CNN on CIFR Assignment:

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.

In [2]:
```
# 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
from keras.preprocessing.image import ImageDataGenerator
```

In [3]:
```
# Hyperparameters
batch_size = 128
num_classes = 10
epochs = 10
l = 40
num_filter = 12
compression = 0.5
dropout_rate = 0.2
```

In [4]:
```
# 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]

# convert to one hot encoing
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
```

In [5]:
```
(X_train.shape) , (X_test.shape) , (y_train.shape), (y_test.shape)
```

Out[5]:
```
((50000, 32, 32, 3), (10000, 32, 32, 3), (50000, 10), (10000, 10))
```

In [6]:
```
train_datagen = ImageDataGenerator(
        rotation_range=40,
        width_shift_range=0.2,
        height_shift_range=0.2,
        rescale=1./255,
        shear_range=0.2,
        zoom_range=0.2,
        horizontal_flip=True,
        fill_mode='nearest')
```

```
train_generator = train_datagen.flow(X_train, y_train, batch_size=9)

# this is the augmentation configuration we will use for testing:
# only rescaling
test_datagen = ImageDataGenerator(rescale=1./255)

test_generator = test_datagen.flow(X_test, y_test, batch_size=9)
```

In [7]:
```
# 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_3_3 = layers.Conv2D(int(num_filter*compression), (3,3), use_bias=False ,padding='same')(relu)
        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 Blosck
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
```

In [ ]:
```
num_filter = 12
dropout_rate = 0
l = 12
input = layers.Input(shape=(img_height, img_width, channel,))
First_Conv2D = layers.Conv2D(num_filter, (3,3), use_bias=False ,padding='same')(input)
#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)

Forth_Block = denseblock(Third_Transition, num_filter, dropout_rate)
Forth_Transition = transition(Forth_Block, num_filter, dropout_rate)

Fifth_Block = denseblock(Forth_Transition, num_filter, dropout_rate)
Fifth_Transition = transition(Fifth_Block, num_filter, dropout_rate)

#Last_Block = denseblock(Fifth_Transition,  num_filter, dropout_rate)
Last_Block = denseblock(Forth_Transition,  num_filter, dropout_rate)
output = output_layer(Last_Block)
```

In [8]:
```
num_filter = 12
dropout_rate = 0
l = 12
input = layers.Input(shape=(img_height, img_width, channel,))
First_Conv2D = layers.Conv2D(40, (3,3), use_bias=False ,padding='same')(input)
```

```
First_Block = denseblock(First_Conv2D,20, dropout_rate)
First_Transition = transition(First_Block, 75, dropout_rate)

Second_Block = denseblock(First_Transition, 20, dropout_rate)
Second_Transition = transition(Second_Block, 40, dropout_rate)

Third_Block = denseblock(Second_Transition, num_filter, dropout_rate)
Third_Transition = transition(Third_Block, 40, dropout_rate)

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

In [9]:
```
model = Model(inputs=[input], outputs=[output])
model.summary()
```

