activation_94[0][0]
__________________________________________________________________________________________________
concatenate_45 (Concatenate)    (None, 4, 4, 275)    0
concatenate_44[0][0]
                                                                 conv2d_95[0][0]
__________________________________________________________________________________________________
batch_normalization_95 (BatchNo (None, 4, 4, 275)    1100
concatenate_45[0][0]
__________________________________________________________________________________________________
activation_95 (Activation)      (None, 4, 4, 275)    0
batch_normalization_95[0][0]
__________________________________________________________________________________________________
conv2d_96 (Conv2D)              (None, 4, 4, 25)     6875
activation_95[0][0]
__________________________________________________________________________________________________
```

```
batch_normalization_96 (BatchNo (None, 4, 4, 25)     100         conv2d_96[0][0]
__________________________________________________________________________________________
__________________
activation_96 (Activation)      (None, 4, 4, 25)     0
batch_normalization_96[0][0]
__________________________________________________________________________________________
__________________
conv2d_97 (Conv2D)              (None, 4, 4, 25)     5625
activation_96[0][0]
__________________________________________________________________________________________
__________________
concatenate_46 (Concatenate)    (None, 4, 4, 300)    0
concatenate_45[0][0]
                                                                 conv2d_97[0][0]
__________________________________________________________________________________________
__________________
batch_normalization_97 (BatchNo (None, 4, 4, 300)    1200
concatenate_46[0][0]
__________________________________________________________________________________________
__________________
activation_97 (Activation)      (None, 4, 4, 300)    0
batch_normalization_97[0][0]
__________________________________________________________________________________________
__________________
conv2d_98 (Conv2D)              (None, 4, 4, 25)     7500
activation_97[0][0]
__________________________________________________________________________________________
__________________
batch_normalization_98 (BatchNo (None, 4, 4, 25)     100         conv2d_98[0][0]
__________________________________________________________________________________________
__________________
activation_98 (Activation)      (None, 4, 4, 25)     0
batch_normalization_98[0][0]
__________________________________________________________________________________________
__________________
conv2d_99 (Conv2D)              (None, 4, 4, 25)     5625
activation_98[0][0]
__________________________________________________________________________________________
__________________
concatenate_47 (Concatenate)    (None, 4, 4, 325)    0
concatenate_46[0][0]
                                                                 conv2d_99[0][0]
__________________________________________________________________________________________
__________________
batch_normalization_99 (BatchNo (None, 4, 4, 325)    1300
concatenate_47[0][0]
__________________________________________________________________________________________
__________________
```

```
activation_99 (Activation)      (None, 4, 4, 325)    0
batch_normalization_99[0][0]
__________________________________________________________________________________
__________________
average_pooling2d_3 (AveragePoo (None, 2, 2, 325)    0
activation_99[0][0]
__________________________________________________________________________________
__________________
flatten (Flatten)               (None, 1300)         0
average_pooling2d_3[0][0]
__________________________________________________________________________________
__________________
dense (Dense)                   (None, 10)           13010       flatten[0][0]
==================================================================================
==================
Total params: 548,704
Trainable params: 527,818
Non-trainable params: 20,886
__________________________________________________________________________________
__________________
```

[18]:
```
print(len(model5.layers))
```

```
355
```

[19]:
```
model5.
↪compile(optimizer='adam',loss='categorical_crossentropy',metrics=['accuracy'])

model5.fit(aug.
↪flow(X_train,y_train,batch_size=batch_size),epochs=nb_epoch,batch_size=batch_size,verbose=1
          steps_per_epoch=(len(X_train)//batch_size),
          ␣
↪callbacks=[reduce_lr,lr_scheduler,csv_logger,early_stop,model_checkpoint],
          validation_data=(X_test,y_test))
```

```
Epoch 1/100
781/781 [==============================] - 160s 153ms/step - loss: 1.8645 -
accuracy: 0.3217 - val_loss: 2.1654 - val_accuracy: 0.2920

