In [1]:

```
# 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
import tensorflow.python.keras
from tensorflow.python.keras import models, layers
from tensorflow.python.keras.layers import SeparableConv2D, DepthwiseConv2D
from tensorflow.python.keras.models import Model, load_model
from tensorflow.python.keras.layers import BatchNormalization, Activation, Flatten
from tensorflow.python.keras.optimizers import Adam
from keras.preprocessing.image import ImageDataGenerator
import numpy as np
```

```
/usr/local/lib/python3.5/dist-packages/tensorflow/python/framework/dtypes.py:516: FutureWarning: P
assing (type, 1) or '1type' as a synonym of type is deprecated; in a future version of numpy, it w
ill be understood as (type, (1,)) / '(1,)type'.
  _np_qint8 = np.dtype([("qint8", np.int8, 1)])
/usr/local/lib/python3.5/dist-packages/tensorflow/python/framework/dtypes.py:517: FutureWarning: P
assing (type, 1) or '1type' as a synonym of type is deprecated; in a future version of numpy, it w
ill be understood as (type, (1,)) / '(1,)type'.
  _np_quint8 = np.dtype([("quint8", np.uint8, 1)])
/usr/local/lib/python3.5/dist-packages/tensorflow/python/framework/dtypes.py:518: FutureWarning: P
assing (type, 1) or '1type' as a synonym of type is deprecated; in a future version of numpy, it w
ill be understood as (type, (1,)) / '(1,)type'.
  _np_qint16 = np.dtype([("qint16", np.int16, 1)])
/usr/local/lib/python3.5/dist-packages/tensorflow/python/framework/dtypes.py:519: FutureWarning: P
assing (type, 1) or '1type' as a synonym of type is deprecated; in a future version of numpy, it w
ill be understood as (type, (1,)) / '(1,)type'.
  _np_quint16 = np.dtype([("quint16", np.uint16, 1)])
/usr/local/lib/python3.5/dist-packages/tensorflow/python/framework/dtypes.py:520: FutureWarning: P
assing (type, 1) or '1type' as a synonym of type is deprecated; in a future version of numpy, it w
ill be understood as (type, (1,)) / '(1,)type'.
  _np_qint32 = np.dtype([("qint32", np.int32, 1)])
/usr/local/lib/python3.5/dist-packages/tensorflow/python/framework/dtypes.py:525: FutureWarning: P
assing (type, 1) or '1type' as a synonym of type is deprecated; in a future version of numpy, it w
ill be understood as (type, (1,)) / '(1,)type'.
  np_resource = np.dtype([("resource", np.ubyte, 1)])
/usr/local/lib/python3.5/dist-packages/tensorboard/compat/tensorflow_stub/dtypes.py:541:
FutureWarning: Passing (type, 1) or '1type' as a synonym of type is deprecated; in a future
version of numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_qint8 = np.dtype([("qint8", np.int8, 1)])
/usr/local/lib/python3.5/dist-packages/tensorboard/compat/tensorflow_stub/dtypes.py:542:
FutureWarning: Passing (type, 1) or '1type' as a synonym of type is deprecated; in a future
version of numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_quint8 = np.dtype([("quint8", np.uint8, 1)])
/usr/local/lib/python3.5/dist-packages/tensorboard/compat/tensorflow_stub/dtypes.py:543:
FutureWarning: Passing (type, 1) or '1type' as a synonym of type is deprecated; in a future
version of numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_qint16 = np.dtype([("qint16", np.int16, 1)])
/usr/local/lib/python3.5/dist-packages/tensorboard/compat/tensorflow_stub/dtypes.py:544:
FutureWarning: Passing (type, 1) or '1type' as a synonym of type is deprecated; in a future
version of numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_quint16 = np.dtype([("quint16", np.uint16, 1)])
/usr/local/lib/python3.5/dist-packages/tensorboard/compat/tensorflow_stub/dtypes.py:545:
FutureWarning: Passing (type, 1) or '1type' as a synonym of type is deprecated; in a future
version of numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_qint32 = np.dtype([("qint32", np.int32, 1)])
/usr/local/lib/python3.5/dist-packages/tensorboard/compat/tensorflow_stub/dtypes.py:550:
FutureWarning: Passing (type, 1) or '1type' as a synonym of type is deprecated; in a future
version of numpy, it will be understood as (type, (1,)) / '(1,)type'.
  np_resource = np.dtype([("resource", np.ubyte, 1)])
Using TensorFlow backend.
```

In [2]:

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

```
import tensorflow as tf
# from tensorflow import keras

# from keras import backend as k

# Don't pre-allocate memory; allocate as-needed
# import tensorflow as tf
config = tf.ConfigProto()
config.gpu_options.per_process_gpu_memory_fraction = 0.75
config.gpu_options.allow_growth= True
# config = tf.ConfigProto()
# config.gpu_options.allow_growth = True

# Create a session with the above options specified.
# k.tensorflow_backend.set_session(tf.Session(config=config))
```

In [3]:

```
# Hyperparameters
batch_size = 64
num_classes = 10
epochs = 10
l = 40
compression = 0.55
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)
```

In [5]:

```
X_train.shape
```

Out[5]:

```
(50000, 32, 32, 3)
```

In [6]:

```
X_test.shape
```

Out[6]:

```
(10000, 32, 32, 3)
```

In [7]:

```
#pip install --upgrade "tensorflow==1.4" "keras>=2.0"
```

In [8]:

```
X_train_mean = np.mean(X_train, axis=(0,1,2))
X_train_std = np.std(X_train, axis=(0,1,2))
X_train = (X_train - X_train_mean) / X_train_std
X_test = (X_test - X_train_mean) / X_train_std
```

In [9]:

```
# 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.SeparableConv2D(int(num_filter*compression), (5,5), use_bias=False ,pad
ding='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.SeparableConv2D(int(num_filter*compression), (5,5), use_bias=False,p
adding='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=(4,4))(relu)
    #flat = layers.Flatten()(AvgPooling)
    output = layers.SeparableConv2D(num_classes, (5,5), use_bias=False,padding='same', activation='
softmax')(AvgPooling)
    return output
```

In [10]:

```
import keras.backend as K
K.clear_session()
```

In [11]:

```
#pip install --upgrade "tensorflow==1.4" "keras>=2.0"
```

In [12]:

```
num_filter = 126

dropout_rate = 0
l = 7

input = layers.Input(shape=(img_height, img_width, channel,))
First_Conv2D = layers.SeparableConv2D(num_filter, (5,5), 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)
```

```
WARNING:tensorflow:From /usr/local/lib/python3.5/dist-
packages/tensorflow/python/ops/init_ops.py:1251: calling VarianceScaling.__init__ (from
tensorflow.python.ops.init_ops) with dtype is deprecated and will be removed in a future version.
Instructions for updating:
Call initializer instance with the dtype argument instead of passing it to the constructor
```

