In [1]:

```
import warnings
warnings.filterwarnings('ignore')
import tensorflow as tf
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, Fl
from tensorflow.python.keras.optimizers import Adam
from keras.preprocessing.image import ImageDataGenerator
import numpy as np
import os
```

```
Using TensorFlow backend.
```

In [2]:

```
# Hyperparameters
batch_size = 64
num_classes = 10
epochs = 10
l = 40
compression = 0.55
dropout_rate = 0.2
```

In [3]:

```
# 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.sh

# 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 [4]:

```
X_train.shape
```

Out[4]:

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

In [5]:

```
X_test.shape
```

Out[5]:

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

In [7]:

```
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 [8]:

```
#
# 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
        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), (
    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,paddin
    return output
```

In [9]:

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

In [11]:

```
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, padd

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 c:\users\addu\appdata\local\programs\p
ython\python37\lib\site-packages\tensorflow\python\ops\init_op
s.py:1251: calling VarianceScaling.__init__ (from tensorflow.p
ython.ops.init_ops) with dtype is deprecated and will be remov
ed in a future version.
Instructions for updating:
Call initializer instance with the dtype argument instead of p
assing it to the constructor
```

In [12]:

```
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]
__________________________________________________________________________
__________________________________________
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]
__________________________________________________________________________
_____________________________________
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]
__________________________________________________________________
_______________________________________
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 [13]:

```
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 [14]:

```
from tensorflow.python.keras.callbacks import ModelCheckpoint, EarlyStopping,
```

In [15]:

```
filepath="weights-improvement-{epoch:02d}-{val_acc:.2f}.hdf5"
checkpoint_1 = ModelCheckpoint(filepath, monitor='val_acc', verbose=1, mode='
```

In [16]:

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

In [17]:

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

In [18]:

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

In [19]:

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

In [20]:

```
# 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 [21]:

```
history = model.fit_generator(datagen.flow(X_train, y_train_re, batch_size=ba
                    steps_per_epoch=X_train.shape[0] // batch_size,
                    epochs=100,
                    verbose=2,
                    validation_data=(X_test, y_test_re),callbacks=callbacks_
```

```
Epoch 1/100
WARNING:tensorflow:From c:\users\addu\appdata\local\programs\p
ython\python37\lib\site-packages\tensorflow\python\ops\math_gr
ad.py:1250: add_dispatch_support.<locals>.wrapper (from tensor
flow.python.ops.array_ops) is deprecated and will be removed i
n a future version.
Instructions for updating:
Use tf.where in 2.0, which has the same broadcast rule as np.w
here

Epoch 00001: saving model to weights-improvement-01-0.49.hdf5
781/781 - 115s - loss: 1.6273 - acc: 0.3934 - val_loss: 1.4025
- val_acc: 0.4926
Epoch 2/100

Epoch 00002: saving model to weights-improvement-02-0.58.hdf5
781/781 - 106s - loss: 1.1767 - acc: 0.5819 - val_loss: 1.2740
- val_acc: 0.5768
Epoch 3/100

Epoch 00003: saving model to weights-improvement-03-0.63.hdf5
781/781 - 109s - loss: 0.9644 - acc: 0.6608 - val_loss: 1.1408
- val_acc: 0.6313
Epoch 4/100

Epoch 00004: saving model to weights-improvement-04-0.70.hdf5
781/781 - 101s - loss: 0.8385 - acc: 0.7094 - val_loss: 0.9185
- val_acc: 0.6954
Epoch 5/100

Epoch 00005: saving model to weights-improvement-05-0.71.hdf5
781/781 - 101s - loss: 0.7522 - acc: 0.7385 - val_loss: 0.9352
- val_acc: 0.7057
Epoch 6/100

Epoch 00006: saving model to weights-improvement-06-0.72.hdf5
781/781 - 101s - loss: 0.6856 - acc: 0.7621 - val_loss: 0.8337
- val_acc: 0.7202
Epoch 7/100