Epoch 00001: val_accuracy improved from -inf to 0.29200, saving model to
model5_weights.best.hdf5
Epoch 2/100
781/781 [==============================] - 118s 151ms/step - loss: 1.5126 -
accuracy: 0.4451 - val_loss: 2.6054 - val_accuracy: 0.3066

Epoch 00002: val_accuracy improved from 0.29200 to 0.30660, saving model to
model5_weights.best.hdf5
Epoch 3/100
```

```
781/781 [==============================] - 119s 152ms/step - loss: 1.2816 -
accuracy: 0.5356 - val_loss: 1.7561 - val_accuracy: 0.5004

Epoch 00003: val_accuracy improved from 0.30660 to 0.50040, saving model to
model5_weights.best.hdf5
Epoch 4/100
781/781 [==============================] - 120s 153ms/step - loss: 1.0908 -
accuracy: 0.6122 - val_loss: 1.1677 - val_accuracy: 0.6171

Epoch 00004: val_accuracy improved from 0.50040 to 0.61710, saving model to
model5_weights.best.hdf5
Epoch 5/100
781/781 [==============================] - 119s 153ms/step - loss: 0.9554 -
accuracy: 0.6589 - val_loss: 1.0298 - val_accuracy: 0.6521

Epoch 00005: val_accuracy improved from 0.61710 to 0.65210, saving model to
model5_weights.best.hdf5
Epoch 6/100
781/781 [==============================] - 120s 154ms/step - loss: 0.8619 -
accuracy: 0.6957 - val_loss: 1.2446 - val_accuracy: 0.6327

Epoch 00006: val_accuracy did not improve from 0.65210
Epoch 7/100
781/781 [==============================] - 119s 153ms/step - loss: 0.7958 -
accuracy: 0.7197 - val_loss: 0.9859 - val_accuracy: 0.6887

Epoch 00007: val_accuracy improved from 0.65210 to 0.68870, saving model to
model5_weights.best.hdf5
Epoch 8/100
781/781 [==============================] - 120s 153ms/step - loss: 0.7362 -
accuracy: 0.7413 - val_loss: 0.9728 - val_accuracy: 0.6962

Epoch 00008: val_accuracy improved from 0.68870 to 0.69620, saving model to
model5_weights.best.hdf5
Epoch 9/100
781/781 [==============================] - 119s 153ms/step - loss: 0.6962 -
accuracy: 0.7567 - val_loss: 1.1996 - val_accuracy: 0.6552

Epoch 00009: val_accuracy did not improve from 0.69620
Epoch 10/100
781/781 [==============================] - 120s 153ms/step - loss: 0.6580 -
accuracy: 0.7704 - val_loss: 0.8988 - val_accuracy: 0.7022

Epoch 00010: val_accuracy improved from 0.69620 to 0.70220, saving model to
model5_weights.best.hdf5
Epoch 11/100
781/781 [==============================] - 120s 153ms/step - loss: 0.6234 -
accuracy: 0.7828 - val_loss: 0.9954 - val_accuracy: 0.7033
```

```
Epoch 00011: val_accuracy improved from 0.70220 to 0.70330, saving model to
model5_weights.best.hdf5
Epoch 12/100
781/781 [==============================] - 120s 153ms/step - loss: 0.5976 -
accuracy: 0.7914 - val_loss: 0.8875 - val_accuracy: 0.7239

Epoch 00012: val_accuracy improved from 0.70330 to 0.72390, saving model to
model5_weights.best.hdf5
Epoch 13/100
781/781 [==============================] - 119s 153ms/step - loss: 0.5776 -
accuracy: 0.8001 - val_loss: 0.8790 - val_accuracy: 0.7306

Epoch 00013: val_accuracy improved from 0.72390 to 0.73060, saving model to
model5_weights.best.hdf5
Epoch 14/100
781/781 [==============================] - 120s 153ms/step - loss: 0.5595 -
accuracy: 0.8053 - val_loss: 1.1846 - val_accuracy: 0.6676