In [13]:

```
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	
separable_conv2d (SeparableConv	(None, 32, 32, 126)	453	input_1[0][0]
batch_normalization (BatchNorma	(None, 32, 32, 126)	504	separable_conv2d[0][0]
activation (Activation)	(None, 32, 32, 126)	0	batch_normalization[0][0]
separable_conv2d_1 (SeparableCo	(None, 32, 32, 69)	11844	activation[0][0]
concatenate (Concatenate)	(None, 32, 32, 195)	0	separable_conv2d[0][0] separable_conv2d_1[0][0]
batch_normalization_1 (BatchNor	(None, 32, 32, 195)	780	concatenate[0][0]
activation_1 (Activation)	(None, 32, 32, 195)	0	batch_normalization_1[0][0]
separable_conv2d_2 (SeparableCo	(None, 32, 32, 69)	18330	activation_1[0][0]
concatenate_1 (Concatenate)	(None, 32, 32, 264)	0	concatenate[0][0] separable_conv2d_2[0][0]
batch_normalization_2 (BatchNor	(None, 32, 32, 264)	1056	concatenate_1[0][0]
activation_2 (Activation)	(None, 32, 32, 264)	0	batch_normalization_2[0][0]
separable_conv2d_3 (SeparableCo	(None, 32, 32, 69)	24816	activation_2[0][0]
concatenate_2 (Concatenate)	(None, 32, 32, 333)	0	concatenate_1[0][0] separable_conv2d_3[0][0]
batch_normalization_3 (BatchNor	(None, 32, 32, 333)	1332	concatenate_2[0][0]
activation_3 (Activation)	(None, 32, 32, 333)	0	batch_normalization_3[0][0]
separable_conv2d_4 (SeparableCo	(None, 32, 32, 69)	31302	activation_3[0][0]
concatenate_3 (Concatenate)	(None, 32, 32, 402)	0	concatenate_2[0][0] separable_conv2d_4[0][0]
batch_normalization_4 (BatchNor	(None, 32, 32, 402)	1608	concatenate_3[0][0]
activation_4 (Activation)	(None, 32, 32, 402)	0	batch_normalization_4[0][0]
separable_conv2d_5 (SeparableCo	(None, 32, 32, 69)	37788	activation_4[0][0]
concatenate_4 (Concatenate)	(None, 32, 32, 471)	0	concatenate_3[0][0] separable_conv2d_5[0][0]
batch_normalization_5 (BatchNor	(None, 32, 32, 471)	1884	concatenate_4[0][0]
activation_5 (Activation)	(None, 32, 32, 471)	0	batch_normalization_5[0][0]
separable_conv2d_6 (SeparableCo	(None, 32, 32, 69)	44274	activation_5[0][0]
concatenate_5 (Concatenate)	(None, 32, 32, 540)	0	concatenate_4[0][0] separable_conv2d_6[0][0]
batch_normalization_6 (BatchNor	(None, 32, 32, 540)	2160	concatenate_5[0][0]
activation_6 (Activation)	(None, 32, 32, 540)	0	batch_normalization_6[0][0]
separable_conv2d_7 (SeparableCo	(None, 32, 32, 69)	50760	activation_6[0][0]
concatenate_6 (Concatenate)	(None, 32, 32, 609)	0	concatenate_5[0][0] separable_conv2d_7[0][0]
batch_normalization_7 (BatchNor	(None, 32, 32, 609)	2436	concatenate_6[0][0]

batch_normalization_7 (BatchNor	(None, 32, 32, 609)	2436	concatenate_6[0][0]
activation_7 (Activation)	(None, 32, 32, 609)	0	batch_normalization_7[0][0]
separable_conv2d_8 (SeparableCo	(None, 32, 32, 69)	57246	activation_7[0][0]
average_pooling2d (AveragePooli	(None, 16, 16, 69)	0	separable_conv2d_8[0][0]
batch_normalization_8 (BatchNor	(None, 16, 16, 69)	276	average_pooling2d[0][0]
activation_8 (Activation)	(None, 16, 16, 69)	0	batch_normalization_8[0][0]
separable_conv2d_9 (SeparableCo	(None, 16, 16, 69)	6486	activation_8[0][0]
concatenate_7 (Concatenate)	(None, 16, 16, 138)	0	average_pooling2d[0][0] separable_conv2d_9[0][0]
batch_normalization_9 (BatchNor	(None, 16, 16, 138)	552	concatenate_7[0][0]
activation_9 (Activation)	(None, 16, 16, 138)	0	batch_normalization_9[0][0]
separable_conv2d_10 (SeparableC	(None, 16, 16, 69)	12972	activation_9[0][0]
concatenate_8 (Concatenate)	(None, 16, 16, 207)	0	concatenate_7[0][0] separable_conv2d_10[0][0]
batch_normalization_10 (BatchNo	(None, 16, 16, 207)	828	concatenate_8[0][0]
activation_10 (Activation)	(None, 16, 16, 207)	0	batch_normalization_10[0][0]
separable_conv2d_11 (SeparableC	(None, 16, 16, 69)	19458	activation_10[0][0]
concatenate_9 (Concatenate)	(None, 16, 16, 276)	0	concatenate_8[0][0] separable_conv2d_11[0][0]
batch_normalization_11 (BatchNo	(None, 16, 16, 276)	1104	concatenate_9[0][0]
activation_11 (Activation)	(None, 16, 16, 276)	0	batch_normalization_11[0][0]
separable_conv2d_12 (SeparableC	(None, 16, 16, 69)	25944	activation_11[0][0]
concatenate_10 (Concatenate)	(None, 16, 16, 345)	0	concatenate_9[0][0] separable_conv2d_12[0][0]
batch_normalization_12 (BatchNo	(None, 16, 16, 345)	1380	concatenate_10[0][0]
activation_12 (Activation)	(None, 16, 16, 345)	0	batch_normalization_12[0][0]
separable_conv2d_13 (SeparableC	(None, 16, 16, 69)	32430	activation_12[0][0]
concatenate_11 (Concatenate)	(None, 16, 16, 414)	0	concatenate_10[0][0] separable_conv2d_13[0][0]
batch_normalization_13 (BatchNo	(None, 16, 16, 414)	1656	concatenate_11[0][0]
activation_13 (Activation)	(None, 16, 16, 414)	0	batch_normalization_13[0][0]
separable_conv2d_14 (SeparableC	(None, 16, 16, 69)	38916	activation_13[0][0]
concatenate_12 (Concatenate)	(None, 16, 16, 483)	0	concatenate_11[0][0] separable_conv2d_14[0][0]
batch_normalization_14 (BatchNo	(None, 16, 16, 483)	1932	concatenate_12[0][0]
activation_14 (Activation)	(None, 16, 16, 483)	0	batch_normalization_14[0][0]
separable_conv2d_15 (SeparableC	(None, 16, 16, 69)	45402	activation_14[0][0]
concatenate_13 (Concatenate)	(None, 16, 16, 552)	0	concatenate_12[0][0] separable_conv2d_15[0][0]
batch_normalization_15 (BatchNo	(None, 16, 16, 552)	2208	concatenate_13[0][0]
activation_15 (Activation)	(None, 16, 16, 552)	0	batch_normalization_15[0][0]
separable_conv2d_16 (SeparableC	(None, 16, 16, 69)	51888	activation_15[0][0]
average_pooling2d_1 (AveragePoo	(None, 8, 8, 69)	0	separable_conv2d_16[0][0]

average_pooling2d_1 (AveragePoo	(None, 8, 8, 69)	0	separable_conv2d_16[0][0]
batch_normalization_16 (BatchNo	(None, 8, 8, 69)	276	average_pooling2d_1[0][0]
activation_16 (Activation)	(None, 8, 8, 69)	0	batch_normalization_16[0][0]
separable_conv2d_17 (SeparableC	(None, 8, 8, 69)	6486	activation_16[0][0]
concatenate_14 (Concatenate)	(None, 8, 8, 138)	0	average_pooling2d_1[0][0] separable_conv2d_17[0][0]
batch_normalization_17 (BatchNo	(None, 8, 8, 138)	552	concatenate_14[0][0]
activation_17 (Activation)	(None, 8, 8, 138)	0	batch_normalization_17[0][0]
separable_conv2d_18 (SeparableC	(None, 8, 8, 69)	12972	activation_17[0][0]
concatenate_15 (Concatenate)	(None, 8, 8, 207)	0	concatenate_14[0][0] separable_conv2d_18[0][0]
batch_normalization_18 (BatchNo	(None, 8, 8, 207)	828	concatenate_15[0][0]
activation_18 (Activation)	(None, 8, 8, 207)	0	batch_normalization_18[0][0]
separable_conv2d_19 (SeparableC	(None, 8, 8, 69)	19458	activation_18[0][0]
concatenate_16 (Concatenate)	(None, 8, 8, 276)	0	concatenate_15[0][0] separable_conv2d_19[0][0]
batch_normalization_19 (BatchNo	(None, 8, 8, 276)	1104	concatenate_16[0][0]
activation_19 (Activation)	(None, 8, 8, 276)	0	batch_normalization_19[0][0]
separable_conv2d_20 (SeparableC	(None, 8, 8, 69)	25944	activation_19[0][0]
concatenate_17 (Concatenate)	(None, 8, 8, 345)	0	concatenate_16[0][0] separable_conv2d_20[0][0]
batch_normalization_20 (BatchNo	(None, 8, 8, 345)	1380	concatenate_17[0][0]
activation_20 (Activation)	(None, 8, 8, 345)	0	batch_normalization_20[0][0]
separable_conv2d_21 (SeparableC	(None, 8, 8, 69)	32430	activation_20[0][0]
concatenate_18 (Concatenate)	(None, 8, 8, 414)	0	concatenate_17[0][0] separable_conv2d_21[0][0]
batch_normalization_21 (BatchNo	(None, 8, 8, 414)	1656	concatenate_18[0][0]
activation_21 (Activation)	(None, 8, 8, 414)	0	batch_normalization_21[0][0]
separable_conv2d_22 (SeparableC	(None, 8, 8, 69)	38916	activation_21[0][0]
concatenate_19 (Concatenate)	(None, 8, 8, 483)	0	concatenate_18[0][0] separable_conv2d_22[0][0]
batch_normalization_22 (BatchNo	(None, 8, 8, 483)	1932	concatenate_19[0][0]
activation_22 (Activation)	(None, 8, 8, 483)	0	batch_normalization_22[0][0]
separable_conv2d_23 (SeparableC	(None, 8, 8, 69)	45402	activation_22[0][0]
concatenate_20 (Concatenate)	(None, 8, 8, 552)	0	concatenate_19[0][0] separable_conv2d_23[0][0]
batch_normalization_23 (BatchNo	(None, 8, 8, 552)	2208	concatenate_20[0][0]
activation_23 (Activation)	(None, 8, 8, 552)	0	batch_normalization_23[0][0]
separable_conv2d_24 (SeparableC	(None, 8, 8, 69)	51888	activation_23[0][0]
average_pooling2d_2 (AveragePoo	(None, 4, 4, 69)	0	separable_conv2d_24[0][0]
batch_normalization_24 (BatchNo	(None, 4, 4, 69)	276	average_pooling2d_2[0][0]
activation_24 (Activation)	(None, 4, 4, 69)	0	batch_normalization_24[0][0]
separable_conv2d_25 (SeparableC	(None, 4, 4, 69)	6486	activation_24[0][0]