Epoch 00007: saving model to weights-improvement-07-0.72.hdf5
781/781 - 101s - loss: 0.6341 - acc: 0.7794 - val_loss: 0.8199
- val_acc: 0.7237
Epoch 8/100
```

```
Epoch 00008: saving model to weights-improvement-08-0.78.hdf5
781/781 - 101s - loss: 0.5852 - acc: 0.7949 - val_loss: 0.6451
- val_acc: 0.7846
Epoch 9/100

Epoch 00009: saving model to weights-improvement-09-0.80.hdf5
781/781 - 102s - loss: 0.5534 - acc: 0.8084 - val_loss: 0.5858
- val_acc: 0.7970
Epoch 10/100

Epoch 00010: saving model to weights-improvement-10-0.78.hdf5
781/781 - 102s - loss: 0.5156 - acc: 0.8204 - val_loss: 0.6887
- val_acc: 0.7794
Epoch 11/100

Epoch 00011: saving model to weights-improvement-11-0.82.hdf5
781/781 - 101s - loss: 0.4938 - acc: 0.8286 - val_loss: 0.5578
- val_acc: 0.8189
Epoch 12/100

Epoch 00012: saving model to weights-improvement-12-0.81.hdf5
781/781 - 101s - loss: 0.4671 - acc: 0.8371 - val_loss: 0.5667
- val_acc: 0.8123
Epoch 13/100

Epoch 00013: saving model to weights-improvement-13-0.83.hdf5
781/781 - 101s - loss: 0.4413 - acc: 0.8473 - val_loss: 0.5197
- val_acc: 0.8296
Epoch 14/100

Epoch 00014: saving model to weights-improvement-14-0.84.hdf5
781/781 - 101s - loss: 0.4293 - acc: 0.8512 - val_loss: 0.5088
- val_acc: 0.8384
Epoch 15/100

Epoch 00015: saving model to weights-improvement-15-0.82.hdf5
781/781 - 101s - loss: 0.4143 - acc: 0.8549 - val_loss: 0.5425
- val_acc: 0.8236
Epoch 16/100

Epoch 00016: saving model to weights-improvement-16-0.83.hdf5
781/781 - 101s - loss: 0.3955 - acc: 0.8621 - val_loss: 0.5230
- val_acc: 0.8299
Epoch 17/100

Epoch 00017: saving model to weights-improvement-17-0.84.hdf5
781/781 - 101s - loss: 0.3767 - acc: 0.8692 - val_loss: 0.5008
- val_acc: 0.8386
Epoch 18/100

Epoch 00018: saving model to weights-improvement-18-0.86.hdf5
781/781 - 101s - loss: 0.3635 - acc: 0.8751 - val_loss: 0.4452
```

```
- val_acc: 0.8565
Epoch 19/100

Epoch 00019: saving model to weights-improvement-19-0.86.hdf5
781/781 - 101s - loss: 0.3544 - acc: 0.8776 - val_loss: 0.4156
- val_acc: 0.8602
Epoch 20/100

Epoch 00020: saving model to weights-improvement-20-0.86.hdf5
781/781 - 101s - loss: 0.3423 - acc: 0.8806 - val_loss: 0.4210
- val_acc: 0.8606
Epoch 21/100

Epoch 00021: saving model to weights-improvement-21-0.86.hdf5
781/781 - 102s - loss: 0.3282 - acc: 0.8858 - val_loss: 0.4181
- val_acc: 0.8620
Epoch 22/100

Epoch 00022: saving model to weights-improvement-22-0.88.hdf5
781/781 - 101s - loss: 0.3174 - acc: 0.8894 - val_loss: 0.3663
- val_acc: 0.8813
Epoch 23/100

Epoch 00023: saving model to weights-improvement-23-0.85.hdf5
781/781 - 101s - loss: 0.3070 - acc: 0.8928 - val_loss: 0.4768
- val_acc: 0.8516
Epoch 24/100

Epoch 00024: saving model to weights-improvement-24-0.85.hdf5
781/781 - 103s - loss: 0.2977 - acc: 0.8958 - val_loss: 0.4744
- val_acc: 0.8532
Epoch 25/100

Epoch 00025: saving model to weights-improvement-25-0.84.hdf5
781/781 - 102s - loss: 0.2871 - acc: 0.8991 - val_loss: 0.5175
- val_acc: 0.8416
Epoch 26/100

Epoch 00026: ReduceLROnPlateau reducing learning rate to 0.000
10000000474974513.