Epoch 00014: val_accuracy did not improve from 0.73060
Epoch 15/100
781/781 [==============================] - 120s 153ms/step - loss: 0.5326 -
accuracy: 0.8162 - val_loss: 0.6720 - val_accuracy: 0.7863

Epoch 00015: val_accuracy improved from 0.73060 to 0.78630, saving model to
model5_weights.best.hdf5
Epoch 16/100
781/781 [==============================] - 120s 153ms/step - loss: 0.5182 -
accuracy: 0.8208 - val_loss: 0.6716 - val_accuracy: 0.7794

Epoch 00016: val_accuracy did not improve from 0.78630
Epoch 17/100
781/781 [==============================] - 119s 153ms/step - loss: 0.5030 -
accuracy: 0.8265 - val_loss: 0.9736 - val_accuracy: 0.7291

Epoch 00017: val_accuracy did not improve from 0.78630
Epoch 18/100
781/781 [==============================] - 120s 153ms/step - loss: 0.4860 -
accuracy: 0.8317 - val_loss: 0.7766 - val_accuracy: 0.7814

Epoch 00018: val_accuracy did not improve from 0.78630
Epoch 19/100
781/781 [==============================] - 120s 153ms/step - loss: 0.4732 -
accuracy: 0.8361 - val_loss: 1.1807 - val_accuracy: 0.6949

Epoch 00019: val_accuracy did not improve from 0.78630
Epoch 20/100
781/781 [==============================] - 120s 153ms/step - loss: 0.4582 -
```

```
accuracy: 0.8396 - val_loss: 0.6134 - val_accuracy: 0.8037

Epoch 00020: val_accuracy improved from 0.78630 to 0.80370, saving model to
model5_weights.best.hdf5
Epoch 21/100
781/781 [==============================] - 119s 153ms/step - loss: 0.4470 -
accuracy: 0.8440 - val_loss: 0.6685 - val_accuracy: 0.7864

Epoch 00021: val_accuracy did not improve from 0.80370
Epoch 22/100
781/781 [==============================] - 120s 153ms/step - loss: 0.4347 -
accuracy: 0.8498 - val_loss: 0.5627 - val_accuracy: 0.8141

Epoch 00022: val_accuracy improved from 0.80370 to 0.81410, saving model to
model5_weights.best.hdf5
Epoch 23/100
781/781 [==============================] - 119s 153ms/step - loss: 0.4277 -
accuracy: 0.8514 - val_loss: 0.6146 - val_accuracy: 0.8029

Epoch 00023: val_accuracy did not improve from 0.81410
Epoch 24/100
781/781 [==============================] - 119s 152ms/step - loss: 0.4198 -
accuracy: 0.8548 - val_loss: 0.5680 - val_accuracy: 0.8143

Epoch 00024: val_accuracy improved from 0.81410 to 0.81430, saving model to
model5_weights.best.hdf5
Epoch 25/100
781/781 [==============================] - 120s 154ms/step - loss: 0.4065 -
accuracy: 0.8597 - val_loss: 0.7392 - val_accuracy: 0.7805

Epoch 00025: val_accuracy did not improve from 0.81430
Epoch 26/100
781/781 [==============================] - 120s 153ms/step - loss: 0.3311 -
accuracy: 0.8833 - val_loss: 0.3738 - val_accuracy: 0.8762

Epoch 00026: val_accuracy improved from 0.81430 to 0.87620, saving model to
model5_weights.best.hdf5
Epoch 27/100
781/781 [==============================] - 120s 153ms/step - loss: 0.3031 -
accuracy: 0.8946 - val_loss: 0.3818 - val_accuracy: 0.8785

Epoch 00027: val_accuracy improved from 0.87620 to 0.87850, saving model to
model5_weights.best.hdf5
Epoch 28/100
781/781 [==============================] - 120s 153ms/step - loss: 0.2953 -
accuracy: 0.8979 - val_loss: 0.3645 - val_accuracy: 0.8801

Epoch 00028: val_accuracy improved from 0.87850 to 0.88010, saving model to
```

```
model5_weights.best.hdf5
Epoch 29/100
781/781 [==============================] - 120s 154ms/step - loss: 0.2857 -
accuracy: 0.9000 - val_loss: 0.3744 - val_accuracy: 0.8788