```
Model: "model"
_________________________________________________________________________________________________
Layer (type)                 Output Shape              Param #     Connected to
=================================================================================================
input_1 (InputLayer)         [(None, 32, 32, 3)]       0
_________________________________________________________________________________________________
conv2d (Conv2D)              (None, 32, 32, 40)        1080        input_1[0][0]
_________________________________________________________________________________________________
batch_normalization (BatchNorma (None, 32, 32, 40)     160         conv2d[0][0]
_________________________________________________________________________________________________
activation (Activation)      (None, 32, 32, 40)        0           batch_normalization[0][0]
_________________________________________________________________________________________________
conv2d_1 (Conv2D)            (None, 32, 32, 10)        3600        activation[0][0]
_________________________________________________________________________________________________
concatenate (Concatenate)    (None, 32, 32, 50)        0           conv2d[0][0]
                                                                   conv2d_1[0][0]
_________________________________________________________________________________________________
batch_normalization_1 (BatchNor (None, 32, 32, 50)     200         concatenate[0][0]
_________________________________________________________________________________________________
activation_1 (Activation)    (None, 32, 32, 50)        0           batch_normalization_1[0][0]
_________________________________________________________________________________________________
conv2d_2 (Conv2D)            (None, 32, 32, 10)        4500        activation_1[0][0]
_________________________________________________________________________________________________
concatenate_1 (Concatenate)  (None, 32, 32, 60)        0           concatenate[0][0]
                                                                   conv2d_2[0][0]
_________________________________________________________________________________________________
batch_normalization_2 (BatchNor (None, 32, 32, 60)     240         concatenate_1[0][0]
_________________________________________________________________________________________________
activation_2 (Activation)    (None, 32, 32, 60)        0           batch_normalization_2[0][0]
_________________________________________________________________________________________________
conv2d_3 (Conv2D)            (None, 32, 32, 10)        5400        activation_2[0][0]
_________________________________________________________________________________________________
concatenate_2 (Concatenate)  (None, 32, 32, 70)        0           concatenate_1[0][0]
                                                                   conv2d_3[0][0]
_________________________________________________________________________________________________
batch_normalization_3 (BatchNor (None, 32, 32, 70)     280         concatenate_2[0][0]
_________________________________________________________________________________________________
activation_3 (Activation)    (None, 32, 32, 70)        0           batch_normalization_3[0][0]
_________________________________________________________________________________________________
conv2d_4 (Conv2D)            (None, 32, 32, 10)        6300        activation_3[0][0]
_________________________________________________________________________________________________
concatenate_3 (Concatenate)  (None, 32, 32, 80)        0           concatenate_2[0][0]
                                                                   conv2d_4[0][0]
_________________________________________________________________________________________________
batch_normalization_4 (BatchNor (None, 32, 32, 80)     320         concatenate_3[0][0]
_________________________________________________________________________________________________
activation_4 (Activation)    (None, 32, 32, 80)        0           batch_normalization_4[0][0]
_________________________________________________________________________________________________
conv2d_5 (Conv2D)            (None, 32, 32, 10)        7200        activation_4[0][0]
_________________________________________________________________________________________________
concatenate_4 (Concatenate)  (None, 32, 32, 90)        0           concatenate_3[0][0]
                                                                   conv2d_5[0][0]
_________________________________________________________________________________________________
batch_normalization_5 (BatchNor (None, 32, 32, 90)     360         concatenate_4[0][0]
_________________________________________________________________________________________________
activation_5 (Activation)    (None, 32, 32, 90)        0           batch_normalization_5[0][0]
_________________________________________________________________________________________________
conv2d_6 (Conv2D)            (None, 32, 32, 10)        8100        activation_5[0][0]
_________________________________________________________________________________________________
concatenate_5 (Concatenate)  (None, 32, 32, 100)       0           concatenate_4[0][0]
                                                                   conv2d_6[0][0]
_________________________________________________________________________________________________
batch_normalization_6 (BatchNor (None, 32, 32, 100)    400         concatenate_5[0][0]
_________________________________________________________________________________________________
activation_6 (Activation)    (None, 32, 32, 100)       0           batch_normalization_6[0][0]
_________________________________________________________________________________________________
```

conv2d_7 (Conv2D)	(None, 32, 32, 10)	9000	activation_6[0][0]
concatenate_6 (Concatenate)	(None, 32, 32, 110)	0	concatenate_5[0][0] conv2d_7[0][0]
batch_normalization_7 (BatchNor	(None, 32, 32, 110)	440	concatenate_6[0][0]
activation_7 (Activation)	(None, 32, 32, 110)	0	batch_normalization_7[0][0]
conv2d_8 (Conv2D)	(None, 32, 32, 10)	9900	activation_7[0][0]
concatenate_7 (Concatenate)	(None, 32, 32, 120)	0	concatenate_6[0][0] conv2d_8[0][0]
batch_normalization_8 (BatchNor	(None, 32, 32, 120)	480	concatenate_7[0][0]
activation_8 (Activation)	(None, 32, 32, 120)	0	batch_normalization_8[0][0]
conv2d_9 (Conv2D)	(None, 32, 32, 10)	10800	activation_8[0][0]
concatenate_8 (Concatenate)	(None, 32, 32, 130)	0	concatenate_7[0][0] conv2d_9[0][0]
batch_normalization_9 (BatchNor	(None, 32, 32, 130)	520	concatenate_8[0][0]
activation_9 (Activation)	(None, 32, 32, 130)	0	batch_normalization_9[0][0]
conv2d_10 (Conv2D)	(None, 32, 32, 10)	11700	activation_9[0][0]
concatenate_9 (Concatenate)	(None, 32, 32, 140)	0	concatenate_8[0][0] conv2d_10[0][0]
batch_normalization_10 (BatchNo	(None, 32, 32, 140)	560	concatenate_9[0][0]
activation_10 (Activation)	(None, 32, 32, 140)	0	batch_normalization_10[0][0]
conv2d_11 (Conv2D)	(None, 32, 32, 10)	12600	activation_10[0][0]
concatenate_10 (Concatenate)	(None, 32, 32, 150)	0	concatenate_9[0][0] conv2d_11[0][0]
batch_normalization_11 (BatchNo	(None, 32, 32, 150)	600	concatenate_10[0][0]
activation_11 (Activation)	(None, 32, 32, 150)	0	batch_normalization_11[0][0]
conv2d_12 (Conv2D)	(None, 32, 32, 10)	13500	activation_11[0][0]
concatenate_11 (Concatenate)	(None, 32, 32, 160)	0	concatenate_10[0][0] conv2d_12[0][0]
batch_normalization_12 (BatchNo	(None, 32, 32, 160)	640	concatenate_11[0][0]
activation_12 (Activation)	(None, 32, 32, 160)	0	batch_normalization_12[0][0]
conv2d_13 (Conv2D)	(None, 32, 32, 37)	5920	activation_12[0][0]
average_pooling2d (AveragePooli	(None, 16, 16, 37)	0	conv2d_13[0][0]
batch_normalization_13 (BatchNo	(None, 16, 16, 37)	148	average_pooling2d[0][0]
activation_13 (Activation)	(None, 16, 16, 37)	0	batch_normalization_13[0][0]
conv2d_14 (Conv2D)	(None, 16, 16, 10)	3330	activation_13[0][0]
concatenate_12 (Concatenate)	(None, 16, 16, 47)	0	average_pooling2d[0][0] conv2d_14[0][0]
batch_normalization_14 (BatchNo	(None, 16, 16, 47)	188	concatenate_12[0][0]
activation_14 (Activation)	(None, 16, 16, 47)	0	batch_normalization_14[0][0]
conv2d_15 (Conv2D)	(None, 16, 16, 10)	4230	activation_14[0][0]
concatenate_13 (Concatenate)	(None, 16, 16, 57)	0	concatenate_12[0][0] conv2d_15[0][0]
batch_normalization_15 (BatchNo	(None, 16, 16, 57)	228	concatenate_13[0][0]
activation_15 (Activation)	(None, 16, 16, 57)	0	batch_normalization_15[0][0]
conv2d_16 (Conv2D)	(None, 16, 16, 10)	5130	activation_15[0][0]
concatenate_14 (Concatenate)	(None, 16, 16, 67)	0	concatenate_13[0][0]

			conv2d_16[0][0]
batch_normalization_16 (BatchNo	(None, 16, 16, 67)	268	concatenate_14[0][0]
activation_16 (Activation)	(None, 16, 16, 67)	0	batch_normalization_16[0][0]
conv2d_17 (Conv2D)	(None, 16, 16, 10)	6030	activation_16[0][0]
concatenate_15 (Concatenate)	(None, 16, 16, 77)	0	concatenate_14[0][0] conv2d_17[0][0]
batch_normalization_17 (BatchNo	(None, 16, 16, 77)	308	concatenate_15[0][0]
activation_17 (Activation)	(None, 16, 16, 77)	0	batch_normalization_17[0][0]
conv2d_18 (Conv2D)	(None, 16, 16, 10)	6930	activation_17[0][0]
concatenate_16 (Concatenate)	(None, 16, 16, 87)	0	concatenate_15[0][0] conv2d_18[0][0]
batch_normalization_18 (BatchNo	(None, 16, 16, 87)	348	concatenate_16[0][0]
activation_18 (Activation)	(None, 16, 16, 87)	0	batch_normalization_18[0][0]
conv2d_19 (Conv2D)	(None, 16, 16, 10)	7830	activation_18[0][0]
concatenate_17 (Concatenate)	(None, 16, 16, 97)	0	concatenate_16[0][0] conv2d_19[0][0]
batch_normalization_19 (BatchNo	(None, 16, 16, 97)	388	concatenate_17[0][0]
activation_19 (Activation)	(None, 16, 16, 97)	0	batch_normalization_19[0][0]
conv2d_20 (Conv2D)	(None, 16, 16, 10)	8730	activation_19[0][0]
concatenate_18 (Concatenate)	(None, 16, 16, 107)	0	concatenate_17[0][0] conv2d_20[0][0]
batch_normalization_20 (BatchNo	(None, 16, 16, 107)	428	concatenate_18[0][0]
activation_20 (Activation)	(None, 16, 16, 107)	0	batch_normalization_20[0][0]
conv2d_21 (Conv2D)	(None, 16, 16, 10)	9630	activation_20[0][0]
concatenate_19 (Concatenate)	(None, 16, 16, 117)	0	concatenate_18[0][0] conv2d_21[0][0]
batch_normalization_21 (BatchNo	(None, 16, 16, 117)	468	concatenate_19[0][0]
activation_21 (Activation)	(None, 16, 16, 117)	0	batch_normalization_21[0][0]
conv2d_22 (Conv2D)	(None, 16, 16, 10)	10530	activation_21[0][0]
concatenate_20 (Concatenate)	(None, 16, 16, 127)	0	concatenate_19[0][0] conv2d_22[0][0]
batch_normalization_22 (BatchNo	(None, 16, 16, 127)	508	concatenate_20[0][0]
activation_22 (Activation)	(None, 16, 16, 127)	0	batch_normalization_22[0][0]
conv2d_23 (Conv2D)	(None, 16, 16, 10)	11430	activation_22[0][0]
concatenate_21 (Concatenate)	(None, 16, 16, 137)	0	concatenate_20[0][0] conv2d_23[0][0]
batch_normalization_23 (BatchNo	(None, 16, 16, 137)	548	concatenate_21[0][0]
activation_23 (Activation)	(None, 16, 16, 137)	0	batch_normalization_23[0][0]
conv2d_24 (Conv2D)	(None, 16, 16, 10)	12330	activation_23[0][0]
concatenate_22 (Concatenate)	(None, 16, 16, 147)	0	concatenate_21[0][0] conv2d_24[0][0]
batch_normalization_24 (BatchNo	(None, 16, 16, 147)	588	concatenate_22[0][0]
activation_24 (Activation)	(None, 16, 16, 147)	0	batch_normalization_24[0][0]
conv2d_25 (Conv2D)	(None, 16, 16, 10)	13230	activation_24[0][0]
concatenate_23 (Concatenate)	(None, 16, 16, 157)	0	concatenate_22[0][0] conv2d_25[0][0]

batch_normalization_25 (BatchNo	(None, 16, 16, 157)	628	concatenate_23[0][0]
activation_25 (Activation)	(None, 16, 16, 157)	0	batch_normalization_25[0][0]
conv2d_26 (Conv2D)	(None, 16, 16, 20)	3140	activation_25[0][0]
average_pooling2d_1 (AveragePoo	(None, 8, 8, 20)	0	conv2d_26[0][0]
batch_normalization_26 (BatchNo	(None, 8, 8, 20)	80	average_pooling2d_1[0][0]
activation_26 (Activation)	(None, 8, 8, 20)	0	batch_normalization_26[0][0]
conv2d_27 (Conv2D)	(None, 8, 8, 6)	1080	activation_26[0][0]
concatenate_24 (Concatenate)	(None, 8, 8, 26)	0	average_pooling2d_1[0][0] conv2d_27[0][0]
batch_normalization_27 (BatchNo	(None, 8, 8, 26)	104	concatenate_24[0][0]
activation_27 (Activation)	(None, 8, 8, 26)	0	batch_normalization_27[0][0]
conv2d_28 (Conv2D)	(None, 8, 8, 6)	1404	activation_27[0][0]
concatenate_25 (Concatenate)	(None, 8, 8, 32)	0	concatenate_24[0][0] conv2d_28[0][0]
batch_normalization_28 (BatchNo	(None, 8, 8, 32)	128	concatenate_25[0][0]
activation_28 (Activation)	(None, 8, 8, 32)	0	batch_normalization_28[0][0]
conv2d_29 (Conv2D)	(None, 8, 8, 6)	1728	activation_28[0][0]
concatenate_26 (Concatenate)	(None, 8, 8, 38)	0	concatenate_25[0][0] conv2d_29[0][0]
batch_normalization_29 (BatchNo	(None, 8, 8, 38)	152	concatenate_26[0][0]
activation_29 (Activation)	(None, 8, 8, 38)	0	batch_normalization_29[0][0]
conv2d_30 (Conv2D)	(None, 8, 8, 6)	2052	activation_29[0][0]
concatenate_27 (Concatenate)	(None, 8, 8, 44)	0	concatenate_26[0][0] conv2d_30[0][0]
batch_normalization_30 (BatchNo	(None, 8, 8, 44)	176	concatenate_27[0][0]
activation_30 (Activation)	(None, 8, 8, 44)	0	batch_normalization_30[0][0]
conv2d_31 (Conv2D)	(None, 8, 8, 6)	2376	activation_30[0][0]
concatenate_28 (Concatenate)	(None, 8, 8, 50)	0	concatenate_27[0][0] conv2d_31[0][0]
batch_normalization_31 (BatchNo	(None, 8, 8, 50)	200	concatenate_28[0][0]
activation_31 (Activation)	(None, 8, 8, 50)	0	batch_normalization_31[0][0]
conv2d_32 (Conv2D)	(None, 8, 8, 6)	2700	activation_31[0][0]
concatenate_29 (Concatenate)	(None, 8, 8, 56)	0	concatenate_28[0][0] conv2d_32[0][0]
batch_normalization_32 (BatchNo	(None, 8, 8, 56)	224	concatenate_29[0][0]
activation_32 (Activation)	(None, 8, 8, 56)	0	batch_normalization_32[0][0]
conv2d_33 (Conv2D)	(None, 8, 8, 6)	3024	activation_32[0][0]
concatenate_30 (Concatenate)	(None, 8, 8, 62)	0	concatenate_29[0][0] conv2d_33[0][0]
batch_normalization_33 (BatchNo	(None, 8, 8, 62)	248	concatenate_30[0][0]
activation_33 (Activation)	(None, 8, 8, 62)	0	batch_normalization_33[0][0]
conv2d_34 (Conv2D)	(None, 8, 8, 6)	3348	activation_33[0][0]
concatenate_31 (Concatenate)	(None, 8, 8, 68)	0	concatenate_30[0][0] conv2d_34[0][0]
batch_normalization_34 (BatchNo	(None, 8, 8, 68)	272	concatenate_31[0][0]
activation_34 (Activation)	(None, 8, 8, 68)	0	batch_normalization_34[0][0]

conv2d_35 (Conv2D)	(None, 8, 8, 6)	3672	activation_34[0][0]
concatenate_32 (Concatenate)	(None, 8, 8, 74)	0	concatenate_31[0][0] conv2d_35[0][0]
batch_normalization_35 (BatchNo	(None, 8, 8, 74)	296	concatenate_32[0][0]
activation_35 (Activation)	(None, 8, 8, 74)	0	batch_normalization_35[0][0]
conv2d_36 (Conv2D)	(None, 8, 8, 6)	3996	activation_35[0][0]
concatenate_33 (Concatenate)	(None, 8, 8, 80)	0	concatenate_32[0][0] conv2d_36[0][0]
batch_normalization_36 (BatchNo	(None, 8, 8, 80)	320	concatenate_33[0][0]
activation_36 (Activation)	(None, 8, 8, 80)	0	batch_normalization_36[0][0]
conv2d_37 (Conv2D)	(None, 8, 8, 6)	4320	activation_36[0][0]
concatenate_34 (Concatenate)	(None, 8, 8, 86)	0	concatenate_33[0][0] conv2d_37[0][0]
batch_normalization_37 (BatchNo	(None, 8, 8, 86)	344	concatenate_34[0][0]
activation_37 (Activation)	(None, 8, 8, 86)	0	batch_normalization_37[0][0]
conv2d_38 (Conv2D)	(None, 8, 8, 6)	4644	activation_37[0][0]
concatenate_35 (Concatenate)	(None, 8, 8, 92)	0	concatenate_34[0][0] conv2d_38[0][0]
batch_normalization_38 (BatchNo	(None, 8, 8, 92)	368	concatenate_35[0][0]
activation_38 (Activation)	(None, 8, 8, 92)	0	batch_normalization_38[0][0]
conv2d_39 (Conv2D)	(None, 8, 8, 20)	1840	activation_38[0][0]
average_pooling2d_2 (AveragePoo	(None, 4, 4, 20)	0	conv2d_39[0][0]
batch_normalization_39 (BatchNo	(None, 4, 4, 20)	80	average_pooling2d_2[0][0]
activation_39 (Activation)	(None, 4, 4, 20)	0	batch_normalization_39[0][0]
conv2d_40 (Conv2D)	(None, 4, 4, 6)	1080	activation_39[0][0]
concatenate_36 (Concatenate)	(None, 4, 4, 26)	0	average_pooling2d_2[0][0] conv2d_40[0][0]
batch_normalization_40 (BatchNo	(None, 4, 4, 26)	104	concatenate_36[0][0]
activation_40 (Activation)	(None, 4, 4, 26)	0	batch_normalization_40[0][0]
conv2d_41 (Conv2D)	(None, 4, 4, 6)	1404	activation_40[0][0]
concatenate_37 (Concatenate)	(None, 4, 4, 32)	0	concatenate_36[0][0] conv2d_41[0][0]
batch_normalization_41 (BatchNo	(None, 4, 4, 32)	128	concatenate_37[0][0]
activation_41 (Activation)	(None, 4, 4, 32)	0	batch_normalization_41[0][0]
conv2d_42 (Conv2D)	(None, 4, 4, 6)	1728	activation_41[0][0]
concatenate_38 (Concatenate)	(None, 4, 4, 38)	0	concatenate_37[0][0] conv2d_42[0][0]
batch_normalization_42 (BatchNo	(None, 4, 4, 38)	152	concatenate_38[0][0]
activation_42 (Activation)	(None, 4, 4, 38)	0	batch_normalization_42[0][0]
conv2d_43 (Conv2D)	(None, 4, 4, 6)	2052	activation_42[0][0]
concatenate_39 (Concatenate)	(None, 4, 4, 44)	0	concatenate_38[0][0] conv2d_43[0][0]
batch_normalization_43 (BatchNo	(None, 4, 4, 44)	176	concatenate_39[0][0]
activation_43 (Activation)	(None, 4, 4, 44)	0	batch_normalization_43[0][0]
conv2d_44 (Conv2D)	(None, 4, 4, 6)	2376	activation_43[0][0]