```
separable_conv2d_25 (SeparableC (None, 4, 4, 69)     6486        activation_24[0][0]
__________________________________________________________________________________________________
concatenate_21 (Concatenate)    (None, 4, 4, 138)    0           average_pooling2d_2[0][0]
                                                                 separable_conv2d_25[0][0]
__________________________________________________________________________________________________
batch_normalization_25 (BatchNo (None, 4, 4, 138)    552         concatenate_21[0][0]
__________________________________________________________________________________________________
activation_25 (Activation)      (None, 4, 4, 138)    0           batch_normalization_25[0][0]
__________________________________________________________________________________________________
separable_conv2d_26 (SeparableC (None, 4, 4, 69)     12972       activation_25[0][0]
__________________________________________________________________________________________________
concatenate_22 (Concatenate)    (None, 4, 4, 207)    0           concatenate_21[0][0]
                                                                 separable_conv2d_26[0][0]
__________________________________________________________________________________________________
batch_normalization_26 (BatchNo (None, 4, 4, 207)    828         concatenate_22[0][0]
__________________________________________________________________________________________________
activation_26 (Activation)      (None, 4, 4, 207)    0           batch_normalization_26[0][0]
__________________________________________________________________________________________________
separable_conv2d_27 (SeparableC (None, 4, 4, 69)     19458       activation_26[0][0]
__________________________________________________________________________________________________
concatenate_23 (Concatenate)    (None, 4, 4, 276)    0           concatenate_22[0][0]
                                                                 separable_conv2d_27[0][0]
__________________________________________________________________________________________________
batch_normalization_27 (BatchNo (None, 4, 4, 276)    1104        concatenate_23[0][0]
__________________________________________________________________________________________________
activation_27 (Activation)      (None, 4, 4, 276)    0           batch_normalization_27[0][0]
__________________________________________________________________________________________________
separable_conv2d_28 (SeparableC (None, 4, 4, 69)     25944       activation_27[0][0]
__________________________________________________________________________________________________
concatenate_24 (Concatenate)    (None, 4, 4, 345)    0           concatenate_23[0][0]
                                                                 separable_conv2d_28[0][0]
__________________________________________________________________________________________________
batch_normalization_28 (BatchNo (None, 4, 4, 345)    1380        concatenate_24[0][0]
__________________________________________________________________________________________________
activation_28 (Activation)      (None, 4, 4, 345)    0           batch_normalization_28[0][0]
__________________________________________________________________________________________________
separable_conv2d_29 (SeparableC (None, 4, 4, 69)     32430       activation_28[0][0]
__________________________________________________________________________________________________
concatenate_25 (Concatenate)    (None, 4, 4, 414)    0           concatenate_24[0][0]
                                                                 separable_conv2d_29[0][0]
__________________________________________________________________________________________________
batch_normalization_29 (BatchNo (None, 4, 4, 414)    1656        concatenate_25[0][0]
__________________________________________________________________________________________________
activation_29 (Activation)      (None, 4, 4, 414)    0           batch_normalization_29[0][0]
__________________________________________________________________________________________________
separable_conv2d_30 (SeparableC (None, 4, 4, 69)     38916       activation_29[0][0]
__________________________________________________________________________________________________
concatenate_26 (Concatenate)    (None, 4, 4, 483)    0           concatenate_25[0][0]
                                                                 separable_conv2d_30[0][0]
__________________________________________________________________________________________________
batch_normalization_30 (BatchNo (None, 4, 4, 483)    1932        concatenate_26[0][0]
__________________________________________________________________________________________________
activation_30 (Activation)      (None, 4, 4, 483)    0           batch_normalization_30[0][0]
__________________________________________________________________________________________________
separable_conv2d_31 (SeparableC (None, 4, 4, 69)     45402       activation_30[0][0]
__________________________________________________________________________________________________
concatenate_27 (Concatenate)    (None, 4, 4, 552)    0           concatenate_26[0][0]
                                                                 separable_conv2d_31[0][0]
__________________________________________________________________________________________________
batch_normalization_31 (BatchNo (None, 4, 4, 552)    2208        concatenate_27[0][0]
__________________________________________________________________________________________________
activation_31 (Activation)      (None, 4, 4, 552)    0           batch_normalization_31[0][0]
__________________________________________________________________________________________________
average_pooling2d_3 (AveragePoo (None, 1, 1, 552)    0           activation_31[0][0]
__________________________________________________________________________________________________
separable_conv2d_32 (SeparableC (None, 1, 1, 10)     19320       average_pooling2d_3[0][0]
==================================================================================================
Total params: 986,301
Trainable params: 965,517
Non-trainable params: 20,784
__________________________________________________________________________________________________
```

In [14]:

```
datagen = ImageDataGenerator(
    rotation_range=30,
```

```
    width_shift_range=0.15,
    height_shift_range=0.15,
    horizontal_flip=True,
    zoom_range=0.10,
    )
datagen.fit(X_train)
```

In [15]:

```
from tensorflow.python.keras.callbacks import ModelCheckpoint, EarlyStopping,ReduceLROnPlateau, Le
arningRateScheduler
```

In [16]:

```
#https://machinelearningmastery.com/check-point-deep-learning-models-keras/
filepath="epochs:{epoch:03d}-val_acc:{val_acc:.3f}.hdf5"
checkpoint_1 = ModelCheckpoint(filepath, monitor='val_acc', verbose=1, mode='max')
```

In [17]:

```
reduce_lr_1 = ReduceLROnPlateau(monitor='val_loss', factor=0.1,
                                patience=4,verbose = 1)
```

In [18]:

```
earlystopping_1 = EarlyStopping(monitor='val_loss', patience=40, verbose=1)
```

In [19]:

```
callbacks_list = [earlystopping_1,reduce_lr_1,checkpoint_1]
```

In [20]:

```
# determine Loss function and Optimizer
model.compile(loss='categorical_crossentropy',
              optimizer="adam",
              metrics=['accuracy'])
```

In [21]:

```
# reshaping to match with convoultion output layer
y_train_re = np.reshape(y_train, (50000,1,1,10))
y_test_re = np.reshape(y_test, (10000,1,1,10))
```

In [ ]:

```
history = model.fit_generator(datagen.flow(X_train, y_train_re, batch_size=batch_size),
                    steps_per_epoch=X_train.shape[0] // batch_size,
                    epochs=100,
                    verbose=1,
                    validation_data=(X_test, y_test_re),callbacks=callbacks_list)
```

```
Epoch 1/100
WARNING:tensorflow:From /usr/local/lib/python3.5/dist-
packages/tensorflow/python/ops/math_grad.py:1250: add_dispatch_support.<locals>.wrapper (from
tensorflow.python.ops.array_ops) is deprecated and will be removed in a future version.
Instructions for updating:
Use tf.where in 2.0, which has the same broadcast rule as np.where
780/781 [============================>.] - ETA: 0s - loss: 1.6015 - acc: 0.4069
Epoch 00001: saving model to epochs:001-val_acc:0.509.hdf5
781/781 [==============================] - 142s 182ms/step - loss: 1.6011 - acc: 0.4070 -
val_loss: 1.4417 - val_acc: 0.5087
Epoch 2/100
780/781 [============================>.] - ETA: 0s - loss: 1.1707 - acc: 0.5825
Epoch 00002: saving model to epochs:002-val_acc:0.530.hdf5
781/781 [==============================] - 125s 160ms/step - loss: 1.1703 - acc: 0.5827 -
val_loss: 1.5555 - val_acc: 0.5298
Epoch 3/100
780/781 [============================>.] - ETA: 0s - loss: 0.9674 - acc: 0.6601
```