Epoch 00029: val_accuracy did not improve from 0.88010
Epoch 30/100
781/781 [==============================] - 120s 154ms/step - loss: 0.2830 -
accuracy: 0.9021 - val_loss: 0.3479 - val_accuracy: 0.8904

Epoch 00030: val_accuracy improved from 0.88010 to 0.89040, saving model to
model5_weights.best.hdf5
Epoch 31/100
781/781 [==============================] - 120s 153ms/step - loss: 0.2742 -
accuracy: 0.9052 - val_loss: 0.3228 - val_accuracy: 0.8932

Epoch 00031: val_accuracy improved from 0.89040 to 0.89320, saving model to
model5_weights.best.hdf5
Epoch 32/100
781/781 [==============================] - 121s 154ms/step - loss: 0.2747 -
accuracy: 0.9045 - val_loss: 0.3600 - val_accuracy: 0.8826

Epoch 00032: val_accuracy did not improve from 0.89320
Epoch 33/100
781/781 [==============================] - 120s 154ms/step - loss: 0.2678 -
accuracy: 0.9067 - val_loss: 0.3407 - val_accuracy: 0.8885

Epoch 00033: val_accuracy did not improve from 0.89320
Epoch 34/100
781/781 [==============================] - 120s 154ms/step - loss: 0.2657 -
accuracy: 0.9079 - val_loss: 0.3401 - val_accuracy: 0.8903

Epoch 00034: val_accuracy did not improve from 0.89320
Epoch 35/100
781/781 [==============================] - 122s 156ms/step - loss: 0.2603 -
accuracy: 0.9085 - val_loss: 0.3519 - val_accuracy: 0.8881

Epoch 00035: val_accuracy did not improve from 0.89320
Epoch 36/100
781/781 [==============================] - 122s 156ms/step - loss: 0.2561 -
accuracy: 0.9113 - val_loss: 0.3397 - val_accuracy: 0.8891

Epoch 00036: val_accuracy did not improve from 0.89320
Epoch 37/100
781/781 [==============================] - 122s 156ms/step - loss: 0.2539 -
accuracy: 0.9115 - val_loss: 0.3564 - val_accuracy: 0.8879

Epoch 00037: val_accuracy did not improve from 0.89320
```

```
Epoch 38/100
781/781 [==============================] - 121s 155ms/step - loss: 0.2542 -
accuracy: 0.9126 - val_loss: 0.3587 - val_accuracy: 0.8870

Epoch 00038: val_accuracy did not improve from 0.89320
Epoch 39/100
781/781 [==============================] - 121s 155ms/step - loss: 0.2510 -
accuracy: 0.9121 - val_loss: 0.3576 - val_accuracy: 0.8875

Epoch 00039: val_accuracy did not improve from 0.89320
Epoch 40/100
781/781 [==============================] - 121s 155ms/step - loss: 0.2467 -
accuracy: 0.9143 - val_loss: 0.3505 - val_accuracy: 0.8896

Epoch 00040: val_accuracy did not improve from 0.89320
Epoch 41/100
781/781 [==============================] - 121s 155ms/step - loss: 0.2480 -
accuracy: 0.9129 - val_loss: 0.3604 - val_accuracy: 0.8866

Epoch 00041: val_accuracy did not improve from 0.89320
Epoch 42/100
781/781 [==============================] - 121s 155ms/step - loss: 0.2457 -
accuracy: 0.9144 - val_loss: 0.3695 - val_accuracy: 0.8819

Epoch 00042: val_accuracy did not improve from 0.89320
Epoch 43/100
781/781 [==============================] - 121s 155ms/step - loss: 0.2406 -
accuracy: 0.9162 - val_loss: 0.3325 - val_accuracy: 0.8966