```
concatenate_40 (Concatenate)    (None, 4, 4, 50)     0           concatenate_39[0][0]
                                                                 conv2d_44[0][0]
__________________________________________________________________________________________________
batch_normalization_44 (BatchNo (None, 4, 4, 50)     200         concatenate_40[0][0]
__________________________________________________________________________________________________
activation_44 (Activation)      (None, 4, 4, 50)     0           batch_normalization_44[0][0]
__________________________________________________________________________________________________
conv2d_45 (Conv2D)              (None, 4, 4, 6)      2700        activation_44[0][0]
__________________________________________________________________________________________________
concatenate_41 (Concatenate)    (None, 4, 4, 56)     0           concatenate_40[0][0]
                                                                 conv2d_45[0][0]
__________________________________________________________________________________________________
batch_normalization_45 (BatchNo (None, 4, 4, 56)     224         concatenate_41[0][0]
__________________________________________________________________________________________________
activation_45 (Activation)      (None, 4, 4, 56)     0           batch_normalization_45[0][0]
__________________________________________________________________________________________________
conv2d_46 (Conv2D)              (None, 4, 4, 6)      3024        activation_45[0][0]
__________________________________________________________________________________________________
concatenate_42 (Concatenate)    (None, 4, 4, 62)     0           concatenate_41[0][0]
                                                                 conv2d_46[0][0]
__________________________________________________________________________________________________
batch_normalization_46 (BatchNo (None, 4, 4, 62)     248         concatenate_42[0][0]
__________________________________________________________________________________________________
activation_46 (Activation)      (None, 4, 4, 62)     0           batch_normalization_46[0][0]
__________________________________________________________________________________________________
conv2d_47 (Conv2D)              (None, 4, 4, 6)      3348        activation_46[0][0]
__________________________________________________________________________________________________
concatenate_43 (Concatenate)    (None, 4, 4, 68)     0           concatenate_42[0][0]
                                                                 conv2d_47[0][0]
__________________________________________________________________________________________________
batch_normalization_47 (BatchNo (None, 4, 4, 68)     272         concatenate_43[0][0]
__________________________________________________________________________________________________
activation_47 (Activation)      (None, 4, 4, 68)     0           batch_normalization_47[0][0]
__________________________________________________________________________________________________
conv2d_48 (Conv2D)              (None, 4, 4, 6)      3672        activation_47[0][0]
__________________________________________________________________________________________________
concatenate_44 (Concatenate)    (None, 4, 4, 74)     0           concatenate_43[0][0]
                                                                 conv2d_48[0][0]
__________________________________________________________________________________________________
batch_normalization_48 (BatchNo (None, 4, 4, 74)     296         concatenate_44[0][0]
__________________________________________________________________________________________________
activation_48 (Activation)      (None, 4, 4, 74)     0           batch_normalization_48[0][0]
__________________________________________________________________________________________________
conv2d_49 (Conv2D)              (None, 4, 4, 6)      3996        activation_48[0][0]
__________________________________________________________________________________________________
concatenate_45 (Concatenate)    (None, 4, 4, 80)     0           concatenate_44[0][0]
                                                                 conv2d_49[0][0]
__________________________________________________________________________________________________
batch_normalization_49 (BatchNo (None, 4, 4, 80)     320         concatenate_45[0][0]
__________________________________________________________________________________________________
activation_49 (Activation)      (None, 4, 4, 80)     0           batch_normalization_49[0][0]
__________________________________________________________________________________________________
conv2d_50 (Conv2D)              (None, 4, 4, 6)      4320        activation_49[0][0]
__________________________________________________________________________________________________
concatenate_46 (Concatenate)    (None, 4, 4, 86)     0           concatenate_45[0][0]
                                                                 conv2d_50[0][0]
__________________________________________________________________________________________________
batch_normalization_50 (BatchNo (None, 4, 4, 86)     344         concatenate_46[0][0]
__________________________________________________________________________________________________
activation_50 (Activation)      (None, 4, 4, 86)     0           batch_normalization_50[0][0]
__________________________________________________________________________________________________
conv2d_51 (Conv2D)              (None, 4, 4, 6)      4644        activation_50[0][0]
__________________________________________________________________________________________________
concatenate_47 (Concatenate)    (None, 4, 4, 92)     0           concatenate_46[0][0]
                                                                 conv2d_51[0][0]
__________________________________________________________________________________________________
batch_normalization_51 (BatchNo (None, 4, 4, 92)     368         concatenate_47[0][0]
__________________________________________________________________________________________________
activation_51 (Activation)      (None, 4, 4, 92)     0           batch_normalization_51[0][0]
__________________________________________________________________________________________________
average_pooling2d_3 (AveragePoo (None, 2, 2, 92)     0           activation_51[0][0]
__________________________________________________________________________________________________
flatten (Flatten)               (None, 368)          0           average_pooling2d_3[0][0]
__________________________________________________________________________________________________
dense (Dense)                   (None, 10)           3690        flatten[0][0]
==================================================================================================
Total params: 302,386
Trainable params: 294,352
Non-trainable params: 8,034
__________________________________________________________________________________________________
```

In [15]:
```
from tensorflow.keras.callbacks import ModelCheckpoint
```

```
filepath="model_save/model.{epoch:02d}-{val_accuracy:.2f}.h5"
checkpoint = ModelCheckpoint(filepath=filepath, monitor='val_accuracy', verbose=1, save_best_only=True, mode='auto')
```

In [17]:
```
model.compile(loss='categorical_crossentropy',
              optimizer='Adam', metrics=['accuracy'])
```

In [18]:
```
train_datagen = ImageDataGenerator(
        rotation_range=40,
        width_shift_range=0.1,
        height_shift_range=0.2,
        rescale=1./255,
        shear_range=0.2,
        zoom_range=0.2,
        horizontal_flip=True,
        fill_mode='nearest')

train_generator = train_datagen.flow(X_train, y_train, batch_size=80)

# this is the augmentation configuration we will use for testing:
# only rescaling
test_datagen = ImageDataGenerator(rescale=1./255)
steps_epoch = int(X_train.shape[0] / 40)


test_generator = test_datagen.flow(X_test, y_test, batch_size=9)
history = model.fit(train_generator ,epochs=290, validation_data=test_generator, verbose=2,callbacks=checkpoint)
```

```
Epoch 1/290
625/625 - 103s - loss: 1.6267 - accuracy: 0.4048 - val_loss: 1.4905 - val_accuracy: 0.4548

Epoch 00001: val_accuracy improved from -inf to 0.45480, saving model to model_save/model.01-0.45.h5
Epoch 2/290
625/625 - 90s - loss: 1.2927 - accuracy: 0.5349 - val_loss: 1.1202 - val_accuracy: 0.6043

Epoch 00002: val_accuracy improved from 0.45480 to 0.60430, saving model to model_save/model.02-0.60.h5
Epoch 3/290
625/625 - 90s - loss: 1.1375 - accuracy: 0.5915 - val_loss: 1.1536 - val_accuracy: 0.6073

Epoch 00003: val_accuracy improved from 0.60430 to 0.60730, saving model to model_save/model.03-0.61.h5
Epoch 4/290
625/625 - 90s - loss: 1.0449 - accuracy: 0.6300 - val_loss: 1.2896 - val_accuracy: 0.5766

Epoch 00004: val_accuracy did not improve from 0.60730
Epoch 5/290
625/625 - 90s - loss: 0.9683 - accuracy: 0.6579 - val_loss: 1.2816 - val_accuracy: 0.5879

Epoch 00005: val_accuracy did not improve from 0.60730
Epoch 6/290
625/625 - 90s - loss: 0.9013 - accuracy: 0.6816 - val_loss: 0.9602 - val_accuracy: 0.6588

Epoch 00006: val_accuracy improved from 0.60730 to 0.65880, saving model to model_save/model.06-0.66.h5
Epoch 7/290
625/625 - 90s - loss: 0.8584 - accuracy: 0.6979 - val_loss: 1.0211 - val_accuracy: 0.6645

Epoch 00007: val_accuracy improved from 0.65880 to 0.66450, saving model to model_save/model.07-0.66.h5
Epoch 8/290
625/625 - 90s - loss: 0.8151 - accuracy: 0.7135 - val_loss: 1.0139 - val_accuracy: 0.6722

Epoch 00008: val_accuracy improved from 0.66450 to 0.67220, saving model to model_save/model.08-0.67.h5
Epoch 9/290
625/625 - 90s - loss: 0.7867 - accuracy: 0.7271 - val_loss: 0.7766 - val_accuracy: 0.7331

Epoch 00009: val_accuracy improved from 0.67220 to 0.73310, saving model to model_save/model.09-0.73.h5
Epoch 10/290
625/625 - 90s - loss: 0.7572 - accuracy: 0.7342 - val_loss: 1.0114 - val_accuracy: 0.6804

Epoch 00010: val_accuracy did not improve from 0.73310
Epoch 11/290
625/625 - 90s - loss: 0.7291 - accuracy: 0.7469 - val_loss: 0.7166 - val_accuracy: 0.7572

Epoch 00011: val_accuracy improved from 0.73310 to 0.75720, saving model to model_save/model.11-0.76.h5
Epoch 12/290
625/625 - 90s - loss: 0.7089 - accuracy: 0.7522 - val_loss: 0.9279 - val_accuracy: 0.7018

Epoch 00012: val_accuracy did not improve from 0.75720
Epoch 13/290
625/625 - 90s - loss: 0.6885 - accuracy: 0.7627 - val_loss: 0.7383 - val_accuracy: 0.7482

Epoch 00013: val_accuracy did not improve from 0.75720
Epoch 14/290
625/625 - 90s - loss: 0.6658 - accuracy: 0.7692 - val_loss: 0.7143 - val_accuracy: 0.7694
```

```
Epoch 00014: val_accuracy improved from 0.75720 to 0.76940, saving model to model_save/model.14-0.77.h5
Epoch 15/290
625/625 - 90s - loss: 0.6526 - accuracy: 0.7731 - val_loss: 0.8104 - val_accuracy: 0.7394

Epoch 00015: val_accuracy did not improve from 0.76940
Epoch 16/290
625/625 - 90s - loss: 0.6331 - accuracy: 0.7804 - val_loss: 0.7425 - val_accuracy: 0.7559

Epoch 00016: val_accuracy did not improve from 0.76940
Epoch 17/290
625/625 - 90s - loss: 0.6187 - accuracy: 0.7841 - val_loss: 0.7612 - val_accuracy: 0.7503

Epoch 00017: val_accuracy did not improve from 0.76940
Epoch 18/290
625/625 - 90s - loss: 0.6023 - accuracy: 0.7898 - val_loss: 1.0252 - val_accuracy: 0.6853

Epoch 00018: val_accuracy did not improve from 0.76940
Epoch 19/290
625/625 - 90s - loss: 0.5938 - accuracy: 0.7934 - val_loss: 0.7654 - val_accuracy: 0.7487

Epoch 00019: val_accuracy did not improve from 0.76940
Epoch 20/290
625/625 - 90s - loss: 0.5774 - accuracy: 0.7995 - val_loss: 0.5764 - val_accuracy: 0.8007

Epoch 00020: val_accuracy improved from 0.76940 to 0.80070, saving model to model_save/model.20-0.80.h5
Epoch 21/290
625/625 - 90s - loss: 0.5753 - accuracy: 0.8010 - val_loss: 0.6261 - val_accuracy: 0.7900

Epoch 00021: val_accuracy did not improve from 0.80070
Epoch 22/290
625/625 - 90s - loss: 0.5654 - accuracy: 0.8050 - val_loss: 0.6839 - val_accuracy: 0.7832

Epoch 00022: val_accuracy did not improve from 0.80070
Epoch 23/290
625/625 - 90s - loss: 0.5465 - accuracy: 0.8088 - val_loss: 0.8340 - val_accuracy: 0.7350

Epoch 00023: val_accuracy did not improve from 0.80070
Epoch 24/290
625/625 - 90s - loss: 0.5389 - accuracy: 0.8140 - val_loss: 0.7265 - val_accuracy: 0.7730

Epoch 00024: val_accuracy did not improve from 0.80070
Epoch 25/290
625/625 - 90s - loss: 0.5312 - accuracy: 0.8148 - val_loss: 0.6561 - val_accuracy: 0.7854

Epoch 00025: val_accuracy did not improve from 0.80070
Epoch 26/290
625/625 - 90s - loss: 0.5219 - accuracy: 0.8184 - val_loss: 0.5953 - val_accuracy: 0.8056

Epoch 00026: val_accuracy improved from 0.80070 to 0.80560, saving model to model_save/model.26-0.81.h5
Epoch 27/290
625/625 - 90s - loss: 0.5143 - accuracy: 0.8237 - val_loss: 0.5090 - val_accuracy: 0.8281