```
Epoch 00003: saving model to epochs:003-val_acc:0.590.hdf5
781/781 [==============================] - 125s 160ms/step - loss: 0.9678 - acc: 0.6600 -
val_loss: 1.3740 - val_acc: 0.5901
Epoch 4/100
780/781 [==============================>.] - ETA: 0s - loss: 0.8379 - acc: 0.7098
Epoch 00004: saving model to epochs:004-val_acc:0.704.hdf5
781/781 [==============================] - 125s 160ms/step - loss: 0.8377 - acc: 0.7098 -
val_loss: 0.8627 - val_acc: 0.7037
Epoch 5/100
780/781 [==============================>.] - ETA: 0s - loss: 0.7499 - acc: 0.7396
Epoch 00005: saving model to epochs:005-val_acc:0.717.hdf5
781/781 [==============================] - 125s 160ms/step - loss: 0.7500 - acc: 0.7395 -
val_loss: 0.8827 - val_acc: 0.7166
Epoch 6/100
780/781 [==============================>.] - ETA: 0s - loss: 0.6839 - acc: 0.7615
Epoch 00006: saving model to epochs:006-val_acc:0.784.hdf5
781/781 [==============================] - 124s 159ms/step - loss: 0.6837 - acc: 0.7617 -
val_loss: 0.6355 - val_acc: 0.7838
Epoch 7/100
780/781 [==============================>.] - ETA: 0s - loss: 0.6392 - acc: 0.7787
Epoch 00007: saving model to epochs:007-val_acc:0.772.hdf5
781/781 [==============================] - 124s 159ms/step - loss: 0.6391 - acc: 0.7787 -
val_loss: 0.6830 - val_acc: 0.7720
Epoch 8/100
780/781 [==============================>.] - ETA: 0s - loss: 0.5996 - acc: 0.7930
Epoch 00008: saving model to epochs:008-val_acc:0.791.hdf5
781/781 [==============================] - 124s 159ms/step - loss: 0.5996 - acc: 0.7929 -
val_loss: 0.6126 - val_acc: 0.7910
Epoch 9/100
780/781 [==============================>.] - ETA: 0s - loss: 0.5590 - acc: 0.8089
Epoch 00009: saving model to epochs:009-val_acc:0.771.hdf5
781/781 [==============================] - 125s 160ms/step - loss: 0.5590 - acc: 0.8088 -
val_loss: 0.6974 - val_acc: 0.7709
Epoch 10/100
780/781 [==============================>.] - ETA: 0s - loss: 0.5264 - acc: 0.8171
Epoch 00010: saving model to epochs:010-val_acc:0.824.hdf5
781/781 [==============================] - 124s 159ms/step - loss: 0.5265 - acc: 0.8171 -
val_loss: 0.5226 - val_acc: 0.8243
Epoch 11/100
780/781 [==============================>.] - ETA: 0s - loss: 0.4998 - acc: 0.8252
Epoch 00011: saving model to epochs:011-val_acc:0.807.hdf5
781/781 [==============================] - 124s 159ms/step - loss: 0.4996 - acc: 0.8253 -
val_loss: 0.5991 - val_acc: 0.8068
Epoch 12/100
780/781 [==============================>.] - ETA: 0s - loss: 0.4670 - acc: 0.8384
Epoch 00012: saving model to epochs:012-val_acc:0.835.hdf5
781/781 [==============================] - 124s 159ms/step - loss: 0.4672 - acc: 0.8384 -
val_loss: 0.5170 - val_acc: 0.8345
Epoch 13/100
780/781 [==============================>.] - ETA: 0s - loss: 0.4477 - acc: 0.8452
Epoch 00013: saving model to epochs:013-val_acc:0.837.hdf5
781/781 [==============================] - 124s 159ms/step - loss: 0.4477 - acc: 0.8451 -
val_loss: 0.4697 - val_acc: 0.8374
Epoch 14/100
780/781 [==============================>.] - ETA: 0s - loss: 0.4284 - acc: 0.8511
Epoch 00014: saving model to epochs:014-val_acc:0.839.hdf5
781/781 [==============================] - 124s 159ms/step - loss: 0.4282 - acc: 0.8512 -
val_loss: 0.4808 - val_acc: 0.8393
Epoch 15/100
780/781 [==============================>.] - ETA: 0s - loss: 0.4078 - acc: 0.8567
Epoch 00015: saving model to epochs:015-val_acc:0.853.hdf5
781/781 [==============================] - 124s 159ms/step - loss: 0.4078 - acc: 0.8568 -
val_loss: 0.4367 - val_acc: 0.8533
Epoch 16/100
780/781 [==============================>.] - ETA: 0s - loss: 0.3958 - acc: 0.8643
Epoch 00016: saving model to epochs:016-val_acc:0.846.hdf5
781/781 [==============================] - 124s 159ms/step - loss: 0.3957 - acc: 0.8643 -
val_loss: 0.4704 - val_acc: 0.8462
Epoch 17/100
780/781 [==============================>.] - ETA: 0s - loss: 0.3833 - acc: 0.8663
Epoch 00017: saving model to epochs:017-val_acc:0.853.hdf5
781/781 [==============================] - 125s 160ms/step - loss: 0.3832 - acc: 0.8664 -
val_loss: 0.4462 - val_acc: 0.8528
Epoch 18/100
780/781 [==============================>.] - ETA: 0s - loss: 0.3667 - acc: 0.8735
Epoch 00018: saving model to epochs:018-val_acc:0.849.hdf5
781/781 [==============================] - 124s 159ms/step - loss: 0.3668 - acc: 0.8735 -
```

```
781/781 [==============================] - 124s 159ms/step - loss: 0.3000 - acc: 0.8755 -
val_loss: 0.4600 - val_acc: 0.8485
Epoch 19/100
780/781 [==============================>.] - ETA: 0s - loss: 0.3537 - acc: 0.8770
Epoch 00019: saving model to epochs:019-val_acc:0.866.hdf5
781/781 [==============================] - 125s 160ms/step - loss: 0.3537 - acc: 0.8770 -
val_loss: 0.3959 - val_acc: 0.8656
Epoch 20/100
780/781 [==============================>.] - ETA: 0s - loss: 0.3347 - acc: 0.8835
Epoch 00020: saving model to epochs:020-val_acc:0.852.hdf5
781/781 [==============================] - 128s 164ms/step - loss: 0.3347 - acc: 0.8835 -
val_loss: 0.4636 - val_acc: 0.8523
Epoch 21/100
780/781 [==============================>.] - ETA: 0s - loss: 0.3247 - acc: 0.8865
Epoch 00021: saving model to epochs:021-val_acc:0.877.hdf5
781/781 [==============================] - 128s 164ms/step - loss: 0.3247 - acc: 0.8865 -
val_loss: 0.3769 - val_acc: 0.8768
Epoch 22/100
780/781 [==============================>.] - ETA: 0s - loss: 0.3181 - acc: 0.8886
Epoch 00022: saving model to epochs:022-val_acc:0.871.hdf5
781/781 [==============================] - 129s 165ms/step - loss: 0.3182 - acc: 0.8886 -
val_loss: 0.4012 - val_acc: 0.8708
Epoch 23/100
780/781 [==============================>.] - ETA: 0s - loss: 0.3068 - acc: 0.8914
Epoch 00023: saving model to epochs:023-val_acc:0.852.hdf5
781/781 [==============================] - 130s 167ms/step - loss: 0.3067 - acc: 0.8914 -
val_loss: 0.4906 - val_acc: 0.8523
Epoch 24/100
780/781 [==============================>.] - ETA: 0s - loss: 0.2997 - acc: 0.8959
Epoch 00024: saving model to epochs:024-val_acc:0.864.hdf5
781/781 [==============================] - 131s 167ms/step - loss: 0.2997 - acc: 0.8958 -
val_loss: 0.4362 - val_acc: 0.8643
Epoch 25/100
780/781 [==============================>.] - ETA: 0s - loss: 0.2905 - acc: 0.8986
Epoch 00025: ReduceLROnPlateau reducing learning rate to 0.00010000000474974513.