Epoch 00043: val_accuracy improved from 0.89320 to 0.89660, saving model to
model5_weights.best.hdf5
Epoch 44/100
781/781 [==============================] - 121s 155ms/step - loss: 0.2363 -
accuracy: 0.9167 - val_loss: 0.3364 - val_accuracy: 0.8912

Epoch 00044: val_accuracy did not improve from 0.89660
Epoch 45/100
781/781 [==============================] - 121s 155ms/step - loss: 0.2369 -
accuracy: 0.9161 - val_loss: 0.3447 - val_accuracy: 0.8910

Epoch 00045: val_accuracy did not improve from 0.89660
Epoch 46/100
781/781 [==============================] - 121s 155ms/step - loss: 0.2347 -
accuracy: 0.9184 - val_loss: 0.3308 - val_accuracy: 0.8934

Epoch 00046: val_accuracy did not improve from 0.89660
Epoch 47/100
781/781 [==============================] - 121s 155ms/step - loss: 0.2294 -
```

```
accuracy: 0.9199 - val_loss: 0.3310 - val_accuracy: 0.8966

Epoch 00047: val_accuracy did not improve from 0.89660
Epoch 48/100
781/781 [==============================] - 122s 156ms/step - loss: 0.2279 -
accuracy: 0.9204 - val_loss: 0.3455 - val_accuracy: 0.8918

Epoch 00048: val_accuracy did not improve from 0.89660
Epoch 49/100
781/781 [==============================] - 122s 156ms/step - loss: 0.2311 -
accuracy: 0.9192 - val_loss: 0.3227 - val_accuracy: 0.8988

Epoch 00049: val_accuracy improved from 0.89660 to 0.89880, saving model to
model5_weights.best.hdf5
Epoch 50/100
781/781 [==============================] - 121s 155ms/step - loss: 0.2281 -
accuracy: 0.9198 - val_loss: 0.3356 - val_accuracy: 0.8942

Epoch 00050: val_accuracy did not improve from 0.89880
Epoch 51/100
781/781 [==============================] - 121s 155ms/step - loss: 0.2194 -
accuracy: 0.9224 - val_loss: 0.3308 - val_accuracy: 0.8966

Epoch 00051: val_accuracy did not improve from 0.89880
Epoch 52/100
781/781 [==============================] - 121s 155ms/step - loss: 0.2182 -
accuracy: 0.9234 - val_loss: 0.3265 - val_accuracy: 0.8978

Epoch 00052: val_accuracy did not improve from 0.89880
Epoch 53/100
781/781 [==============================] - 121s 155ms/step - loss: 0.2164 -
accuracy: 0.9233 - val_loss: 0.3286 - val_accuracy: 0.8979

Epoch 00053: val_accuracy did not improve from 0.89880
Epoch 54/100
781/781 [==============================] - 121s 154ms/step - loss: 0.2166 -
accuracy: 0.9241 - val_loss: 0.3309 - val_accuracy: 0.8973

Epoch 00054: val_accuracy did not improve from 0.89880
Epoch 55/100
781/781 [==============================] - 121s 155ms/step - loss: 0.2165 -
accuracy: 0.9248 - val_loss: 0.3279 - val_accuracy: 0.8978

Epoch 00055: val_accuracy did not improve from 0.89880
Epoch 56/100
781/781 [==============================] - 121s 155ms/step - loss: 0.2141 -
accuracy: 0.9245 - val_loss: 0.3245 - val_accuracy: 0.8983
```

```
Epoch 00056: val_accuracy did not improve from 0.89880
Epoch 57/100
781/781 [==============================] - 121s 155ms/step - loss: 0.2153 -
accuracy: 0.9244 - val_loss: 0.3288 - val_accuracy: 0.8982

Epoch 00057: val_accuracy did not improve from 0.89880
Epoch 58/100
781/781 [==============================] - 121s 155ms/step - loss: 0.2150 -
accuracy: 0.9241 - val_loss: 0.3253 - val_accuracy: 0.8985

Epoch 00058: val_accuracy did not improve from 0.89880
Epoch 59/100
781/781 [==============================] - 121s 155ms/step - loss: 0.2099 -
accuracy: 0.9261 - val_loss: 0.3230 - val_accuracy: 0.8998