Epoch 00027: val_accuracy improved from 0.80560 to 0.82810, saving model to model_save/model.27-0.83.h5
Epoch 28/290
625/625 - 90s - loss: 0.5069 - accuracy: 0.8265 - val_loss: 0.5128 - val_accuracy: 0.8283

Epoch 00028: val_accuracy improved from 0.82810 to 0.82830, saving model to model_save/model.28-0.83.h5
Epoch 29/290
625/625 - 90s - loss: 0.5009 - accuracy: 0.8271 - val_loss: 0.5932 - val_accuracy: 0.8070

Epoch 00029: val_accuracy did not improve from 0.82830
Epoch 30/290
625/625 - 90s - loss: 0.4941 - accuracy: 0.8278 - val_loss: 0.7071 - val_accuracy: 0.7750

Epoch 00030: val_accuracy did not improve from 0.82830
Epoch 31/290
625/625 - 90s - loss: 0.4862 - accuracy: 0.8321 - val_loss: 0.5843 - val_accuracy: 0.8073

Epoch 00031: val_accuracy did not improve from 0.82830
Epoch 32/290
625/625 - 90s - loss: 0.4828 - accuracy: 0.8318 - val_loss: 0.5582 - val_accuracy: 0.8155

Epoch 00032: val_accuracy did not improve from 0.82830
Epoch 33/290
625/625 - 90s - loss: 0.4743 - accuracy: 0.8355 - val_loss: 0.4919 - val_accuracy: 0.8354

Epoch 00033: val_accuracy improved from 0.82830 to 0.83540, saving model to model_save/model.33-0.84.h5
Epoch 34/290
625/625 - 90s - loss: 0.4654 - accuracy: 0.8381 - val_loss: 0.5331 - val_accuracy: 0.8222

Epoch 00034: val_accuracy did not improve from 0.83540
Epoch 35/290
```

```
625/625 - 90s - loss: 0.4648 - accuracy: 0.8376 - val_loss: 0.5529 - val_accuracy: 0.8176

Epoch 00035: val_accuracy did not improve from 0.83540
Epoch 36/290
625/625 - 90s - loss: 0.4593 - accuracy: 0.8398 - val_loss: 0.6046 - val_accuracy: 0.8073

Epoch 00036: val_accuracy did not improve from 0.83540
Epoch 37/290
625/625 - 90s - loss: 0.4506 - accuracy: 0.8423 - val_loss: 0.6747 - val_accuracy: 0.7910

Epoch 00037: val_accuracy did not improve from 0.83540
Epoch 38/290
625/625 - 90s - loss: 0.4461 - accuracy: 0.8458 - val_loss: 0.6035 - val_accuracy: 0.8063

Epoch 00038: val_accuracy did not improve from 0.83540
Epoch 39/290
625/625 - 90s - loss: 0.4382 - accuracy: 0.8472 - val_loss: 0.6630 - val_accuracy: 0.7982

Epoch 00039: val_accuracy did not improve from 0.83540
Epoch 40/290
625/625 - 90s - loss: 0.4347 - accuracy: 0.8506 - val_loss: 0.6376 - val_accuracy: 0.7949

Epoch 00040: val_accuracy did not improve from 0.83540
Epoch 41/290
625/625 - 90s - loss: 0.4319 - accuracy: 0.8504 - val_loss: 0.5949 - val_accuracy: 0.8135

Epoch 00041: val_accuracy did not improve from 0.83540
Epoch 42/290
625/625 - 90s - loss: 0.4242 - accuracy: 0.8520 - val_loss: 0.4822 - val_accuracy: 0.8446

Epoch 00042: val_accuracy improved from 0.83540 to 0.84460, saving model to model_save/model.42-0.84.h5
Epoch 43/290
625/625 - 90s - loss: 0.4194 - accuracy: 0.8535 - val_loss: 0.5990 - val_accuracy: 0.8138

Epoch 00043: val_accuracy did not improve from 0.84460
Epoch 44/290
625/625 - 90s - loss: 0.4196 - accuracy: 0.8543 - val_loss: 0.5720 - val_accuracy: 0.8210

Epoch 00044: val_accuracy did not improve from 0.84460
Epoch 45/290
625/625 - 90s - loss: 0.4147 - accuracy: 0.8559 - val_loss: 0.6115 - val_accuracy: 0.8124

Epoch 00045: val_accuracy did not improve from 0.84460
Epoch 46/290
625/625 - 90s - loss: 0.4111 - accuracy: 0.8573 - val_loss: 0.5005 - val_accuracy: 0.8352

Epoch 00046: val_accuracy did not improve from 0.84460
Epoch 47/290
625/625 - 90s - loss: 0.4089 - accuracy: 0.8585 - val_loss: 0.4859 - val_accuracy: 0.8424

Epoch 00047: val_accuracy did not improve from 0.84460
Epoch 48/290
625/625 - 90s - loss: 0.4026 - accuracy: 0.8603 - val_loss: 0.4787 - val_accuracy: 0.8431

Epoch 00048: val_accuracy did not improve from 0.84460
Epoch 49/290
625/625 - 90s - loss: 0.3976 - accuracy: 0.8607 - val_loss: 0.5543 - val_accuracy: 0.8220

Epoch 00049: val_accuracy did not improve from 0.84460
Epoch 50/290
625/625 - 90s - loss: 0.3972 - accuracy: 0.8615 - val_loss: 0.4039 - val_accuracy: 0.8677

Epoch 00050: val_accuracy improved from 0.84460 to 0.86770, saving model to model_save/model.50-0.87.h5
Epoch 51/290
625/625 - 90s - loss: 0.3951 - accuracy: 0.8630 - val_loss: 0.5718 - val_accuracy: 0.8280

Epoch 00051: val_accuracy did not improve from 0.86770
Epoch 52/290
625/625 - 90s - loss: 0.3879 - accuracy: 0.8665 - val_loss: 0.5576 - val_accuracy: 0.8238

Epoch 00052: val_accuracy did not improve from 0.86770
Epoch 53/290
625/625 - 91s - loss: 0.3873 - accuracy: 0.8640 - val_loss: 0.4980 - val_accuracy: 0.8417

Epoch 00053: val_accuracy did not improve from 0.86770
Epoch 54/290
625/625 - 90s - loss: 0.3843 - accuracy: 0.8673 - val_loss: 0.5844 - val_accuracy: 0.8195

Epoch 00054: val_accuracy did not improve from 0.86770
Epoch 55/290
625/625 - 90s - loss: 0.3794 - accuracy: 0.8684 - val_loss: 0.4437 - val_accuracy: 0.8509

Epoch 00055: val_accuracy did not improve from 0.86770
```

```
Epoch 56/290
625/625 - 90s - loss: 0.3758 - accuracy: 0.8677 - val_loss: 0.4522 - val_accuracy: 0.8518

Epoch 00056: val_accuracy did not improve from 0.86770
Epoch 57/290
625/625 - 91s - loss: 0.3753 - accuracy: 0.8699 - val_loss: 0.5008 - val_accuracy: 0.8414

Epoch 00057: val_accuracy did not improve from 0.86770
Epoch 58/290
625/625 - 90s - loss: 0.3685 - accuracy: 0.8715 - val_loss: 0.5257 - val_accuracy: 0.8405

Epoch 00058: val_accuracy did not improve from 0.86770
Epoch 59/290
625/625 - 90s - loss: 0.3690 - accuracy: 0.8715 - val_loss: 0.4251 - val_accuracy: 0.8632

Epoch 00059: val_accuracy did not improve from 0.86770
Epoch 60/290
625/625 - 90s - loss: 0.3639 - accuracy: 0.8728 - val_loss: 0.4269 - val_accuracy: 0.8609

Epoch 00060: val_accuracy did not improve from 0.86770
Epoch 61/290
625/625 - 90s - loss: 0.3675 - accuracy: 0.8719 - val_loss: 0.5408 - val_accuracy: 0.8386

Epoch 00061: val_accuracy did not improve from 0.86770
Epoch 62/290
625/625 - 90s - loss: 0.3646 - accuracy: 0.8718 - val_loss: 0.4885 - val_accuracy: 0.8446

Epoch 00062: val_accuracy did not improve from 0.86770
Epoch 63/290
625/625 - 90s - loss: 0.3596 - accuracy: 0.8749 - val_loss: 0.5281 - val_accuracy: 0.8358

Epoch 00063: val_accuracy did not improve from 0.86770
Epoch 64/290
625/625 - 90s - loss: 0.3560 - accuracy: 0.8759 - val_loss: 0.5361 - val_accuracy: 0.8357

Epoch 00064: val_accuracy did not improve from 0.86770
Epoch 65/290
625/625 - 90s - loss: 0.3570 - accuracy: 0.8755 - val_loss: 0.4819 - val_accuracy: 0.8466

Epoch 00065: val_accuracy did not improve from 0.86770
Epoch 66/290
625/625 - 90s - loss: 0.3523 - accuracy: 0.8790 - val_loss: 0.4427 - val_accuracy: 0.8575

Epoch 00066: val_accuracy did not improve from 0.86770
Epoch 67/290
625/625 - 90s - loss: 0.3480 - accuracy: 0.8776 - val_loss: 0.7439 - val_accuracy: 0.7909

Epoch 00067: val_accuracy did not improve from 0.86770
Epoch 68/290
625/625 - 90s - loss: 0.3468 - accuracy: 0.8785 - val_loss: 0.4550 - val_accuracy: 0.8537

Epoch 00068: val_accuracy did not improve from 0.86770
Epoch 69/290
625/625 - 90s - loss: 0.3476 - accuracy: 0.8782 - val_loss: 0.3971 - val_accuracy: 0.8697

Epoch 00069: val_accuracy improved from 0.86770 to 0.86970, saving model to model_save/model.69-0.87.h5
Epoch 70/290
625/625 - 90s - loss: 0.3449 - accuracy: 0.8798 - val_loss: 0.6429 - val_accuracy: 0.8097

Epoch 00070: val_accuracy did not improve from 0.86970
Epoch 71/290
625/625 - 90s - loss: 0.3407 - accuracy: 0.8810 - val_loss: 0.5555 - val_accuracy: 0.8333

Epoch 00071: val_accuracy did not improve from 0.86970
Epoch 72/290
625/625 - 90s - loss: 0.3378 - accuracy: 0.8828 - val_loss: 0.5790 - val_accuracy: 0.8243

Epoch 00072: val_accuracy did not improve from 0.86970
Epoch 73/290
625/625 - 90s - loss: 0.3398 - accuracy: 0.8816 - val_loss: 0.4610 - val_accuracy: 0.8598

Epoch 00073: val_accuracy did not improve from 0.86970
Epoch 74/290
625/625 - 90s - loss: 0.3340 - accuracy: 0.8822 - val_loss: 0.4717 - val_accuracy: 0.8497

Epoch 00074: val_accuracy did not improve from 0.86970
Epoch 75/290
625/625 - 90s - loss: 0.3322 - accuracy: 0.8841 - val_loss: 0.4729 - val_accuracy: 0.8541

Epoch 00075: val_accuracy did not improve from 0.86970
Epoch 76/290
625/625 - 90s - loss: 0.3350 - accuracy: 0.8830 - val_loss: 0.4004 - val_accuracy: 0.8675
```

```
Epoch 00076: val_accuracy did not improve from 0.86970
Epoch 77/290
625/625 - 90s - loss: 0.3291 - accuracy: 0.8858 - val_loss: 0.4537 - val_accuracy: 0.8591

Epoch 00077: val_accuracy did not improve from 0.86970
Epoch 78/290
625/625 - 90s - loss: 0.3254 - accuracy: 0.8848 - val_loss: 0.3759 - val_accuracy: 0.8800

Epoch 00078: val_accuracy improved from 0.86970 to 0.88000, saving model to model_save/model.78-0.88.h5
Epoch 79/290
625/625 - 90s - loss: 0.3239 - accuracy: 0.8864 - val_loss: 0.4679 - val_accuracy: 0.8512