Epoch 00025: saving model to epochs:025-val_acc:0.854.hdf5
781/781 [==============================] - 131s 168ms/step - loss: 0.2904 - acc: 0.8986 -
val_loss: 0.4713 - val_acc: 0.8538
Epoch 26/100
780/781 [==============================>.] - ETA: 0s - loss: 0.2166 - acc: 0.9256
Epoch 00026: saving model to epochs:026-val_acc:0.899.hdf5
781/781 [==============================] - 131s 167ms/step - loss: 0.2167 - acc: 0.9255 -
val_loss: 0.3181 - val_acc: 0.8991
Epoch 27/100
 31/781 [>.............................] - ETA: 1:57 - loss: 0.2121 - acc: 0.9315
```

In [28]:

```
#Connection got disconnected, so resuminf the traimimg process from epoch27
```

In [22]:

```
checkpoint_path = "epochs:026-val_acc:0.899.hdf5"
model = load_model(checkpoint_path)
```

```
WARNING:tensorflow:From /usr/local/lib/python3.5/dist-
packages/tensorflow/python/ops/init_ops.py:97: calling GlorotUniform.__init__ (from
tensorflow.python.ops.init_ops) with dtype is deprecated and will be removed in a future version.
Instructions for updating:
Call initializer instance with the dtype argument instead of passing it to the constructor
WARNING:tensorflow:From /usr/local/lib/python3.5/dist-
packages/tensorflow/python/ops/init_ops.py:97: calling Zeros.__init__ (from
tensorflow.python.ops.init_ops) with dtype is deprecated and will be removed in a future version.
Instructions for updating:
Call initializer instance with the dtype argument instead of passing it to the constructor
WARNING:tensorflow:From /usr/local/lib/python3.5/dist-
packages/tensorflow/python/ops/init_ops.py:97: calling Ones.__init__ (from
tensorflow.python.ops.init_ops) with dtype is deprecated and will be removed in a future version.
Instructions for updating:
Call initializer instance with the dtype argument instead of passing it to the constructor
WARNING:tensorflow:From /usr/local/lib/python3.5/dist-
packages/tensorflow/python/ops/math_grad.py:1250: add_dispatch_support.<locals>.wrapper (from
tensorflow.python.ops.array_ops) is deprecated and will be removed in a future version.
Instructions for updating:
```

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

In [24]:

```
model.fit_generator(datagen.flow(X_train, y_train_re, batch_size=batch_size),
                    steps_per_epoch=X_train.shape[0] // batch_size,
                    epochs=100,
                    verbose=1,
                    validation_data=(X_test, y_test_re),callbacks=callbacks_list, initial_epoch=26)
```

```
Epoch 27/100
780/781 [============================>.] - ETA: 0s - loss: 0.1915 - acc: 0.9328
Epoch 00027: saving model to epochs:027-val_acc:0.902.hdf5
781/781 [==============================] - 144s 184ms/step - loss: 0.1913 - acc: 0.9328 -
val_loss: 0.3185 - val_acc: 0.9017
Epoch 28/100
780/781 [============================>.] - ETA: 0s - loss: 0.1796 - acc: 0.9379
Epoch 00028: saving model to epochs:028-val_acc:0.902.hdf5
781/781 [==============================] - 127s 162ms/step - loss: 0.1795 - acc: 0.9379 -
val_loss: 0.3165 - val_acc: 0.9021
Epoch 29/100
780/781 [============================>.] - ETA: 0s - loss: 0.1752 - acc: 0.9392
Epoch 00029: saving model to epochs:029-val_acc:0.905.hdf5
781/781 [==============================] - 127s 162ms/step - loss: 0.1752 - acc: 0.9391 -
val_loss: 0.3142 - val_acc: 0.9052
Epoch 30/100
780/781 [============================>.] - ETA: 0s - loss: 0.1696 - acc: 0.9407
Epoch 00030: saving model to epochs:030-val_acc:0.904.hdf5
781/781 [==============================] - 127s 163ms/step - loss: 0.1695 - acc: 0.9407 -
val_loss: 0.3111 - val_acc: 0.9044
Epoch 31/100
780/781 [============================>.] - ETA: 0s - loss: 0.1641 - acc: 0.9429
Epoch 00031: saving model to epochs:031-val_acc:0.904.hdf5
781/781 [==============================] - 127s 163ms/step - loss: 0.1640 - acc: 0.9429 -
val_loss: 0.3155 - val_acc: 0.9040
Epoch 32/100
780/781 [============================>.] - ETA: 0s - loss: 0.1589 - acc: 0.9453
Epoch 00032: saving model to epochs:032-val_acc:0.903.hdf5
781/781 [==============================] - 127s 163ms/step - loss: 0.1590 - acc: 0.9453 -
val_loss: 0.3259 - val_acc: 0.9031
Epoch 33/100
780/781 [============================>.] - ETA: 0s - loss: 0.1578 - acc: 0.9444
Epoch 00033: saving model to epochs:033-val_acc:0.904.hdf5
781/781 [==============================] - 127s 163ms/step - loss: 0.1580 - acc: 0.9443 -
val_loss: 0.3252 - val_acc: 0.9042
Epoch 34/100
780/781 [============================>.] - ETA: 0s - loss: 0.1499 - acc: 0.9469
Epoch 00034: ReduceLROnPlateau reducing learning rate to 1.0000000474974514e-05.

Epoch 00034: saving model to epochs:034-val_acc:0.906.hdf5
781/781 [==============================] - 128s 164ms/step - loss: 0.1499 - acc: 0.9470 -
val_loss: 0.3187 - val_acc: 0.9057
Epoch 35/100
780/781 [============================>.] - ETA: 0s - loss: 0.1458 - acc: 0.9482
Epoch 00035: saving model to epochs:035-val_acc:0.908.hdf5
781/781 [==============================] - 127s 163ms/step - loss: 0.1458 - acc: 0.9482 -
val_loss: 0.3098 - val_acc: 0.9075
Epoch 36/100
780/781 [============================>.] - ETA: 0s - loss: 0.1462 - acc: 0.9498
Epoch 00036: saving model to epochs:036-val_acc:0.907.hdf5
781/781 [==============================] - 128s 163ms/step - loss: 0.1462 - acc: 0.9498 -
val_loss: 0.3088 - val_acc: 0.9071
Epoch 37/100
780/781 [============================>.] - ETA: 0s - loss: 0.1436 - acc: 0.9495
Epoch 00037: saving model to epochs:037-val_acc:0.908.hdf5
781/781 [==============================] - 128s 163ms/step - loss: 0.1435 - acc: 0.9495 -
val_loss: 0.3077 - val_acc: 0.9083
Epoch 38/100
780/781 [============================>.] - ETA: 0s - loss: 0.1416 - acc: 0.9499
Epoch 00038: saving model to epochs:038-val_acc:0.907.hdf5
781/781 [==============================] - 127s 163ms/step - loss: 0.1417 - acc: 0.9499 -
val_loss: 0.3097 - val_acc: 0.9074
Epoch 39/100
780/781 [============================>.] - ETA: 0s - loss: 0.1412 - acc: 0.9510
Epoch 00039: saving model to epochs:039-val_acc:0.909.hdf5
```

```
781/781 [==============================] - 128s 163ms/step - loss: 0.1413 - acc: 0.9510 -
val_loss: 0.3077 - val_acc: 0.9086
Epoch 40/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1413 - acc: 0.9500
Epoch 00040: saving model to epochs:040-val_acc:0.908.hdf5
781/781 [==============================] - 127s 163ms/step - loss: 0.1413 - acc: 0.9501 -
val_loss: 0.3082 - val_acc: 0.9081
Epoch 41/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1390 - acc: 0.9513
Epoch 00041: ReduceLROnPlateau reducing learning rate to 1.0000000656873453e-06.

Epoch 00041: saving model to epochs:041-val_acc:0.909.hdf5
781/781 [==============================] - 127s 163ms/step - loss: 0.1389 - acc: 0.9513 -
val_loss: 0.3102 - val_acc: 0.9087
Epoch 42/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1417 - acc: 0.9501
Epoch 00042: saving model to epochs:042-val_acc:0.909.hdf5
781/781 [==============================] - 127s 163ms/step - loss: 0.1417 - acc: 0.9501 -
val_loss: 0.3119 - val_acc: 0.9085
Epoch 43/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1395 - acc: 0.9514
Epoch 00043: saving model to epochs:043-val_acc:0.908.hdf5
781/781 [==============================] - 127s 163ms/step - loss: 0.1395 - acc: 0.9515 -
val_loss: 0.3106 - val_acc: 0.9082
Epoch 44/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1402 - acc: 0.9507
Epoch 00044: saving model to epochs:044-val_acc:0.909.hdf5
781/781 [==============================] - 127s 163ms/step - loss: 0.1402 - acc: 0.9507 -
val_loss: 0.3099 - val_acc: 0.9092
Epoch 45/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1337 - acc: 0.9534
Epoch 00045: ReduceLROnPlateau reducing learning rate to 1.0000001111620805e-07.

Epoch 00045: saving model to epochs:045-val_acc:0.909.hdf5
781/781 [==============================] - 127s 163ms/step - loss: 0.1336 - acc: 0.9534 -
val_loss: 0.3104 - val_acc: 0.9089
Epoch 46/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1370 - acc: 0.9532
Epoch 00046: saving model to epochs:046-val_acc:0.908.hdf5
781/781 [==============================] - 127s 163ms/step - loss: 0.1370 - acc: 0.9532 -
val_loss: 0.3099 - val_acc: 0.9081
Epoch 47/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1387 - acc: 0.9515
Epoch 00047: saving model to epochs:047-val_acc:0.909.hdf5
781/781 [==============================] - 128s 163ms/step - loss: 0.1387 - acc: 0.9515 -
val_loss: 0.3096 - val_acc: 0.9090
Epoch 48/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1378 - acc: 0.9534
Epoch 00048: saving model to epochs:048-val_acc:0.909.hdf5
781/781 [==============================] - 128s 163ms/step - loss: 0.1379 - acc: 0.9534 -
val_loss: 0.3106 - val_acc: 0.9087
Epoch 49/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1412 - acc: 0.9512
Epoch 00049: ReduceLROnPlateau reducing learning rate to 1.000000082740371e-08.

Epoch 00049: saving model to epochs:049-val_acc:0.909.hdf5
781/781 [==============================] - 128s 163ms/step - loss: 0.1413 - acc: 0.9512 -
val_loss: 0.3091 - val_acc: 0.9087
Epoch 50/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1389 - acc: 0.9514
Epoch 00050: saving model to epochs:050-val_acc:0.909.hdf5
781/781 [==============================] - 128s 163ms/step - loss: 0.1388 - acc: 0.9514 -
val_loss: 0.3107 - val_acc: 0.9088
Epoch 51/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1358 - acc: 0.9536
Epoch 00051: saving model to epochs:051-val_acc:0.909.hdf5
781/781 [==============================] - 127s 163ms/step - loss: 0.1358 - acc: 0.9535 -
val_loss: 0.3088 - val_acc: 0.9086
Epoch 52/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1399 - acc: 0.9511
Epoch 00052: saving model to epochs:052-val_acc:0.908.hdf5
781/781 [==============================] - 127s 163ms/step - loss: 0.1398 - acc: 0.9511 -
val_loss: 0.3092 - val_acc: 0.9083
Epoch 53/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1359 - acc: 0.9531
Epoch 00053: ReduceLROnPlateau reducing learning rate to 1.000000082740371e-09.
```

```
Epoch 00053: saving model to epochs:053-val_acc:0.908.hdf5
781/781 [==============================] - 127s 163ms/step - loss: 0.1359 - acc: 0.9531 -
val_loss: 0.3096 - val_acc: 0.9081
Epoch 54/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1366 - acc: 0.9534
Epoch 00054: saving model to epochs:054-val_acc:0.909.hdf5
781/781 [==============================] - 127s 163ms/step - loss: 0.1365 - acc: 0.9535 -
val_loss: 0.3101 - val_acc: 0.9087
Epoch 55/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1367 - acc: 0.9522
Epoch 00055: saving model to epochs:055-val_acc:0.908.hdf5
781/781 [==============================] - 127s 163ms/step - loss: 0.1367 - acc: 0.9522 -
val_loss: 0.3102 - val_acc: 0.9082
Epoch 56/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1368 - acc: 0.9522
Epoch 00056: saving model to epochs:056-val_acc:0.909.hdf5
781/781 [==============================] - 127s 163ms/step - loss: 0.1368 - acc: 0.9522 -
val_loss: 0.3088 - val_acc: 0.9091
Epoch 57/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1346 - acc: 0.9527
Epoch 00057: ReduceLROnPlateau reducing learning rate to 1.000000082740371e-10.

Epoch 00057: saving model to epochs:057-val_acc:0.909.hdf5
781/781 [==============================] - 127s 163ms/step - loss: 0.1347 - acc: 0.9527 -
val_loss: 0.3091 - val_acc: 0.9090
Epoch 58/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1371 - acc: 0.9536
Epoch 00058: saving model to epochs:058-val_acc:0.908.hdf5
781/781 [==============================] - 127s 163ms/step - loss: 0.1370 - acc: 0.9536 -
val_loss: 0.3102 - val_acc: 0.9081
Epoch 59/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1372 - acc: 0.9521
Epoch 00059: saving model to epochs:059-val_acc:0.908.hdf5
781/781 [==============================] - 127s 163ms/step - loss: 0.1372 - acc: 0.9521 -
val_loss: 0.3118 - val_acc: 0.9082
Epoch 60/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1378 - acc: 0.9510
Epoch 00060: saving model to epochs:060-val_acc:0.910.hdf5
781/781 [==============================] - 127s 163ms/step - loss: 0.1378 - acc: 0.9510 -
val_loss: 0.3090 - val_acc: 0.9095
Epoch 61/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1374 - acc: 0.9533
Epoch 00061: ReduceLROnPlateau reducing learning rate to 1.000000082740371e-11.

Epoch 00061: saving model to epochs:061-val_acc:0.909.hdf5
781/781 [==============================] - 128s 163ms/step - loss: 0.1373 - acc: 0.9533 -
val_loss: 0.3096 - val_acc: 0.9085
Epoch 62/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1383 - acc: 0.9534
Epoch 00062: saving model to epochs:062-val_acc:0.909.hdf5
781/781 [==============================] - 128s 163ms/step - loss: 0.1383 - acc: 0.9534 -
val_loss: 0.3094 - val_acc: 0.9086
Epoch 63/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1366 - acc: 0.9526
Epoch 00063: saving model to epochs:063-val_acc:0.909.hdf5
781/781 [==============================] - 128s 163ms/step - loss: 0.1366 - acc: 0.9526 -
val_loss: 0.3107 - val_acc: 0.9088
Epoch 64/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1355 - acc: 0.9521
Epoch 00064: saving model to epochs:064-val_acc:0.909.hdf5
781/781 [==============================] - 131s 168ms/step - loss: 0.1353 - acc: 0.9521 -
val_loss: 0.3099 - val_acc: 0.9088
Epoch 65/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1394 - acc: 0.9512
Epoch 00065: ReduceLROnPlateau reducing learning rate to 1.000000082740371e-12.

Epoch 00065: saving model to epochs:065-val_acc:0.909.hdf5
781/781 [==============================] - 128s 164ms/step - loss: 0.1393 - acc: 0.9512 -
val_loss: 0.3093 - val_acc: 0.9090
Epoch 66/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1357 - acc: 0.9520
Epoch 00066: saving model to epochs:066-val_acc:0.909.hdf5
781/781 [==============================] - 128s 164ms/step - loss: 0.1357 - acc: 0.9520 -
val_loss: 0.3098 - val_acc: 0.9091
Epoch 67/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1336 - acc: 0.9537
Epoch 00067: saving model to epochs:067-val_acc:0.909.hdf5
```

```
781/781 [==============================] - 128s 163ms/step - loss: 0.1336 - acc: 0.9536 -
val_loss: 0.3110 - val_acc: 0.9088
Epoch 68/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1361 - acc: 0.9523
Epoch 00068: saving model to epochs:068-val_acc:0.909.hdf5
781/781 [==============================] - 128s 163ms/step - loss: 0.1361 - acc: 0.9524 -
val_loss: 0.3095 - val_acc: 0.9088
Epoch 69/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1437 - acc: 0.9506
Epoch 00069: ReduceLROnPlateau reducing learning rate to 1.0000001044244145e-13.

Epoch 00069: saving model to epochs:069-val_acc:0.908.hdf5
781/781 [==============================] - 127s 163ms/step - loss: 0.1437 - acc: 0.9506 -
val_loss: 0.3105 - val_acc: 0.9081
Epoch 70/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1371 - acc: 0.9524
Epoch 00070: saving model to epochs:070-val_acc:0.909.hdf5
781/781 [==============================] - 127s 163ms/step - loss: 0.1370 - acc: 0.9524 -
val_loss: 0.3086 - val_acc: 0.9087
Epoch 71/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1394 - acc: 0.9518
Epoch 00071: saving model to epochs:071-val_acc:0.909.hdf5
781/781 [==============================] - 128s 163ms/step - loss: 0.1394 - acc: 0.9518 -
val_loss: 0.3087 - val_acc: 0.9087
Epoch 72/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1378 - acc: 0.9515
Epoch 00072: saving model to epochs:072-val_acc:0.908.hdf5
781/781 [==============================] - 127s 163ms/step - loss: 0.1378 - acc: 0.9515 -
val_loss: 0.3105 - val_acc: 0.9081
Epoch 73/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1385 - acc: 0.9511
Epoch 00073: ReduceLROnPlateau reducing learning rate to 1.0000001179769417e-14.

Epoch 00073: saving model to epochs:073-val_acc:0.908.hdf5
781/781 [==============================] - 128s 164ms/step - loss: 0.1384 - acc: 0.9511 -
val_loss: 0.3133 - val_acc: 0.9079
Epoch 74/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1406 - acc: 0.9505
Epoch 00074: saving model to epochs:074-val_acc:0.909.hdf5
781/781 [==============================] - 128s 163ms/step - loss: 0.1405 - acc: 0.9505 -
val_loss: 0.3097 - val_acc: 0.9091
Epoch 75/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1375 - acc: 0.9522
Epoch 00075: saving model to epochs:075-val_acc:0.908.hdf5
781/781 [==============================] - 128s 163ms/step - loss: 0.1376 - acc: 0.9522 -
val_loss: 0.3110 - val_acc: 0.9084
Epoch 76/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1390 - acc: 0.9520
Epoch 00076: saving model to epochs:076-val_acc:0.909.hdf5
781/781 [==============================] - 127s 163ms/step - loss: 0.1389 - acc: 0.9520 -
val_loss: 0.3100 - val_acc: 0.9086
Epoch 77/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1382 - acc: 0.9524
Epoch 00077: ReduceLROnPlateau reducing learning rate to 1.0000001518582595e-15.

Epoch 00077: saving model to epochs:077-val_acc:0.909.hdf5
781/781 [==============================] - 127s 163ms/step - loss: 0.1382 - acc: 0.9524 -
val_loss: 0.3106 - val_acc: 0.9090
Epoch 78/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1394 - acc: 0.9519
Epoch 00078: saving model to epochs:078-val_acc:0.908.hdf5
781/781 [==============================] - 128s 163ms/step - loss: 0.1396 - acc: 0.9519 -
val_loss: 0.3105 - val_acc: 0.9083
Epoch 79/100
780/781 [==============================>.] - ETA: 0s - loss: 0.1405 - acc: 0.9512
Epoch 00079: saving model to epochs:079-val_acc:0.909.hdf5
781/781 [==============================] - 127s 163ms/step - loss: 0.1404 - acc: 0.9513 -
val_loss: 0.3116 - val_acc: 0.9088
Epoch 00079: early stopping
```

Out[24]:

```
<tensorflow.python.keras.callbacks.History at 0x7ff6c6819fd0>
```

In [26]:

```
# Test the model
score = model.evaluate(X_test, y_test_re, verbose=1)
print('Test loss:', score[0])
print('Test accuracy:', score[1])
```

```
10000/10000 [==============================] - 7s 652us/sample - loss: 0.3113 - acc: 0.9088
Test loss: 0.31126459009647367
Test accuracy: 0.9088
```

In [27]:

```
# Save the trained weights in to .h5 format
model.save_weights("DNST_model.h5")
print("Saved model to disk")
```

```
Saved model to disk
```