Epoch 00059: val_accuracy improved from 0.89880 to 0.89980, saving model to
model5_weights.best.hdf5
Epoch 60/100
781/781 [==============================] - 121s 155ms/step - loss: 0.2105 -
accuracy: 0.9263 - val_loss: 0.3285 - val_accuracy: 0.8978

Epoch 00060: val_accuracy did not improve from 0.89980
Epoch 61/100
781/781 [==============================] - 121s 155ms/step - loss: 0.2122 -
accuracy: 0.9259 - val_loss: 0.3254 - val_accuracy: 0.8990

Epoch 00061: val_accuracy did not improve from 0.89980
Epoch 62/100
781/781 [==============================] - 121s 155ms/step - loss: 0.2066 -
accuracy: 0.9275 - val_loss: 0.3238 - val_accuracy: 0.8991

Epoch 00062: val_accuracy did not improve from 0.89980
Epoch 63/100
781/781 [==============================] - 121s 155ms/step - loss: 0.2088 -
accuracy: 0.9268 - val_loss: 0.3285 - val_accuracy: 0.8968

Epoch 00063: val_accuracy did not improve from 0.89980
Epoch 64/100
781/781 [==============================] - 122s 156ms/step - loss: 0.2140 -
accuracy: 0.9231 - val_loss: 0.3257 - val_accuracy: 0.8979

Epoch 00064: val_accuracy did not improve from 0.89980
Epoch 65/100
781/781 [==============================] - 121s 155ms/step - loss: 0.2067 -
accuracy: 0.9280 - val_loss: 0.3275 - val_accuracy: 0.8980

Epoch 00065: val_accuracy did not improve from 0.89980
Epoch 66/100
```

```
781/781 [==============================] - 121s 155ms/step - loss: 0.2089 -
accuracy: 0.9256 - val_loss: 0.3267 - val_accuracy: 0.8980

Epoch 00066: val_accuracy did not improve from 0.89980
Epoch 67/100
781/781 [==============================] - 121s 155ms/step - loss: 0.2127 -
accuracy: 0.9258 - val_loss: 0.3208 - val_accuracy: 0.8991

Epoch 00067: val_accuracy did not improve from 0.89980
Epoch 68/100
781/781 [==============================] - 121s 155ms/step - loss: 0.2119 -
accuracy: 0.9255 - val_loss: 0.3262 - val_accuracy: 0.8983

Epoch 00068: val_accuracy did not improve from 0.89980
Epoch 69/100
781/781 [==============================] - 121s 155ms/step - loss: 0.2091 -
accuracy: 0.9264 - val_loss: 0.3237 - val_accuracy: 0.8991

Epoch 00069: val_accuracy did not improve from 0.89980
Epoch 70/100
781/781 [==============================] - 121s 155ms/step - loss: 0.2090 -
accuracy: 0.9274 - val_loss: 0.3212 - val_accuracy: 0.9015

Epoch 00070: val_accuracy improved from 0.89980 to 0.90150, saving model to
model5_weights.best.hdf5
Epoch 71/100
781/781 [==============================] - 121s 155ms/step - loss: 0.2102 -
accuracy: 0.9264 - val_loss: 0.3249 - val_accuracy: 0.8994

Epoch 00071: val_accuracy did not improve from 0.90150
Epoch 72/100
781/781 [==============================] - 121s 154ms/step - loss: 0.2115 -
accuracy: 0.9262 - val_loss: 0.3298 - val_accuracy: 0.8973

Epoch 00072: val_accuracy did not improve from 0.90150
```

[19]:
```
<tensorflow.python.keras.callbacks.History at 0x7f80f632c350>
```

[20]:
```
import pandas as pd
import numpy as np
training_log = pd.read_csv('/content/training.log')
training_log.head(100)
```

[20]:

	epoch	accuracy	loss	lr	val_accuracy	val_loss
0	0	0.321692	1.864464	0.0100	0.2920	2.165388
1	1	0.445070	1.512568	0.0100	0.3066	2.605386
2	2	0.535646	1.281641	0.0100	0.5004	1.756118