Epoch 00026: saving model to weights-improvement-26-0.86.hdf5
781/781 - 101s - loss: 0.2771 - acc: 0.9026 - val_loss: 0.4370
- val_acc: 0.8614
Epoch 27/100

Epoch 00027: saving model to weights-improvement-27-0.90.hdf5
781/781 - 101s - loss: 0.2141 - acc: 0.9256 - val_loss: 0.3077
- val_acc: 0.9011
Epoch 28/100

Epoch 00028: saving model to weights-improvement-28-0.91.hdf5
781/781 - 101s - loss: 0.1873 - acc: 0.9355 - val_loss: 0.2864
```

```
- val_acc: 0.9084
Epoch 29/100

Epoch 00029: saving model to weights-improvement-29-0.90.hdf5
781/781 - 101s - loss: 0.1781 - acc: 0.9388 - val_loss: 0.3104
- val_acc: 0.9029
Epoch 30/100

Epoch 00030: saving model to weights-improvement-30-0.90.hdf5
781/781 - 101s - loss: 0.1670 - acc: 0.9419 - val_loss: 0.3119
- val_acc: 0.9037
Epoch 31/100

Epoch 00031: saving model to weights-improvement-31-0.91.hdf5
781/781 - 101s - loss: 0.1624 - acc: 0.9444 - val_loss: 0.3107
- val_acc: 0.9058
Epoch 32/100

Epoch 00032: ReduceLROnPlateau reducing learning rate to 1.000
0000474974514e-05.

Epoch 00032: saving model to weights-improvement-32-0.90.hdf5
781/781 - 101s - loss: 0.1591 - acc: 0.9452 - val_loss: 0.3129
- val_acc: 0.9046
Epoch 33/100

Epoch 00033: saving model to weights-improvement-33-0.91.hdf5
781/781 - 101s - loss: 0.1508 - acc: 0.9468 - val_loss: 0.3057
- val_acc: 0.9085
Epoch 34/100

Epoch 00034: saving model to weights-improvement-34-0.91.hdf5
781/781 - 101s - loss: 0.1501 - acc: 0.9470 - val_loss: 0.3020
- val_acc: 0.9092
Epoch 35/100

Epoch 00035: saving model to weights-improvement-35-0.91.hdf5
781/781 - 101s - loss: 0.1484 - acc: 0.9489 - val_loss: 0.3024
- val_acc: 0.9091
Epoch 36/100

Epoch 00036: ReduceLROnPlateau reducing learning rate to 1.000
0000656873453e-06.

Epoch 00036: saving model to weights-improvement-36-0.91.hdf5
781/781 - 101s - loss: 0.1476 - acc: 0.9494 - val_loss: 0.3028
- val_acc: 0.9081
Epoch 37/100

Epoch 00037: saving model to weights-improvement-37-0.91.hdf5
781/781 - 101s - loss: 0.1413 - acc: 0.9507 - val_loss: 0.3018
- val_acc: 0.9087
Epoch 38/100
```

```
Epoch 00038: saving model to weights-improvement-38-0.91.hdf5
781/781 - 101s - loss: 0.1489 - acc: 0.9474 - val_loss: 0.3008
- val_acc: 0.9087
Epoch 39/100

Epoch 00039: saving model to weights-improvement-39-0.91.hdf5
781/781 - 101s - loss: 0.1456 - acc: 0.9500 - val_loss: 0.3008
- val_acc: 0.9084
Epoch 40/100

Epoch 00040: ReduceLROnPlateau reducing learning rate to 1.000
0001111620805e-07.

Epoch 00040: saving model to weights-improvement-40-0.91.hdf5
781/781 - 101s - loss: 0.1454 - acc: 0.9496 - val_loss: 0.3009
- val_acc: 0.9092
Epoch 41/100

Epoch 00041: saving model to weights-improvement-41-0.91.hdf5
781/781 - 101s - loss: 0.1446 - acc: 0.9492 - val_loss: 0.3018
- val_acc: 0.9084
Epoch 42/100

Epoch 00042: saving model to weights-improvement-42-0.91.hdf5
781/781 - 101s - loss: 0.1452 - acc: 0.9496 - val_loss: 0.3035
- val_acc: 0.9082
Epoch 43/100

Epoch 00043: saving model to weights-improvement-43-0.91.hdf5
781/781 - 101s - loss: 0.1427 - acc: 0.9507 - val_loss: 0.3012
- val_acc: 0.9089
Epoch 44/100

Epoch 00044: ReduceLROnPlateau reducing learning rate to 1.000
000082740371e-08.

Epoch 00044: saving model to weights-improvement-44-0.91.hdf5
781/781 - 101s - loss: 0.1493 - acc: 0.9487 - val_loss: 0.3034
- val_acc: 0.9083
Epoch 45/100

Epoch 00045: saving model to weights-improvement-45-0.91.hdf5
781/781 - 101s - loss: 0.1458 - acc: 0.9482 - val_loss: 0.2996
- val_acc: 0.9092
Epoch 46/100

Epoch 00046: saving model to weights-improvement-46-0.91.hdf5
781/781 - 101s - loss: 0.1443 - acc: 0.9492 - val_loss: 0.3015
- val_acc: 0.9089
Epoch 47/100

Epoch 00047: saving model to weights-improvement-47-0.91.hdf5
```

```
781/781 - 101s - loss: 0.1446 - acc: 0.9501 - val_loss: 0.3008
- val_acc: 0.9090
Epoch 48/100

Epoch 00048: ReduceLROnPlateau reducing learning rate to 1.000
000082740371e-09.

Epoch 00048: saving model to weights-improvement-48-0.91.hdf5

781/781 - 101s - loss: 0.1457 - acc: 0.9489 - val_loss: 0.3012
- val_acc: 0.9083
Epoch 49/100

Epoch 00049: saving model to weights-improvement-49-0.91.hdf5
781/781 - 101s - loss: 0.1437 - acc: 0.9496 - val_loss: 0.3002
- val_acc: 0.9088
Epoch 50/100

Epoch 00050: saving model to weights-improvement-50-0.91.hdf5
781/781 - 107s - loss: 0.1438 - acc: 0.9504 - val_loss: 0.3000
- val_acc: 0.9092
Epoch 51/100

Epoch 00051: saving model to weights-improvement-51-0.91.hdf5
781/781 - 107s - loss: 0.1459 - acc: 0.9500 - val_loss: 0.3047
- val_acc: 0.9070
Epoch 52/100

Epoch 00052: ReduceLROnPlateau reducing learning rate to 1.000
000082740371e-10.

Epoch 00052: saving model to weights-improvement-52-0.91.hdf5
781/781 - 102s - loss: 0.1446 - acc: 0.9495 - val_loss: 0.3031
- val_acc: 0.9076
Epoch 53/100

Epoch 00053: saving model to weights-improvement-53-0.91.hdf5
781/781 - 106s - loss: 0.1439 - acc: 0.9503 - val_loss: 0.2994
- val_acc: 0.9097
Epoch 54/100

Epoch 00054: saving model to weights-improvement-54-0.91.hdf5
781/781 - 106s - loss: 0.1446 - acc: 0.9495 - val_loss: 0.3015
- val_acc: 0.9086
Epoch 55/100

Epoch 00055: saving model to weights-improvement-55-0.91.hdf5
781/781 - 106s - loss: 0.1461 - acc: 0.9480 - val_loss: 0.3024
- val_acc: 0.9089
Epoch 56/100

Epoch 00056: ReduceLROnPlateau reducing learning rate to 1.000
000082740371e-11.
```

```
Epoch 00056: saving model to weights-improvement-56-0.91.hdf5
781/781 - 107s - loss: 0.1462 - acc: 0.9492 - val_loss: 0.3012
- val_acc: 0.9083
Epoch 57/100

Epoch 00057: saving model to weights-improvement-57-0.91.hdf5
781/781 - 106s - loss: 0.1449 - acc: 0.9505 - val_loss: 0.3023
- val_acc: 0.9088
Epoch 58/100

Epoch 00058: saving model to weights-improvement-58-0.91.hdf5
781/781 - 106s - loss: 0.1445 - acc: 0.9491 - val_loss: 0.3021
- val_acc: 0.9089
Epoch 59/100

Epoch 00059: saving model to weights-improvement-59-0.91.hdf5
781/781 - 107s - loss: 0.1459 - acc: 0.9485 - val_loss: 0.3023
- val_acc: 0.9084
Epoch 60/100

Epoch 00060: ReduceLROnPlateau reducing learning rate to 1.000
000082740371e-12.

Epoch 00060: saving model to weights-improvement-60-0.91.hdf5
781/781 - 107s - loss: 0.1468 - acc: 0.9489 - val_loss: 0.3016
- val_acc: 0.9091
Epoch 61/100

Epoch 00061: saving model to weights-improvement-61-0.91.hdf5
781/781 - 107s - loss: 0.1451 - acc: 0.9490 - val_loss: 0.3023
- val_acc: 0.9081
Epoch 62/100

Epoch 00062: saving model to weights-improvement-62-0.91.hdf5
781/781 - 106s - loss: 0.1421 - acc: 0.9502 - val_loss: 0.3008
- val_acc: 0.9085
Epoch 63/100

Epoch 00063: saving model to weights-improvement-63-0.91.hdf5
781/781 - 106s - loss: 0.1442 - acc: 0.9498 - val_loss: 0.3014
- val_acc: 0.9088
Epoch 64/100

Epoch 00064: ReduceLROnPlateau reducing learning rate to 1.000
0001044244145e-13.

Epoch 00064: saving model to weights-improvement-64-0.91.hdf5
781/781 - 131s - loss: 0.1457 - acc: 0.9480 - val_loss: 0.3023
- val_acc: 0.9089
Epoch 65/100

Epoch 00065: saving model to weights-improvement-65-0.91.hdf5
```

```
781/781 - 115s - loss: 0.1415 - acc: 0.9511 - val_loss: 0.3004
- val_acc: 0.9090
Epoch 66/100

Epoch 00066: saving model to weights-improvement-66-0.91.hdf5
781/781 - 103s - loss: 0.1411 - acc: 0.9511 - val_loss: 0.3045
- val_acc: 0.9079
Epoch 67/100

Epoch 00067: saving model to weights-improvement-67-0.91.hdf5
781/781 - 101s - loss: 0.1454 - acc: 0.9485 - val_loss: 0.3010
- val_acc: 0.9091
Epoch 68/100

Epoch 00068: ReduceLROnPlateau reducing learning rate to 1.000
0001179769417e-14.

Epoch 00068: saving model to weights-improvement-68-0.91.hdf5
781/781 - 101s - loss: 0.1433 - acc: 0.9496 - val_loss: 0.3024
- val_acc: 0.9088
Epoch 00068: early stopping
```

In [24]:

```
# 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 [==============================] - 5s 549us/sample
- loss: 0.3026 - acc: 0.9088
Test loss: 0.3025546526670456
Test accuracy: 0.9088
```

In [25]:

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

```
Saved model to disk
```

Summary

- Applied DenseNet architecture on CIFR10 dataset
- Tuned the architecture
- Obtained a test accuracy of 90.88