Epoch 00079: val_accuracy did not improve from 0.88000
Epoch 80/290
625/625 - 90s - loss: 0.3210 - accuracy: 0.8882 - val_loss: 0.4323 - val_accuracy: 0.8541

Epoch 00080: val_accuracy did not improve from 0.88000
Epoch 81/290
625/625 - 90s - loss: 0.3203 - accuracy: 0.8877 - val_loss: 0.4501 - val_accuracy: 0.8626

Epoch 00081: val_accuracy did not improve from 0.88000
Epoch 82/290
625/625 - 90s - loss: 0.3209 - accuracy: 0.8880 - val_loss: 0.4531 - val_accuracy: 0.8591

Epoch 00082: val_accuracy did not improve from 0.88000
Epoch 83/290
625/625 - 90s - loss: 0.3211 - accuracy: 0.8874 - val_loss: 0.4427 - val_accuracy: 0.8605

Epoch 00083: val_accuracy did not improve from 0.88000
Epoch 84/290
625/625 - 90s - loss: 0.3155 - accuracy: 0.8898 - val_loss: 0.4655 - val_accuracy: 0.8548

Epoch 00084: val_accuracy did not improve from 0.88000
Epoch 85/290
625/625 - 90s - loss: 0.3164 - accuracy: 0.8896 - val_loss: 0.4518 - val_accuracy: 0.8623

Epoch 00085: val_accuracy did not improve from 0.88000
Epoch 86/290
625/625 - 90s - loss: 0.3155 - accuracy: 0.8885 - val_loss: 0.6026 - val_accuracy: 0.8218

Epoch 00086: val_accuracy did not improve from 0.88000
Epoch 87/290
625/625 - 90s - loss: 0.3107 - accuracy: 0.8912 - val_loss: 0.4216 - val_accuracy: 0.8642

Epoch 00087: val_accuracy did not improve from 0.88000
Epoch 88/290
625/625 - 90s - loss: 0.3147 - accuracy: 0.8906 - val_loss: 0.4322 - val_accuracy: 0.8671

Epoch 00088: val_accuracy did not improve from 0.88000
Epoch 89/290
625/625 - 90s - loss: 0.3045 - accuracy: 0.8927 - val_loss: 0.4062 - val_accuracy: 0.8714

Epoch 00089: val_accuracy did not improve from 0.88000
Epoch 90/290
625/625 - 90s - loss: 0.3072 - accuracy: 0.8920 - val_loss: 0.4192 - val_accuracy: 0.8674

Epoch 00090: val_accuracy did not improve from 0.88000
Epoch 91/290
625/625 - 90s - loss: 0.3061 - accuracy: 0.8929 - val_loss: 0.5025 - val_accuracy: 0.8430

Epoch 00091: val_accuracy did not improve from 0.88000
Epoch 92/290
625/625 - 90s - loss: 0.3010 - accuracy: 0.8949 - val_loss: 0.5485 - val_accuracy: 0.8366

Epoch 00092: val_accuracy did not improve from 0.88000
Epoch 93/290
625/625 - 90s - loss: 0.3017 - accuracy: 0.8945 - val_loss: 0.4579 - val_accuracy: 0.8578

Epoch 00093: val_accuracy did not improve from 0.88000
Epoch 94/290
625/625 - 90s - loss: 0.3034 - accuracy: 0.8927 - val_loss: 0.4880 - val_accuracy: 0.8500

Epoch 00094: val_accuracy did not improve from 0.88000
Epoch 95/290
625/625 - 90s - loss: 0.3027 - accuracy: 0.8941 - val_loss: 0.4293 - val_accuracy: 0.8675

Epoch 00095: val_accuracy did not improve from 0.88000
Epoch 96/290
625/625 - 90s - loss: 0.2996 - accuracy: 0.8948 - val_loss: 0.5190 - val_accuracy: 0.8457

Epoch 00096: val_accuracy did not improve from 0.88000
Epoch 97/290
625/625 - 90s - loss: 0.3017 - accuracy: 0.8944 - val_loss: 0.4637 - val_accuracy: 0.8598
```

```
Epoch 00097: val_accuracy did not improve from 0.88000
Epoch 98/290
625/625 - 90s - loss: 0.2974 - accuracy: 0.8970 - val_loss: 0.4022 - val_accuracy: 0.8723

Epoch 00098: val_accuracy did not improve from 0.88000
Epoch 99/290
625/625 - 90s - loss: 0.2925 - accuracy: 0.8981 - val_loss: 0.4327 - val_accuracy: 0.8643

Epoch 00099: val_accuracy did not improve from 0.88000
Epoch 100/290
625/625 - 90s - loss: 0.2951 - accuracy: 0.8968 - val_loss: 0.4278 - val_accuracy: 0.8640

Epoch 00100: val_accuracy did not improve from 0.88000
Epoch 101/290
625/625 - 90s - loss: 0.2961 - accuracy: 0.8970 - val_loss: 0.4546 - val_accuracy: 0.8584

Epoch 00101: val_accuracy did not improve from 0.88000
Epoch 102/290
625/625 - 90s - loss: 0.2920 - accuracy: 0.8982 - val_loss: 0.4640 - val_accuracy: 0.8590

Epoch 00102: val_accuracy did not improve from 0.88000
Epoch 103/290
625/625 - 90s - loss: 0.2931 - accuracy: 0.8981 - val_loss: 0.4099 - val_accuracy: 0.8723

Epoch 00103: val_accuracy did not improve from 0.88000
Epoch 104/290
625/625 - 90s - loss: 0.2918 - accuracy: 0.8978 - val_loss: 0.4595 - val_accuracy: 0.8577

Epoch 00104: val_accuracy did not improve from 0.88000
Epoch 105/290
625/625 - 90s - loss: 0.2905 - accuracy: 0.8982 - val_loss: 0.4215 - val_accuracy: 0.8694

Epoch 00105: val_accuracy did not improve from 0.88000
Epoch 106/290
625/625 - 90s - loss: 0.2875 - accuracy: 0.9002 - val_loss: 0.5805 - val_accuracy: 0.8230

Epoch 00106: val_accuracy did not improve from 0.88000
Epoch 107/290
625/625 - 90s - loss: 0.2871 - accuracy: 0.8997 - val_loss: 0.4203 - val_accuracy: 0.8705

Epoch 00107: val_accuracy did not improve from 0.88000
Epoch 108/290
625/625 - 90s - loss: 0.2866 - accuracy: 0.8994 - val_loss: 0.4756 - val_accuracy: 0.8521

Epoch 00108: val_accuracy did not improve from 0.88000
Epoch 109/290
625/625 - 90s - loss: 0.2817 - accuracy: 0.9014 - val_loss: 0.5549 - val_accuracy: 0.8376

Epoch 00109: val_accuracy did not improve from 0.88000
Epoch 110/290
625/625 - 90s - loss: 0.2819 - accuracy: 0.9011 - val_loss: 0.4355 - val_accuracy: 0.8687

Epoch 00110: val_accuracy did not improve from 0.88000
Epoch 111/290
625/625 - 90s - loss: 0.2827 - accuracy: 0.9001 - val_loss: 0.4328 - val_accuracy: 0.8682

Epoch 00111: val_accuracy did not improve from 0.88000
Epoch 112/290
625/625 - 90s - loss: 0.2795 - accuracy: 0.9018 - val_loss: 0.3954 - val_accuracy: 0.8794

Epoch 00112: val_accuracy did not improve from 0.88000
Epoch 113/290
625/625 - 90s - loss: 0.2802 - accuracy: 0.9025 - val_loss: 0.4479 - val_accuracy: 0.8650

Epoch 00113: val_accuracy did not improve from 0.88000
Epoch 114/290
625/625 - 90s - loss: 0.2786 - accuracy: 0.9025 - val_loss: 0.4433 - val_accuracy: 0.8616

Epoch 00114: val_accuracy did not improve from 0.88000
Epoch 115/290
625/625 - 90s - loss: 0.2781 - accuracy: 0.9034 - val_loss: 0.4270 - val_accuracy: 0.8731

Epoch 00115: val_accuracy did not improve from 0.88000
Epoch 116/290
625/625 - 90s - loss: 0.2782 - accuracy: 0.9019 - val_loss: 0.4070 - val_accuracy: 0.8753

Epoch 00116: val_accuracy did not improve from 0.88000
Epoch 117/290
625/625 - 90s - loss: 0.2736 - accuracy: 0.9053 - val_loss: 0.4020 - val_accuracy: 0.8789

Epoch 00117: val_accuracy did not improve from 0.88000
Epoch 118/290
```

```
625/625 - 90s - loss: 0.2749 - accuracy: 0.9035 - val_loss: 0.3982 - val_accuracy: 0.8810

Epoch 00118: val_accuracy improved from 0.88000 to 0.88100, saving model to model_save/model.118-0.88.h5
Epoch 119/290
625/625 - 90s - loss: 0.2724 - accuracy: 0.9045 - val_loss: 0.4856 - val_accuracy: 0.8579

Epoch 00119: val_accuracy did not improve from 0.88100
Epoch 120/290
625/625 - 90s - loss: 0.2728 - accuracy: 0.9048 - val_loss: 0.4635 - val_accuracy: 0.8598

Epoch 00120: val_accuracy did not improve from 0.88100
Epoch 121/290
625/625 - 90s - loss: 0.2720 - accuracy: 0.9062 - val_loss: 0.5829 - val_accuracy: 0.8365

Epoch 00121: val_accuracy did not improve from 0.88100
Epoch 122/290
625/625 - 90s - loss: 0.2677 - accuracy: 0.9062 - val_loss: 0.4438 - val_accuracy: 0.8696

Epoch 00122: val_accuracy did not improve from 0.88100
Epoch 123/290
625/625 - 90s - loss: 0.2709 - accuracy: 0.9047 - val_loss: 0.5454 - val_accuracy: 0.8463

Epoch 00123: val_accuracy did not improve from 0.88100
Epoch 124/290
625/625 - 90s - loss: 0.2661 - accuracy: 0.9067 - val_loss: 0.4627 - val_accuracy: 0.8654

Epoch 00124: val_accuracy did not improve from 0.88100
Epoch 125/290
625/625 - 90s - loss: 0.2700 - accuracy: 0.9052 - val_loss: 0.4699 - val_accuracy: 0.8619

Epoch 00125: val_accuracy did not improve from 0.88100
Epoch 126/290
625/625 - 90s - loss: 0.2716 - accuracy: 0.9044 - val_loss: 0.4305 - val_accuracy: 0.8672

Epoch 00126: val_accuracy did not improve from 0.88100
Epoch 127/290
625/625 - 90s - loss: 0.2686 - accuracy: 0.9069 - val_loss: 0.4978 - val_accuracy: 0.8586

Epoch 00127: val_accuracy did not improve from 0.88100
Epoch 128/290
625/625 - 90s - loss: 0.2670 - accuracy: 0.9077 - val_loss: 0.5228 - val_accuracy: 0.8494

Epoch 00128: val_accuracy did not improve from 0.88100
Epoch 129/290
625/625 - 90s - loss: 0.2685 - accuracy: 0.9058 - val_loss: 0.4388 - val_accuracy: 0.8652

Epoch 00129: val_accuracy did not improve from 0.88100
Epoch 130/290
625/625 - 90s - loss: 0.2711 - accuracy: 0.9046 - val_loss: 0.5047 - val_accuracy: 0.8501

Epoch 00130: val_accuracy did not improve from 0.88100
Epoch 131/290
625/625 - 90s - loss: 0.2634 - accuracy: 0.9069 - val_loss: 0.4256 - val_accuracy: 0.8695

Epoch 00131: val_accuracy did not improve from 0.88100
Epoch 132/290
625/625 - 90s - loss: 0.2637 - accuracy: 0.9072 - val_loss: 0.4704 - val_accuracy: 0.8623

Epoch 00132: val_accuracy did not improve from 0.88100
Epoch 133/290
625/625 - 90s - loss: 0.2603 - accuracy: 0.9082 - val_loss: 0.4313 - val_accuracy: 0.8638

Epoch 00133: val_accuracy did not improve from 0.88100
Epoch 134/290
625/625 - 90s - loss: 0.2634 - accuracy: 0.9084 - val_loss: 0.3886 - val_accuracy: 0.8829

Epoch 00134: val_accuracy improved from 0.88100 to 0.88290, saving model to model_save/model.134-0.88.h5
Epoch 135/290
625/625 - 90s - loss: 0.2610 - accuracy: 0.9077 - val_loss: 0.4334 - val_accuracy: 0.8702

Epoch 00135: val_accuracy did not improve from 0.88290
Epoch 136/290
625/625 - 90s - loss: 0.2612 - accuracy: 0.9076 - val_loss: 0.4101 - val_accuracy: 0.8764

Epoch 00136: val_accuracy did not improve from 0.88290
Epoch 137/290
625/625 - 90s - loss: 0.2580 - accuracy: 0.9091 - val_loss: 0.5500 - val_accuracy: 0.8406

Epoch 00137: val_accuracy did not improve from 0.88290
Epoch 138/290
625/625 - 90s - loss: 0.2567 - accuracy: 0.9104 - val_loss: 0.4613 - val_accuracy: 0.8598

Epoch 00138: val_accuracy did not improve from 0.88290
```

```
Epoch 139/290
625/625 - 90s - loss: 0.2546 - accuracy: 0.9105 - val_loss: 0.3918 - val_accuracy: 0.8820

Epoch 00139: val_accuracy did not improve from 0.88290
Epoch 140/290
625/625 - 90s - loss: 0.2573 - accuracy: 0.9098 - val_loss: 0.3694 - val_accuracy: 0.8856

Epoch 00140: val_accuracy improved from 0.88290 to 0.88560, saving model to model_save/model.140-0.89.h5
Epoch 141/290
625/625 - 90s - loss: 0.2533 - accuracy: 0.9115 - val_loss: 0.4440 - val_accuracy: 0.8663

Epoch 00141: val_accuracy did not improve from 0.88560
Epoch 142/290
625/625 - 90s - loss: 0.2553 - accuracy: 0.9093 - val_loss: 0.4508 - val_accuracy: 0.8606

Epoch 00142: val_accuracy did not improve from 0.88560
Epoch 143/290
625/625 - 90s - loss: 0.2509 - accuracy: 0.9117 - val_loss: 0.3664 - val_accuracy: 0.8851

Epoch 00143: val_accuracy did not improve from 0.88560
Epoch 144/290
625/625 - 90s - loss: 0.2528 - accuracy: 0.9118 - val_loss: 0.3926 - val_accuracy: 0.8784

Epoch 00144: val_accuracy did not improve from 0.88560
Epoch 145/290
625/625 - 90s - loss: 0.2505 - accuracy: 0.9116 - val_loss: 0.4439 - val_accuracy: 0.8660

Epoch 00145: val_accuracy did not improve from 0.88560
Epoch 146/290
625/625 - 90s - loss: 0.2485 - accuracy: 0.9126 - val_loss: 0.4395 - val_accuracy: 0.8709

Epoch 00146: val_accuracy did not improve from 0.88560
Epoch 147/290
625/625 - 90s - loss: 0.2528 - accuracy: 0.9119 - val_loss: 0.4918 - val_accuracy: 0.8628

Epoch 00147: val_accuracy did not improve from 0.88560
Epoch 148/290
625/625 - 90s - loss: 0.2523 - accuracy: 0.9108 - val_loss: 0.5320 - val_accuracy: 0.8498

Epoch 00148: val_accuracy did not improve from 0.88560
Epoch 149/290
625/625 - 90s - loss: 0.2472 - accuracy: 0.9118 - val_loss: 0.4001 - val_accuracy: 0.8744

Epoch 00149: val_accuracy did not improve from 0.88560
Epoch 150/290
625/625 - 90s - loss: 0.2426 - accuracy: 0.9146 - val_loss: 0.3773 - val_accuracy: 0.8832

Epoch 00150: val_accuracy did not improve from 0.88560
Epoch 151/290
625/625 - 90s - loss: 0.2503 - accuracy: 0.9134 - val_loss: 0.3812 - val_accuracy: 0.8844

Epoch 00151: val_accuracy did not improve from 0.88560
Epoch 152/290
625/625 - 90s - loss: 0.2506 - accuracy: 0.9120 - val_loss: 0.3948 - val_accuracy: 0.8794

Epoch 00152: val_accuracy did not improve from 0.88560
Epoch 153/290
625/625 - 90s - loss: 0.2466 - accuracy: 0.9140 - val_loss: 0.4638 - val_accuracy: 0.8627

Epoch 00153: val_accuracy did not improve from 0.88560
Epoch 154/290
625/625 - 90s - loss: 0.2456 - accuracy: 0.9138 - val_loss: 0.3956 - val_accuracy: 0.8780

Epoch 00154: val_accuracy did not improve from 0.88560
Epoch 155/290
625/625 - 90s - loss: 0.2514 - accuracy: 0.9118 - val_loss: 0.3943 - val_accuracy: 0.8807

Epoch 00155: val_accuracy did not improve from 0.88560
Epoch 156/290
625/625 - 90s - loss: 0.2440 - accuracy: 0.9132 - val_loss: 0.5945 - val_accuracy: 0.8384

Epoch 00156: val_accuracy did not improve from 0.88560
Epoch 157/290
625/625 - 90s - loss: 0.2432 - accuracy: 0.9153 - val_loss: 0.3629 - val_accuracy: 0.8908

Epoch 00157: val_accuracy improved from 0.88560 to 0.89080, saving model to model_save/model.157-0.89.h5
Epoch 158/290
625/625 - 90s - loss: 0.2401 - accuracy: 0.9144 - val_loss: 0.3554 - val_accuracy: 0.8903

Epoch 00158: val_accuracy did not improve from 0.89080
Epoch 159/290
625/625 - 90s - loss: 0.2427 - accuracy: 0.9151 - val_loss: 0.4189 - val_accuracy: 0.8749
```

```
Epoch 00159: val_accuracy did not improve from 0.89080
Epoch 160/290
625/625 - 90s - loss: 0.2412 - accuracy: 0.9142 - val_loss: 0.4080 - val_accuracy: 0.8783

Epoch 00160: val_accuracy did not improve from 0.89080
Epoch 161/290
625/625 - 91s - loss: 0.2415 - accuracy: 0.9152 - val_loss: 0.3768 - val_accuracy: 0.8858

Epoch 00161: val_accuracy did not improve from 0.89080
Epoch 162/290
625/625 - 90s - loss: 0.2380 - accuracy: 0.9163 - val_loss: 0.4709 - val_accuracy: 0.8641

Epoch 00162: val_accuracy did not improve from 0.89080
Epoch 163/290
625/625 - 90s - loss: 0.2383 - accuracy: 0.9150 - val_loss: 0.4279 - val_accuracy: 0.8683

Epoch 00163: val_accuracy did not improve from 0.89080
Epoch 164/290
625/625 - 90s - loss: 0.2362 - accuracy: 0.9164 - val_loss: 0.4025 - val_accuracy: 0.8805

Epoch 00164: val_accuracy did not improve from 0.89080
Epoch 165/290
625/625 - 90s - loss: 0.2381 - accuracy: 0.9160 - val_loss: 0.6009 - val_accuracy: 0.8393

Epoch 00165: val_accuracy did not improve from 0.89080
Epoch 166/290
625/625 - 90s - loss: 0.2354 - accuracy: 0.9173 - val_loss: 0.3910 - val_accuracy: 0.8813

Epoch 00166: val_accuracy did not improve from 0.89080
Epoch 167/290
625/625 - 90s - loss: 0.2364 - accuracy: 0.9162 - val_loss: 0.4293 - val_accuracy: 0.8723

Epoch 00167: val_accuracy did not improve from 0.89080
Epoch 168/290
625/625 - 90s - loss: 0.2309 - accuracy: 0.9186 - val_loss: 0.4583 - val_accuracy: 0.8691

Epoch 00168: val_accuracy did not improve from 0.89080
Epoch 169/290
625/625 - 90s - loss: 0.2345 - accuracy: 0.9175 - val_loss: 0.4198 - val_accuracy: 0.8740

Epoch 00169: val_accuracy did not improve from 0.89080
Epoch 170/290
625/625 - 90s - loss: 0.2368 - accuracy: 0.9171 - val_loss: 0.3989 - val_accuracy: 0.8796

Epoch 00170: val_accuracy did not improve from 0.89080
Epoch 171/290
625/625 - 90s - loss: 0.2335 - accuracy: 0.9175 - val_loss: 0.3444 - val_accuracy: 0.8935

Epoch 00171: val_accuracy improved from 0.89080 to 0.89350, saving model to model_save/model.171-0.89.h5
Epoch 172/290
625/625 - 90s - loss: 0.2334 - accuracy: 0.9174 - val_loss: 0.5238 - val_accuracy: 0.8517

Epoch 00172: val_accuracy did not improve from 0.89350
Epoch 173/290
625/625 - 90s - loss: 0.2341 - accuracy: 0.9169 - val_loss: 0.4009 - val_accuracy: 0.8859

Epoch 00173: val_accuracy did not improve from 0.89350
Epoch 174/290
625/625 - 90s - loss: 0.2330 - accuracy: 0.9174 - val_loss: 0.4056 - val_accuracy: 0.8791

Epoch 00174: val_accuracy did not improve from 0.89350
Epoch 175/290
625/625 - 90s - loss: 0.2299 - accuracy: 0.9180 - val_loss: 0.4798 - val_accuracy: 0.8674

Epoch 00175: val_accuracy did not improve from 0.89350
Epoch 176/290
625/625 - 90s - loss: 0.2345 - accuracy: 0.9179 - val_loss: 0.4558 - val_accuracy: 0.8674

Epoch 00176: val_accuracy did not improve from 0.89350
Epoch 177/290
625/625 - 90s - loss: 0.2318 - accuracy: 0.9190 - val_loss: 0.4007 - val_accuracy: 0.8777

Epoch 00177: val_accuracy did not improve from 0.89350
Epoch 178/290
625/625 - 90s - loss: 0.2297 - accuracy: 0.9197 - val_loss: 0.4196 - val_accuracy: 0.8759

Epoch 00178: val_accuracy did not improve from 0.89350
Epoch 179/290
625/625 - 90s - loss: 0.2291 - accuracy: 0.9182 - val_loss: 0.4249 - val_accuracy: 0.8784

Epoch 00179: val_accuracy did not improve from 0.89350
Epoch 180/290
625/625 - 90s - loss: 0.2317 - accuracy: 0.9191 - val_loss: 0.4473 - val_accuracy: 0.8663
```

```
Epoch 00180: val_accuracy did not improve from 0.89350
Epoch 181/290
625/625 - 90s - loss: 0.2321 - accuracy: 0.9175 - val_loss: 0.4762 - val_accuracy: 0.8671

Epoch 00181: val_accuracy did not improve from 0.89350
Epoch 182/290
625/625 - 90s - loss: 0.2266 - accuracy: 0.9200 - val_loss: 0.4843 - val_accuracy: 0.8623

Epoch 00182: val_accuracy did not improve from 0.89350
Epoch 183/290
625/625 - 90s - loss: 0.2258 - accuracy: 0.9184 - val_loss: 0.3971 - val_accuracy: 0.8811

Epoch 00183: val_accuracy did not improve from 0.89350
Epoch 184/290
625/625 - 90s - loss: 0.2289 - accuracy: 0.9192 - val_loss: 0.4278 - val_accuracy: 0.8708

Epoch 00184: val_accuracy did not improve from 0.89350
Epoch 185/290
625/625 - 90s - loss: 0.2267 - accuracy: 0.9195 - val_loss: 0.3771 - val_accuracy: 0.8875

Epoch 00185: val_accuracy did not improve from 0.89350
Epoch 186/290
625/625 - 90s - loss: 0.2268 - accuracy: 0.9212 - val_loss: 0.4669 - val_accuracy: 0.8689

Epoch 00186: val_accuracy did not improve from 0.89350
Epoch 187/290
625/625 - 90s - loss: 0.2231 - accuracy: 0.9207 - val_loss: 0.3935 - val_accuracy: 0.8799

Epoch 00187: val_accuracy did not improve from 0.89350
Epoch 188/290
625/625 - 90s - loss: 0.2269 - accuracy: 0.9202 - val_loss: 0.4369 - val_accuracy: 0.8770

Epoch 00188: val_accuracy did not improve from 0.89350
Epoch 189/290
625/625 - 90s - loss: 0.2244 - accuracy: 0.9210 - val_loss: 0.4749 - val_accuracy: 0.8690

Epoch 00189: val_accuracy did not improve from 0.89350
Epoch 190/290
625/625 - 90s - loss: 0.2195 - accuracy: 0.9222 - val_loss: 0.4136 - val_accuracy: 0.8786

Epoch 00190: val_accuracy did not improve from 0.89350
Epoch 191/290
625/625 - 90s - loss: 0.2228 - accuracy: 0.9199 - val_loss: 0.4015 - val_accuracy: 0.8845

Epoch 00191: val_accuracy did not improve from 0.89350
Epoch 192/290
625/625 - 90s - loss: 0.2200 - accuracy: 0.9222 - val_loss: 0.4104 - val_accuracy: 0.8817

Epoch 00192: val_accuracy did not improve from 0.89350
Epoch 193/290
625/625 - 90s - loss: 0.2264 - accuracy: 0.9197 - val_loss: 0.3814 - val_accuracy: 0.8872

Epoch 00193: val_accuracy did not improve from 0.89350
Epoch 194/290
625/625 - 90s - loss: 0.2193 - accuracy: 0.9221 - val_loss: 0.4355 - val_accuracy: 0.8727

Epoch 00194: val_accuracy did not improve from 0.89350
Epoch 195/290
625/625 - 90s - loss: 0.2217 - accuracy: 0.9214 - val_loss: 0.4049 - val_accuracy: 0.8797

Epoch 00195: val_accuracy did not improve from 0.89350
Epoch 196/290
625/625 - 90s - loss: 0.2164 - accuracy: 0.9239 - val_loss: 0.4453 - val_accuracy: 0.8682

Epoch 00196: val_accuracy did not improve from 0.89350
Epoch 197/290
625/625 - 90s - loss: 0.2186 - accuracy: 0.9233 - val_loss: 0.5055 - val_accuracy: 0.8547

Epoch 00197: val_accuracy did not improve from 0.89350
Epoch 198/290
625/625 - 90s - loss: 0.2213 - accuracy: 0.9220 - val_loss: 0.3710 - val_accuracy: 0.8895

Epoch 00198: val_accuracy did not improve from 0.89350
Epoch 199/290
625/625 - 90s - loss: 0.2166 - accuracy: 0.9239 - val_loss: 0.3645 - val_accuracy: 0.8883

Epoch 00199: val_accuracy did not improve from 0.89350
Epoch 200/290
625/625 - 90s - loss: 0.2234 - accuracy: 0.9203 - val_loss: 0.4414 - val_accuracy: 0.8823

Epoch 00200: val_accuracy did not improve from 0.89350
Epoch 201/290
```

```
625/625 - 90s - loss: 0.2209 - accuracy: 0.9214 - val_loss: 0.4230 - val_accuracy: 0.8730

Epoch 00201: val_accuracy did not improve from 0.89350
Epoch 202/290
625/625 - 90s - loss: 0.2140 - accuracy: 0.9249 - val_loss: 0.3635 - val_accuracy: 0.8891

Epoch 00202: val_accuracy did not improve from 0.89350
Epoch 203/290
625/625 - 90s - loss: 0.2191 - accuracy: 0.9232 - val_loss: 0.4134 - val_accuracy: 0.8810

Epoch 00203: val_accuracy did not improve from 0.89350
Epoch 204/290
625/625 - 90s - loss: 0.2158 - accuracy: 0.9236 - val_loss: 0.4417 - val_accuracy: 0.8750

Epoch 00204: val_accuracy did not improve from 0.89350
Epoch 205/290
625/625 - 90s - loss: 0.2149 - accuracy: 0.9245 - val_loss: 0.4059 - val_accuracy: 0.8818

Epoch 00205: val_accuracy did not improve from 0.89350
Epoch 206/290
625/625 - 90s - loss: 0.2151 - accuracy: 0.9236 - val_loss: 0.4497 - val_accuracy: 0.8720

Epoch 00206: val_accuracy did not improve from 0.89350
Epoch 207/290
625/625 - 90s - loss: 0.2163 - accuracy: 0.9233 - val_loss: 0.4182 - val_accuracy: 0.8808

Epoch 00207: val_accuracy did not improve from 0.89350
Epoch 208/290
625/625 - 90s - loss: 0.2194 - accuracy: 0.9227 - val_loss: 0.3852 - val_accuracy: 0.8836

Epoch 00208: val_accuracy did not improve from 0.89350
Epoch 209/290
625/625 - 90s - loss: 0.2149 - accuracy: 0.9242 - val_loss: 0.3950 - val_accuracy: 0.8862

Epoch 00209: val_accuracy did not improve from 0.89350
Epoch 210/290
625/625 - 90s - loss: 0.2141 - accuracy: 0.9256 - val_loss: 0.4155 - val_accuracy: 0.8798

Epoch 00210: val_accuracy did not improve from 0.89350
Epoch 211/290
625/625 - 90s - loss: 0.2128 - accuracy: 0.9248 - val_loss: 0.4335 - val_accuracy: 0.8796

Epoch 00211: val_accuracy did not improve from 0.89350
Epoch 212/290
625/625 - 90s - loss: 0.2136 - accuracy: 0.9245 - val_loss: 0.4235 - val_accuracy: 0.8770

Epoch 00212: val_accuracy did not improve from 0.89350
Epoch 213/290
625/625 - 90s - loss: 0.2139 - accuracy: 0.9238 - val_loss: 0.4227 - val_accuracy: 0.8787

Epoch 00213: val_accuracy did not improve from 0.89350
Epoch 214/290
625/625 - 90s - loss: 0.2064 - accuracy: 0.9258 - val_loss: 0.5286 - val_accuracy: 0.8640

Epoch 00214: val_accuracy did not improve from 0.89350
Epoch 215/290
625/625 - 90s - loss: 0.2171 - accuracy: 0.9226 - val_loss: 0.4308 - val_accuracy: 0.8777

Epoch 00215: val_accuracy did not improve from 0.89350
Epoch 216/290
625/625 - 90s - loss: 0.2144 - accuracy: 0.9256 - val_loss: 0.4046 - val_accuracy: 0.8799

Epoch 00216: val_accuracy did not improve from 0.89350
Epoch 217/290
625/625 - 90s - loss: 0.2062 - accuracy: 0.9264 - val_loss: 0.4948 - val_accuracy: 0.8620

Epoch 00217: val_accuracy did not improve from 0.89350
Epoch 218/290
625/625 - 90s - loss: 0.2114 - accuracy: 0.9260 - val_loss: 0.3763 - val_accuracy: 0.8904

Epoch 00218: val_accuracy did not improve from 0.89350
Epoch 219/290
625/625 - 90s - loss: 0.2140 - accuracy: 0.9250 - val_loss: 0.4215 - val_accuracy: 0.8788

Epoch 00219: val_accuracy did not improve from 0.89350
Epoch 220/290
625/625 - 90s - loss: 0.2069 - accuracy: 0.9268 - val_loss: 0.4246 - val_accuracy: 0.8782

Epoch 00220: val_accuracy did not improve from 0.89350
Epoch 221/290
625/625 - 90s - loss: 0.2107 - accuracy: 0.9260 - val_loss: 0.4329 - val_accuracy: 0.8764

Epoch 00221: val_accuracy did not improve from 0.89350
```

```
Epoch 222/290
625/625 - 90s - loss: 0.2126 - accuracy: 0.9257 - val_loss: 0.4660 - val_accuracy: 0.8662

Epoch 00222: val_accuracy did not improve from 0.89350
Epoch 223/290
625/625 - 90s - loss: 0.2080 - accuracy: 0.9261 - val_loss: 0.4169 - val_accuracy: 0.8797

Epoch 00223: val_accuracy did not improve from 0.89350
Epoch 224/290
625/625 - 90s - loss: 0.2060 - accuracy: 0.9262 - val_loss: 0.4067 - val_accuracy: 0.8837

Epoch 00224: val_accuracy did not improve from 0.89350
Epoch 225/290
625/625 - 90s - loss: 0.2123 - accuracy: 0.9247 - val_loss: 0.4236 - val_accuracy: 0.8778

Epoch 00225: val_accuracy did not improve from 0.89350
Epoch 226/290
625/625 - 91s - loss: 0.2043 - accuracy: 0.9276 - val_loss: 0.4457 - val_accuracy: 0.8753

Epoch 00226: val_accuracy did not improve from 0.89350
Epoch 227/290
625/625 - 90s - loss: 0.2077 - accuracy: 0.9259 - val_loss: 0.4146 - val_accuracy: 0.8824

Epoch 00227: val_accuracy did not improve from 0.89350
Epoch 228/290
625/625 - 90s - loss: 0.2064 - accuracy: 0.9265 - val_loss: 0.3803 - val_accuracy: 0.8912

Epoch 00228: val_accuracy did not improve from 0.89350
Epoch 229/290
625/625 - 90s - loss: 0.2078 - accuracy: 0.9272 - val_loss: 0.4160 - val_accuracy: 0.8783

Epoch 00229: val_accuracy did not improve from 0.89350
Epoch 230/290
625/625 - 90s - loss: 0.2058 - accuracy: 0.9275 - val_loss: 0.4511 - val_accuracy: 0.8760

Epoch 00230: val_accuracy did not improve from 0.89350
Epoch 231/290
625/625 - 90s - loss: 0.2100 - accuracy: 0.9259 - val_loss: 0.4012 - val_accuracy: 0.8798

Epoch 00231: val_accuracy did not improve from 0.89350
Epoch 232/290
625/625 - 90s - loss: 0.2047 - accuracy: 0.9278 - val_loss: 0.5271 - val_accuracy: 0.8554

Epoch 00232: val_accuracy did not improve from 0.89350
Epoch 233/290
625/625 - 90s - loss: 0.2022 - accuracy: 0.9272 - val_loss: 0.3857 - val_accuracy: 0.8898

Epoch 00233: val_accuracy did not improve from 0.89350
Epoch 234/290
625/625 - 90s - loss: 0.2046 - accuracy: 0.9273 - val_loss: 0.4003 - val_accuracy: 0.8825

Epoch 00234: val_accuracy did not improve from 0.89350
Epoch 235/290
625/625 - 90s - loss: 0.2050 - accuracy: 0.9276 - val_loss: 0.5114 - val_accuracy: 0.8616

Epoch 00235: val_accuracy did not improve from 0.89350
Epoch 236/290
625/625 - 90s - loss: 0.2050 - accuracy: 0.9275 - val_loss: 0.3790 - val_accuracy: 0.8914

Epoch 00236: val_accuracy did not improve from 0.89350
Epoch 237/290
625/625 - 90s - loss: 0.2051 - accuracy: 0.9270 - val_loss: 0.4041 - val_accuracy: 0.8806

Epoch 00237: val_accuracy did not improve from 0.89350
Epoch 238/290
625/625 - 90s - loss: 0.2029 - accuracy: 0.9287 - val_loss: 0.4445 - val_accuracy: 0.8772

Epoch 00238: val_accuracy did not improve from 0.89350
Epoch 239/290
625/625 - 91s - loss: 0.2022 - accuracy: 0.9283 - val_loss: 0.5227 - val_accuracy: 0.8590

Epoch 00239: val_accuracy did not improve from 0.89350
Epoch 240/290
625/625 - 90s - loss: 0.2056 - accuracy: 0.9272 - val_loss: 0.4216 - val_accuracy: 0.8768

Epoch 00240: val_accuracy did not improve from 0.89350
Epoch 241/290
625/625 - 90s - loss: 0.1995 - accuracy: 0.9295 - val_loss: 0.3670 - val_accuracy: 0.8939

Epoch 00241: val_accuracy improved from 0.89350 to 0.89390, saving model to model_save/model.241-0.89.h5
Epoch 242/290
625/625 - 90s - loss: 0.1993 - accuracy: 0.9298 - val_loss: 0.4232 - val_accuracy: 0.8793
```

```
Epoch 00242: val_accuracy did not improve from 0.89390
Epoch 243/290
625/625 - 90s - loss: 0.2019 - accuracy: 0.9283 - val_loss: 0.3645 - val_accuracy: 0.8938

Epoch 00243: val_accuracy did not improve from 0.89390
Epoch 244/290
625/625 - 90s - loss: 0.2021 - accuracy: 0.9282 - val_loss: 0.4188 - val_accuracy: 0.8830

Epoch 00244: val_accuracy did not improve from 0.89390
Epoch 245/290
625/625 - 91s - loss: 0.2007 - accuracy: 0.9292 - val_loss: 0.4739 - val_accuracy: 0.8734

Epoch 00245: val_accuracy did not improve from 0.89390
Epoch 246/290
625/625 - 90s - loss: 0.2032 - accuracy: 0.9292 - val_loss: 0.3570 - val_accuracy: 0.8959

Epoch 00246: val_accuracy improved from 0.89390 to 0.89590, saving model to model_save/model.246-0.90.h5
Epoch 247/290
625/625 - 90s - loss: 0.2004 - accuracy: 0.9275 - val_loss: 0.5371 - val_accuracy: 0.8621

Epoch 00247: val_accuracy did not improve from 0.89590
Epoch 248/290
625/625 - 90s - loss: 0.1971 - accuracy: 0.9301 - val_loss: 0.5196 - val_accuracy: 0.8638

Epoch 00248: val_accuracy did not improve from 0.89590
Epoch 249/290
625/625 - 91s - loss: 0.2029 - accuracy: 0.9281 - val_loss: 0.4545 - val_accuracy: 0.8737

Epoch 00249: val_accuracy did not improve from 0.89590
Epoch 250/290
625/625 - 90s - loss: 0.2009 - accuracy: 0.9295 - val_loss: 0.4356 - val_accuracy: 0.8798

Epoch 00250: val_accuracy did not improve from 0.89590
Epoch 251/290
625/625 - 90s - loss: 0.1990 - accuracy: 0.9301 - val_loss: 0.3794 - val_accuracy: 0.8885

Epoch 00251: val_accuracy did not improve from 0.89590
Epoch 252/290
625/625 - 90s - loss: 0.1973 - accuracy: 0.9307 - val_loss: 0.4547 - val_accuracy: 0.8749

Epoch 00252: val_accuracy did not improve from 0.89590
Epoch 253/290
625/625 - 90s - loss: 0.1981 - accuracy: 0.9295 - val_loss: 0.3709 - val_accuracy: 0.8866

Epoch 00253: val_accuracy did not improve from 0.89590
Epoch 254/290
625/625 - 90s - loss: 0.1957 - accuracy: 0.9304 - val_loss: 0.4353 - val_accuracy: 0.8794

Epoch 00254: val_accuracy did not improve from 0.89590
Epoch 255/290
625/625 - 90s - loss: 0.1964 - accuracy: 0.9305 - val_loss: 0.4281 - val_accuracy: 0.8797

Epoch 00255: val_accuracy did not improve from 0.89590
Epoch 256/290
625/625 - 90s - loss: 0.1989 - accuracy: 0.9306 - val_loss: 0.3955 - val_accuracy: 0.8826

Epoch 00256: val_accuracy did not improve from 0.89590
Epoch 257/290
625/625 - 90s - loss: 0.2011 - accuracy: 0.9304 - val_loss: 0.3878 - val_accuracy: 0.8920

Epoch 00257: val_accuracy did not improve from 0.89590
Epoch 258/290
625/625 - 90s - loss: 0.1943 - accuracy: 0.9296 - val_loss: 0.4085 - val_accuracy: 0.8897

Epoch 00258: val_accuracy did not improve from 0.89590
Epoch 259/290
625/625 - 90s - loss: 0.1977 - accuracy: 0.9304 - val_loss: 0.5269 - val_accuracy: 0.8651

Epoch 00259: val_accuracy did not improve from 0.89590
Epoch 260/290
625/625 - 90s - loss: 0.1949 - accuracy: 0.9300 - val_loss: 0.4048 - val_accuracy: 0.8880

Epoch 00260: val_accuracy did not improve from 0.89590
Epoch 261/290
625/625 - 90s - loss: 0.1958 - accuracy: 0.9317 - val_loss: 0.3926 - val_accuracy: 0.8893

Epoch 00261: val_accuracy did not improve from 0.89590
Epoch 262/290
625/625 - 90s - loss: 0.1936 - accuracy: 0.9310 - val_loss: 0.4178 - val_accuracy: 0.8857

Epoch 00262: val_accuracy did not improve from 0.89590
Epoch 263/290
625/625 - 90s - loss: 0.1932 - accuracy: 0.9320 - val_loss: 0.3986 - val_accuracy: 0.8851
```

```
Epoch 00263: val_accuracy did not improve from 0.89590
Epoch 264/290
625/625 - 90s - loss: 0.1956 - accuracy: 0.9308 - val_loss: 0.4162 - val_accuracy: 0.8854

Epoch 00264: val_accuracy did not improve from 0.89590
Epoch 265/290
625/625 - 90s - loss: 0.1935 - accuracy: 0.9316 - val_loss: 0.4307 - val_accuracy: 0.8800

Epoch 00265: val_accuracy did not improve from 0.89590
Epoch 266/290
625/625 - 90s - loss: 0.1978 - accuracy: 0.9303 - val_loss: 0.4269 - val_accuracy: 0.8884

Epoch 00266: val_accuracy did not improve from 0.89590
Epoch 267/290
625/625 - 90s - loss: 0.1900 - accuracy: 0.9332 - val_loss: 0.4196 - val_accuracy: 0.8845

Epoch 00267: val_accuracy did not improve from 0.89590
Epoch 268/290
625/625 - 90s - loss: 0.1916 - accuracy: 0.9323 - val_loss: 0.3544 - val_accuracy: 0.8961

Epoch 00268: val_accuracy improved from 0.89590 to 0.89610, saving model to model_save/model.268-0.90.h5
Epoch 269/290
625/625 - 90s - loss: 0.1933 - accuracy: 0.9319 - val_loss: 0.3892 - val_accuracy: 0.8916

Epoch 00269: val_accuracy did not improve from 0.89610
Epoch 270/290
625/625 - 90s - loss: 0.1916 - accuracy: 0.9331 - val_loss: 0.4257 - val_accuracy: 0.8805

Epoch 00270: val_accuracy did not improve from 0.89610
Epoch 271/290
625/625 - 90s - loss: 0.1903 - accuracy: 0.9322 - val_loss: 0.3816 - val_accuracy: 0.8907

Epoch 00271: val_accuracy did not improve from 0.89610
Epoch 272/290
625/625 - 90s - loss: 0.1940 - accuracy: 0.9309 - val_loss: 0.4049 - val_accuracy: 0.8863

Epoch 00272: val_accuracy did not improve from 0.89610
Epoch 273/290
625/625 - 90s - loss: 0.1900 - accuracy: 0.9332 - val_loss: 0.4544 - val_accuracy: 0.8740

Epoch 00273: val_accuracy did not improve from 0.89610
Epoch 274/290
625/625 - 90s - loss: 0.1907 - accuracy: 0.9340 - val_loss: 0.5268 - val_accuracy: 0.8604

Epoch 00274: val_accuracy did not improve from 0.89610
Epoch 275/290
625/625 - 90s - loss: 0.1908 - accuracy: 0.9326 - val_loss: 0.4058 - val_accuracy: 0.8859

Epoch 00275: val_accuracy did not improve from 0.89610
Epoch 276/290
625/625 - 90s - loss: 0.1864 - accuracy: 0.9339 - val_loss: 0.4163 - val_accuracy: 0.8867

Epoch 00276: val_accuracy did not improve from 0.89610
Epoch 277/290
625/625 - 91s - loss: 0.1883 - accuracy: 0.9331 - val_loss: 0.3774 - val_accuracy: 0.8932

Epoch 00277: val_accuracy did not improve from 0.89610
Epoch 278/290
625/625 - 91s - loss: 0.1891 - accuracy: 0.9342 - val_loss: 0.3752 - val_accuracy: 0.8948

Epoch 00278: val_accuracy did not improve from 0.89610
Epoch 279/290
625/625 - 91s - loss: 0.1911 - accuracy: 0.9334 - val_loss: 0.4656 - val_accuracy: 0.8714

Epoch 00279: val_accuracy did not improve from 0.89610
Epoch 280/290
625/625 - 91s - loss: 0.1865 - accuracy: 0.9335 - val_loss: 0.4099 - val_accuracy: 0.8860

Epoch 00280: val_accuracy did not improve from 0.89610
Epoch 281/290
625/625 - 91s - loss: 0.1872 - accuracy: 0.9348 - val_loss: 0.4337 - val_accuracy: 0.8798

Epoch 00281: val_accuracy did not improve from 0.89610
Epoch 282/290
625/625 - 91s - loss: 0.1892 - accuracy: 0.9332 - val_loss: 0.4514 - val_accuracy: 0.8758

Epoch 00282: val_accuracy did not improve from 0.89610
Epoch 283/290
625/625 - 91s - loss: 0.1858 - accuracy: 0.9341 - val_loss: 0.4254 - val_accuracy: 0.8820

Epoch 00283: val_accuracy did not improve from 0.89610
Epoch 284/290
```

```
625/625 - 91s - loss: 0.1929 - accuracy: 0.9326 - val_loss: 0.3625 - val_accuracy: 0.8948

Epoch 00284: val_accuracy did not improve from 0.89610
Epoch 285/290
625/625 - 90s - loss: 0.1878 - accuracy: 0.9341 - val_loss: 0.4198 - val_accuracy: 0.8879

Epoch 00285: val_accuracy did not improve from 0.89610
Epoch 286/290
625/625 - 91s - loss: 0.1861 - accuracy: 0.9330 - val_loss: 0.4016 - val_accuracy: 0.8908

Epoch 00286: val_accuracy did not improve from 0.89610
Epoch 287/290
625/625 - 91s - loss: 0.1883 - accuracy: 0.9331 - val_loss: 0.4533 - val_accuracy: 0.8744

Epoch 00287: val_accuracy did not improve from 0.89610
Epoch 288/290
625/625 - 90s - loss: 0.1844 - accuracy: 0.9345 - val_loss: 0.3762 - val_accuracy: 0.8944

Epoch 00288: val_accuracy did not improve from 0.89610
Epoch 289/290
625/625 - 90s - loss: 0.1856 - accuracy: 0.9342 - val_loss: 0.3904 - val_accuracy: 0.8927

Epoch 00289: val_accuracy did not improve from 0.89610
Epoch 290/290
625/625 - 90s - loss: 0.1837 - accuracy: 0.9347 - val_loss: 0.3515 - val_accuracy: 0.9006

Epoch 00290: val_accuracy improved from 0.89610 to 0.90060, saving model to model_save/model.290-0.90.h5
```

In [27]:

```
from keras.models import load_model
model_ = load_model('model.290-0.90.h5')
# Test the model
score = model_.evaluate(test_generator ,verbose=1)
print('Test loss:', score[0])
print('Test accuracy:', score[1])
```

```
1112/1112 [==============================] - 9s 7ms/step - loss: 0.3515 - accuracy: 0.9006
Test loss: 0.3514561951160431
Test accuracy: 0.900600016117096
```