```
3       3  0.612224  1.090826  0.0100        0.6171  1.167669
4       4  0.658863  0.955366  0.0100        0.6521  1.029768
..    ...       ...       ...     ...           ...       ...
67     67  0.925485  0.211873  0.0001        0.8983  0.326231
68     68  0.926426  0.209126  0.0001        0.8991  0.323680
69     69  0.927447  0.209021  0.0001        0.9015  0.321206
70     70  0.926446  0.210156  0.0001        0.8994  0.324877
71     71  0.926206  0.211468  0.0001        0.8973  0.329835

[72 rows x 6 columns]
```

[21]:
```
model5.load_weights('/content/model5_weights.best.hdf5')
model5.
 ↪compile(optimizer='adam',loss='categorical_crossentropy',metrics=['accuracy'])
print("Model created and weights loaded from file")
```

```
Model created and weights loaded from file
```

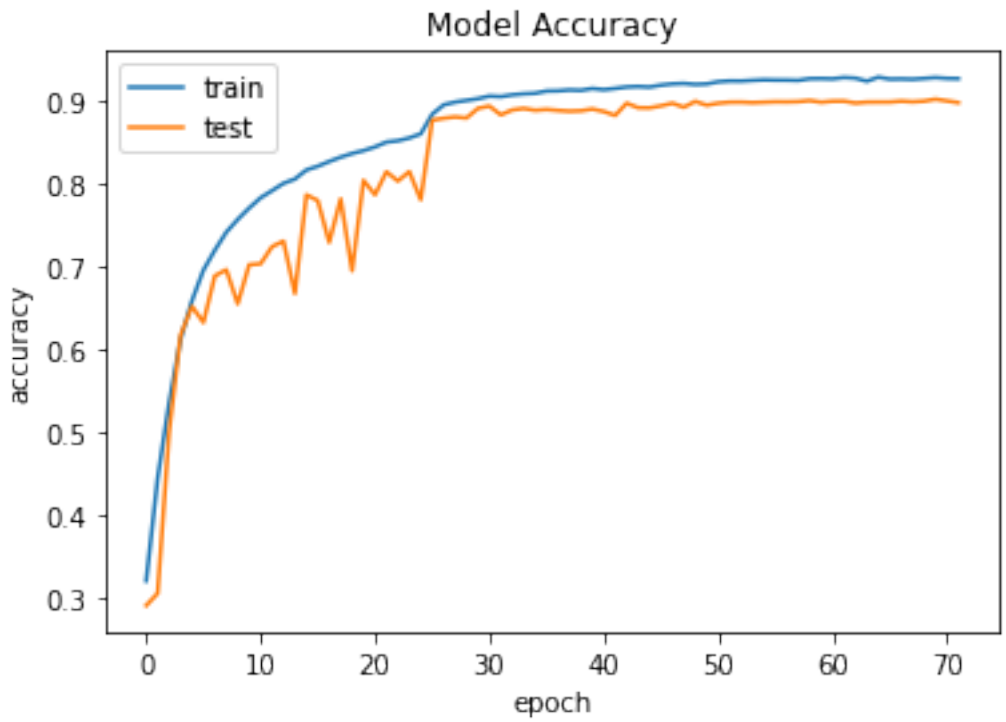
[22]:
```
score = model5.evaluate(X_test,y_test,verbose=0)
print("Test loss = ",score[0])
print("Test accuracy = ",score[1])
```

```
Test loss =  0.32120639085769653
Test accuracy =  0.9014999866485596
```

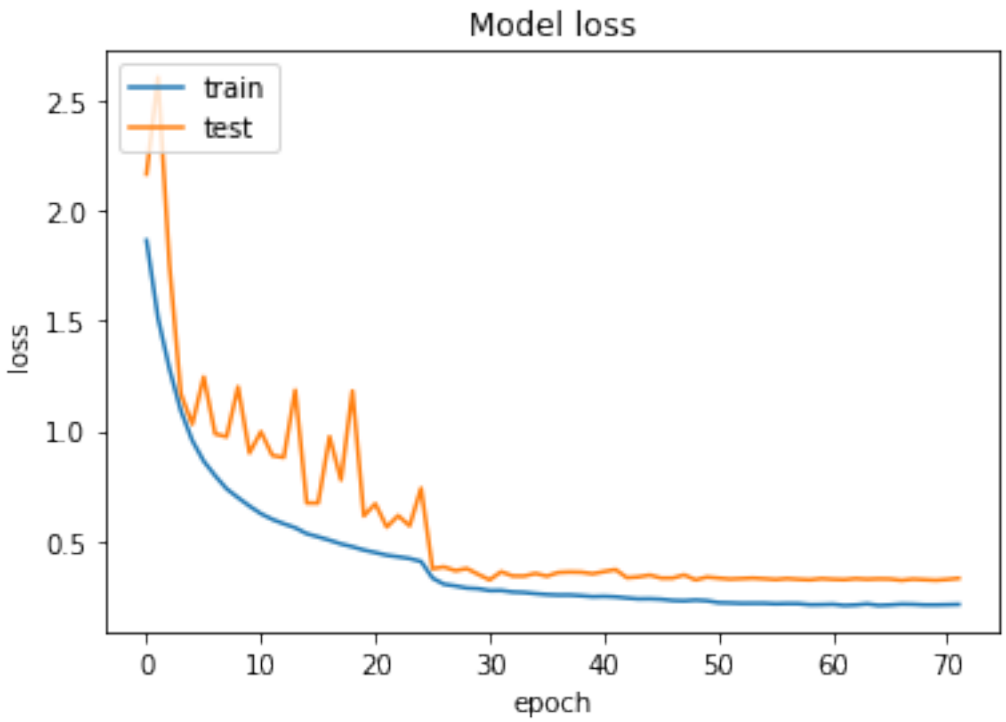
1.3.5 2.5 Plotting loss and accuracy of Model 5 above

[ ]:
```
%matplotlib notebook
%matplotlib inline
import matplotlib.pyplot as plt
import numpy as np
import time
```

[24]:
```
#https://machinelearningmastery.com/
 ↪display-deep-learning-model-training-history-in-keras/
plt.plot(training_log['accuracy'])
plt.plot(training_log['val_accuracy'])
plt.title('Model Accuracy')
plt.ylabel('accuracy')
plt.xlabel('epoch')
plt.legend(['train','test'],loc='upper left')
plt.show()
```



[25]:
```
#https://machinelearningmastery.com/
 ↪display-deep-learning-model-training-history-in-keras/
plt.plot(training_log['loss'])
plt.plot(training_log['val_loss'])
plt.title('Model loss')
plt.xlabel('epoch')
plt.ylabel('loss')
plt.legend(['train','test'],loc='upper left')
plt.show()
```



1.4 3. Conclusion

[1]:
```
from prettytable import PrettyTable

x = PrettyTable()
x.field_names = ['Growth Rate','Compression','# of Blocks','Test Accuracy']
x.add_row([36,0.7,12,90.149])

print(x)
```

```
+-------------+-------------+-------------+---------------+
| Growth Rate | Compression | # of Blocks | Test Accuracy |
+-------------+-------------+-------------+---------------+
|      36     |     0.7     |      12     |     90.149    |
+-------------+-------------+-------------+---------------+
```

Summary:

I have used Keras callbacks to adjust the learning rate as per the performance of the model(ReduceLRonPlateau,LearningRate Sceduler).

Additional links and resuorces:

1. 2016 DenseNet paper summary: https://www.youtube.com/watch?v=hSC_0S8Zf9s

2. Separable Depth wise convolutions: https://towardsdatascience.com/a-basic-introduction-to-separable-convolutions-b99ec3102728
3. Review DenseNet image classification: https://towardsdatascience.com/review-densenet-image-classification-b6631a8ef803

[ ]:

[ ]: