In [ ]:

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

In [1]:

```
import tensorflow as tf
from tensorflow import keras
from keras.datasets import cifar10
from tensorflow.keras import models, layers
from tensorflow.keras.models import Model
from tensorflow.keras.layers import BatchNormalization, Activation, Flatten, Dense, Dro
pout, Flatten, Conv2D, MaxPooling2D, Concatenate, SeparableConv2D
from tensorflow.keras.optimizers import Adam
from keras.preprocessing.image import ImageDataGenerator

import pandas as pd
import matplotlib.pyplot as plt
import numpy as np
```

In [31]:

```
# Hyperparameters
batch_size = 32
num_classes = 10
epochs = 10
l = 12
num_filter = 18
compression = 1
dropout_rate = 0
```

In [32]:

```
# 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 [33]:

```
X_train = X_train.astype('float32')
X_test = X_test.astype('float32')
X_train /= 255
X_test /= 255

print(X_train.shape)
print(X_test.shape)
```

```
(50000, 32, 32, 3)
(10000, 32, 32, 3)
```

Image Augmentation

In [6]:

```
aug = ImageDataGenerator(shear_range=0.2,
                         zoom_range=0.2,
                         height_shift_range=0.1,
                         horizontal_flip=True)
```

Model Building and Training

In [45]:

```
# Dense Block
def denseblock(input, num_filter = 48, dropout_rate = 0.0):
    global compression
    temp = input
    for _ in range(l):
        BatchNorm = layers.BatchNormalization()(temp)
        relu = layers.Activation('relu')(BatchNorm)
        Conv2D_3_3 = layers.Conv2D(int(num_filter*compression), (3,3), use_bias=False ,padding='same')(relu)
        concat = layers.Concatenate(axis=-1)([temp,Conv2D_3_3])
        temp = concat

    return temp

## transition Blosck
def transition(input, num_filter = 48, dropout_rate = 0.0):
    global compression
    BatchNorm = layers.BatchNormalization()(input)
    relu = layers.Activation('relu')(BatchNorm)
    Conv2D_BottleNeck = layers.Conv2D(int(num_filter*compression), (1,1), use_bias=False ,padding='same')(relu)
    avg = layers.AveragePooling2D(pool_size=(2,2))(Conv2D_BottleNeck)
    return avg

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

In [46]:

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

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

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

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

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

In [47]:

```
model = Model(inputs=[input], outputs=[output])
```

In [48]:

```
model.summary()
```

```
Model: "model_5"
__________________________________________________________________________
________________________
Layer (type)                    Output Shape         Param #     Connected
to
==========================================================================
========================
input_6 (InputLayer)            [(None, 32, 32, 3)]  0
__________________________________________________________________________
________________________
conv2d_312 (Conv2D)             (None, 32, 32, 18)   486         input_6
[0][0]
__________________________________________________________________________
________________________
batch_normalization_312 (BatchN (None, 32, 32, 18)   72          conv2d_31
2[0][0]
__________________________________________________________________________
________________________
activation_312 (Activation)     (None, 32, 32, 18)   0           batch_nor
malization_312[0][0]
__________________________________________________________________________
________________________
conv2d_313 (Conv2D)             (None, 32, 32, 18)   2916        activatio
n_312[0][0]
__________________________________________________________________________
________________________
concatenate_288 (Concatenate)   (None, 32, 32, 36)   0           conv2d_31
2[0][0]
                                                                 conv2d_31
3[0][0]
__________________________________________________________________________
________________________
batch_normalization_313 (BatchN (None, 32, 32, 36)   144         concatena
te_288[0][0]
__________________________________________________________________________
________________________
activation_313 (Activation)     (None, 32, 32, 36)   0           batch_nor
malization_313[0][0]
__________________________________________________________________________
________________________
conv2d_314 (Conv2D)             (None, 32, 32, 18)   5832        activatio
n_313[0][0]
__________________________________________________________________________
________________________
concatenate_289 (Concatenate)   (None, 32, 32, 54)   0           concatena
te_288[0][0]
                                                                 conv2d_31
4[0][0]
__________________________________________________________________________
________________________
batch_normalization_314 (BatchN (None, 32, 32, 54)   216         concatena
te_289[0][0]
__________________________________________________________________________
________________________
activation_314 (Activation)     (None, 32, 32, 54)   0           batch_nor
malization_314[0][0]
__________________________________________________________________________
________________________
conv2d_315 (Conv2D)             (None, 32, 32, 18)   8748        activatio
n_314[0][0]
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________________________
concatenate_290 (Concatenate)   (None, 32, 32, 72)   0           concatena
te_289[0][0]
                                                                 conv2d_31
5[0][0]
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________________________
batch_normalization_315 (BatchN (None, 32, 32, 72)   288         concatena
te_290[0][0]
__________________________________________________________________________
________________________
activation_315 (Activation)     (None, 32, 32, 72)   0           batch_nor
malization_315[0][0]
__________________________________________________________________________
________________________
conv2d_316 (Conv2D)             (None, 32, 32, 18)   11664       activatio
n_315[0][0]
__________________________________________________________________________
________________________
concatenate_291 (Concatenate)   (None, 32, 32, 90)   0           concatena
te_290[0][0]
                                                                 conv2d_31
6[0][0]
__________________________________________________________________________
________________________
batch_normalization_316 (BatchN (None, 32, 32, 90)   360         concatena
te_291[0][0]
__________________________________________________________________________
________________________
activation_316 (Activation)     (None, 32, 32, 90)   0           batch_nor
malization_316[0][0]
__________________________________________________________________________
________________________
conv2d_317 (Conv2D)             (None, 32, 32, 18)   14580       activatio
n_316[0][0]
__________________________________________________________________________
________________________
concatenate_292 (Concatenate)   (None, 32, 32, 108)  0           concatena
te_291[0][0]
                                                                 conv2d_31
7[0][0]
__________________________________________________________________________
________________________
batch_normalization_317 (BatchN (None, 32, 32, 108)  432         concatena
te_292[0][0]
__________________________________________________________________________
________________________
activation_317 (Activation)     (None, 32, 32, 108)  0           batch_nor
malization_317[0][0]
__________________________________________________________________________
________________________
conv2d_318 (Conv2D)             (None, 32, 32, 18)   17496       activatio
n_317[0][0]
__________________________________________________________________________
________________________
concatenate_293 (Concatenate)   (None, 32, 32, 126)  0           concatena
te_292[0][0]
                                                                 conv2d_31
8[0][0]
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batch_normalization_318 (BatchN (None, 32, 32, 126)  504         concatena
te_293[0][0]
__________________________________________________________________________
________________________
activation_318 (Activation)     (None, 32, 32, 126)  0           batch_nor
malization_318[0][0]
__________________________________________________________________________
________________________
conv2d_319 (Conv2D)             (None, 32, 32, 18)   20412       activatio
n_318[0][0]
__________________________________________________________________________
________________________
concatenate_294 (Concatenate)   (None, 32, 32, 144)  0           concatena
te_293[0][0]
                                                                 conv2d_31
9[0][0]
__________________________________________________________________________
________________________
batch_normalization_319 (BatchN (None, 32, 32, 144)  576         concatena
te_294[0][0]
__________________________________________________________________________
________________________
activation_319 (Activation)     (None, 32, 32, 144)  0           batch_nor
malization_319[0][0]
__________________________________________________________________________
________________________
conv2d_320 (Conv2D)             (None, 32, 32, 18)   23328       activatio
n_319[0][0]
__________________________________________________________________________
________________________
concatenate_295 (Concatenate)   (None, 32, 32, 162)  0           concatena
te_294[0][0]
                                                                 conv2d_32
0[0][0]
__________________________________________________________________________
________________________
batch_normalization_320 (BatchN (None, 32, 32, 162)  648         concatena
te_295[0][0]
__________________________________________________________________________
________________________
activation_320 (Activation)     (None, 32, 32, 162)  0           batch_nor
malization_320[0][0]
__________________________________________________________________________
________________________
conv2d_321 (Conv2D)             (None, 32, 32, 18)   26244       activatio
n_320[0][0]
__________________________________________________________________________
________________________
concatenate_296 (Concatenate)   (None, 32, 32, 180)  0           concatena
te_295[0][0]
                                                                 conv2d_32
1[0][0]
__________________________________________________________________________
________________________
batch_normalization_321 (BatchN (None, 32, 32, 180)  720         concatena
te_296[0][0]
__________________________________________________________________________
________________________
activation_321 (Activation)     (None, 32, 32, 180)  0           batch_nor
malization_321[0][0]
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________________________
conv2d_322 (Conv2D)             (None, 32, 32, 18)   29160       activatio
n_321[0][0]

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________________________
concatenate_297 (Concatenate)   (None, 32, 32, 198)  0           concatena
te_296[0][0]
                                                                 conv2d_32
2[0][0]

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________________________
batch_normalization_322 (BatchN (None, 32, 32, 198)  792         concatena
te_297[0][0]

__________________________________________________________________________
________________________
activation_322 (Activation)     (None, 32, 32, 198)  0           batch_nor
malization_322[0][0]

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________________________
conv2d_323 (Conv2D)             (None, 32, 32, 18)   32076       activatio
n_322[0][0]

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________________________
concatenate_298 (Concatenate)   (None, 32, 32, 216)  0           concatena
te_297[0][0]
                                                                 conv2d_32
3[0][0]

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________________________
batch_normalization_323 (BatchN (None, 32, 32, 216)  864         concatena
te_298[0][0]

__________________________________________________________________________
________________________
activation_323 (Activation)     (None, 32, 32, 216)  0           batch_nor
malization_323[0][0]

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________________________
conv2d_324 (Conv2D)             (None, 32, 32, 18)   34992       activatio
n_323[0][0]

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________________________
concatenate_299 (Concatenate)   (None, 32, 32, 234)  0           concatena
te_298[0][0]
                                                                 conv2d_32
4[0][0]

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________________________
batch_normalization_324 (BatchN (None, 32, 32, 234)  936         concatena
te_299[0][0]

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________________________
activation_324 (Activation)     (None, 32, 32, 234)  0           batch_nor
malization_324[0][0]

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________________________
conv2d_325 (Conv2D)             (None, 32, 32, 18)   4212        activatio
n_324[0][0]

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________________________
average_pooling2d_24 (AveragePo (None, 16, 16, 18)   0           conv2d_32
5[0][0]
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________________________
batch_normalization_325 (BatchN (None, 16, 16, 18)   72          average_p
ooling2d_24[0][0]

__________________________________________________________________________
________________________
activation_325 (Activation)     (None, 16, 16, 18)   0           batch_nor
malization_325[0][0]

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________________________
conv2d_326 (Conv2D)             (None, 16, 16, 18)   2916        activatio
n_325[0][0]

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________________________
concatenate_300 (Concatenate)   (None, 16, 16, 36)   0           average_p
ooling2d_24[0][0]
                                                                 conv2d_32
6[0][0]

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________________________
batch_normalization_326 (BatchN (None, 16, 16, 36)   144         concatena
te_300[0][0]

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________________________
activation_326 (Activation)     (None, 16, 16, 36)   0           batch_nor
malization_326[0][0]

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________________________
conv2d_327 (Conv2D)             (None, 16, 16, 18)   5832        activatio
n_326[0][0]

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________________________
concatenate_301 (Concatenate)   (None, 16, 16, 54)   0           concatena
te_300[0][0]
                                                                 conv2d_32
7[0][0]

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________________________
batch_normalization_327 (BatchN (None, 16, 16, 54)   216         concatena
te_301[0][0]

__________________________________________________________________________
________________________
activation_327 (Activation)     (None, 16, 16, 54)   0           batch_nor
malization_327[0][0]

__________________________________________________________________________
________________________
conv2d_328 (Conv2D)             (None, 16, 16, 18)   8748        activatio
n_327[0][0]

__________________________________________________________________________
________________________
concatenate_302 (Concatenate)   (None, 16, 16, 72)   0           concatena
te_301[0][0]
                                                                 conv2d_32
8[0][0]

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________________________
batch_normalization_328 (BatchN (None, 16, 16, 72)   288         concatena
te_302[0][0]

__________________________________________________________________________
________________________
activation_328 (Activation)     (None, 16, 16, 72)   0           batch_nor
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malization_328[0][0]
__________________________________________________________________________________________________
conv2d_329 (Conv2D)             (None, 16, 16, 18)   11664       activatio
n_328[0][0]
__________________________________________________________________________________________________
concatenate_303 (Concatenate)   (None, 16, 16, 90)   0           concatena
te_302[0][0]
                                                                 conv2d_32
9[0][0]
__________________________________________________________________________________________________
batch_normalization_329 (BatchN (None, 16, 16, 90)   360         concatena
te_303[0][0]
__________________________________________________________________________________________________
activation_329 (Activation)     (None, 16, 16, 90)   0           batch_nor
malization_329[0][0]
__________________________________________________________________________________________________
conv2d_330 (Conv2D)             (None, 16, 16, 18)   14580       activatio
n_329[0][0]
__________________________________________________________________________________________________
concatenate_304 (Concatenate)   (None, 16, 16, 108)  0           concatena
te_303[0][0]
                                                                 conv2d_33
0[0][0]
__________________________________________________________________________________________________
batch_normalization_330 (BatchN (None, 16, 16, 108)  432         concatena
te_304[0][0]
__________________________________________________________________________________________________
activation_330 (Activation)     (None, 16, 16, 108)  0           batch_nor
malization_330[0][0]
__________________________________________________________________________________________________
conv2d_331 (Conv2D)             (None, 16, 16, 18)   17496       activatio
n_330[0][0]
__________________________________________________________________________________________________
concatenate_305 (Concatenate)   (None, 16, 16, 126)  0           concatena
te_304[0][0]
                                                                 conv2d_33
1[0][0]
__________________________________________________________________________________________________
batch_normalization_331 (BatchN (None, 16, 16, 126)  504         concatena
te_305[0][0]
__________________________________________________________________________________________________
activation_331 (Activation)     (None, 16, 16, 126)  0           batch_nor
malization_331[0][0]
__________________________________________________________________________________________________
conv2d_332 (Conv2D)             (None, 16, 16, 18)   20412       activatio
n_331[0][0]
__________________________________________________________________________________________________
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concatenate_306 (Concatenate)   (None, 16, 16, 144)  0           concatena
te_305[0][0]
                                                                 conv2d_33
2[0][0]
__________________________________________________________________________
________________________
batch_normalization_332 (BatchN (None, 16, 16, 144)  576         concatena
te_306[0][0]
__________________________________________________________________________
________________________
activation_332 (Activation)     (None, 16, 16, 144)  0           batch_nor
malization_332[0][0]
__________________________________________________________________________
________________________
conv2d_333 (Conv2D)             (None, 16, 16, 18)   23328       activatio
n_332[0][0]
__________________________________________________________________________
________________________
concatenate_307 (Concatenate)   (None, 16, 16, 162)  0           concatena
te_306[0][0]
                                                                 conv2d_33
3[0][0]
__________________________________________________________________________
________________________
batch_normalization_333 (BatchN (None, 16, 16, 162)  648         concatena
te_307[0][0]
__________________________________________________________________________
________________________
activation_333 (Activation)     (None, 16, 16, 162)  0           batch_nor
malization_333[0][0]
__________________________________________________________________________
________________________
conv2d_334 (Conv2D)             (None, 16, 16, 18)   26244       activatio
n_333[0][0]
__________________________________________________________________________
________________________
concatenate_308 (Concatenate)   (None, 16, 16, 180)  0           concatena
te_307[0][0]
                                                                 conv2d_33
4[0][0]
__________________________________________________________________________
________________________
batch_normalization_334 (BatchN (None, 16, 16, 180)  720         concatena
te_308[0][0]
__________________________________________________________________________
________________________
activation_334 (Activation)     (None, 16, 16, 180)  0           batch_nor
malization_334[0][0]
__________________________________________________________________________
________________________
conv2d_335 (Conv2D)             (None, 16, 16, 18)   29160       activatio
n_334[0][0]
__________________________________________________________________________
________________________
concatenate_309 (Concatenate)   (None, 16, 16, 198)  0           concatena
te_308[0][0]
                                                                 conv2d_33
5[0][0]
__________________________________________________________________________
________________________
batch_normalization_335 (BatchN (None, 16, 16, 198)  792         concatena
te_309[0][0]                                                              

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________________________
activation_335 (Activation)     (None, 16, 16, 198)  0           batch_nor
malization_335[0][0]             

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________________________
conv2d_336 (Conv2D)             (None, 16, 16, 18)   32076       activatio
n_335[0][0]                      

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________________________
concatenate_310 (Concatenate)   (None, 16, 16, 216)  0           concatena
te_309[0][0]                     
                                                                 conv2d_33
6[0][0]                          

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________________________
batch_normalization_336 (BatchN (None, 16, 16, 216)  864         concatena
te_310[0][0]                     

__________________________________________________________________________
________________________
activation_336 (Activation)     (None, 16, 16, 216)  0           batch_nor
malization_336[0][0]             

__________________________________________________________________________
________________________
conv2d_337 (Conv2D)             (None, 16, 16, 18)   34992       activatio
n_336[0][0]                      

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________________________
concatenate_311 (Concatenate)   (None, 16, 16, 234)  0           concatena
te_310[0][0]                     
                                                                 conv2d_33
7[0][0]                          

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________________________
batch_normalization_337 (BatchN (None, 16, 16, 234)  936         concatena
te_311[0][0]                     

__________________________________________________________________________
________________________
activation_337 (Activation)     (None, 16, 16, 234)  0           batch_nor
malization_337[0][0]             

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________________________
conv2d_338 (Conv2D)             (None, 16, 16, 18)   4212        activatio
n_337[0][0]                      

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________________________
average_pooling2d_25 (AveragePo (None, 8, 8, 18)     0           conv2d_33
8[0][0]                          

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________________________
batch_normalization_338 (BatchN (None, 8, 8, 18)     72          average_p
ooling2d_25[0][0]                

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________________________
activation_338 (Activation)     (None, 8, 8, 18)     0           batch_nor
malization_338[0][0]             

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________________________
conv2d_339 (Conv2D)             (None, 8, 8, 18)     2916        activatio
n_338[0][0]                      
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________________________
concatenate_312 (Concatenate)   (None, 8, 8, 36)     0           average_p
ooling2d_25[0][0]
                                                                 conv2d_33
9[0][0]
__________________________________________________________________________
________________________
batch_normalization_339 (BatchN (None, 8, 8, 36)     144         concatena
te_312[0][0]
__________________________________________________________________________
________________________
activation_339 (Activation)     (None, 8, 8, 36)     0           batch_nor
malization_339[0][0]
__________________________________________________________________________
________________________
conv2d_340 (Conv2D)             (None, 8, 8, 18)     5832        activatio
n_339[0][0]
__________________________________________________________________________
________________________
concatenate_313 (Concatenate)   (None, 8, 8, 54)     0           concatena
te_312[0][0]
                                                                 conv2d_34
0[0][0]
__________________________________________________________________________
________________________
batch_normalization_340 (BatchN (None, 8, 8, 54)     216         concatena
te_313[0][0]
__________________________________________________________________________
________________________
activation_340 (Activation)     (None, 8, 8, 54)     0           batch_nor
malization_340[0][0]
__________________________________________________________________________
________________________
conv2d_341 (Conv2D)             (None, 8, 8, 18)     8748        activatio
n_340[0][0]
__________________________________________________________________________
________________________
concatenate_314 (Concatenate)   (None, 8, 8, 72)     0           concatena
te_313[0][0]
                                                                 conv2d_34
1[0][0]
__________________________________________________________________________
________________________
batch_normalization_341 (BatchN (None, 8, 8, 72)     288         concatena
te_314[0][0]
__________________________________________________________________________
________________________
activation_341 (Activation)     (None, 8, 8, 72)     0           batch_nor
malization_341[0][0]
__________________________________________________________________________
________________________
conv2d_342 (Conv2D)             (None, 8, 8, 18)     11664       activatio
n_341[0][0]
__________________________________________________________________________
________________________
concatenate_315 (Concatenate)   (None, 8, 8, 90)     0           concatena
te_314[0][0]
                                                                 conv2d_34
2[0][0]
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```

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________________________
batch_normalization_342 (BatchN (None, 8, 8, 90)     360         concatena
te_315[0][0]

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________________________
activation_342 (Activation)     (None, 8, 8, 90)     0           batch_nor
malization_342[0][0]

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________________________
conv2d_343 (Conv2D)             (None, 8, 8, 18)     14580       activatio
n_342[0][0]

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________________________
concatenate_316 (Concatenate)   (None, 8, 8, 108)    0           concatena
te_315[0][0]
                                                                 conv2d_34
3[0][0]

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________________________
batch_normalization_343 (BatchN (None, 8, 8, 108)    432         concatena
te_316[0][0]

__________________________________________________________________________

________________________
activation_343 (Activation)     (None, 8, 8, 108)    0           batch_nor
malization_343[0][0]

__________________________________________________________________________

________________________
conv2d_344 (Conv2D)             (None, 8, 8, 18)     17496       activatio
n_343[0][0]

__________________________________________________________________________

________________________
concatenate_317 (Concatenate)   (None, 8, 8, 126)    0           concatena
te_316[0][0]
                                                                 conv2d_34
4[0][0]

__________________________________________________________________________

________________________
batch_normalization_344 (BatchN (None, 8, 8, 126)    504         concatena
te_317[0][0]

__________________________________________________________________________

________________________
activation_344 (Activation)     (None, 8, 8, 126)    0           batch_nor
malization_344[0][0]

__________________________________________________________________________

________________________
conv2d_345 (Conv2D)             (None, 8, 8, 18)     20412       activatio
n_344[0][0]

__________________________________________________________________________

________________________
concatenate_318 (Concatenate)   (None, 8, 8, 144)    0           concatena
te_317[0][0]
                                                                 conv2d_34
5[0][0]

__________________________________________________________________________

________________________
batch_normalization_345 (BatchN (None, 8, 8, 144)    576         concatena
te_318[0][0]

__________________________________________________________________________

________________________
activation_345 (Activation)     (None, 8, 8, 144)    0           batch_nor
malization_345[0][0]
```

```
__________________________________________________________________________
________________________
conv2d_346 (Conv2D)            (None, 8, 8, 18)     23328       activatio
n_345[0][0]
__________________________________________________________________________
________________________
concatenate_319 (Concatenate)  (None, 8, 8, 162)    0           concatena
te_318[0][0]
                                                                 conv2d_34
6[0][0]
__________________________________________________________________________
________________________
batch_normalization_346 (BatchN (None, 8, 8, 162)   648         concatena
te_319[0][0]
__________________________________________________________________________
________________________
activation_346 (Activation)    (None, 8, 8, 162)    0           batch_nor
malization_346[0][0]
__________________________________________________________________________
________________________
conv2d_347 (Conv2D)            (None, 8, 8, 18)     26244       activatio
n_346[0][0]
__________________________________________________________________________
________________________
concatenate_320 (Concatenate)  (None, 8, 8, 180)    0           concatena
te_319[0][0]
                                                                 conv2d_34
7[0][0]
__________________________________________________________________________
________________________
batch_normalization_347 (BatchN (None, 8, 8, 180)   720         concatena
te_320[0][0]
__________________________________________________________________________
________________________
activation_347 (Activation)    (None, 8, 8, 180)    0           batch_nor
malization_347[0][0]
__________________________________________________________________________
________________________
conv2d_348 (Conv2D)            (None, 8, 8, 18)     29160       activatio
n_347[0][0]
__________________________________________________________________________
________________________
concatenate_321 (Concatenate)  (None, 8, 8, 198)    0           concatena
te_320[0][0]
                                                                 conv2d_34
8[0][0]
__________________________________________________________________________
________________________
batch_normalization_348 (BatchN (None, 8, 8, 198)   792         concatena
te_321[0][0]
__________________________________________________________________________
________________________
activation_348 (Activation)    (None, 8, 8, 198)    0           batch_nor
malization_348[0][0]
__________________________________________________________________________
________________________
conv2d_349 (Conv2D)            (None, 8, 8, 18)     32076       activatio
n_348[0][0]
__________________________________________________________________________
________________________
concatenate_322 (Concatenate)  (None, 8, 8, 216)    0           concatena
```

```
te_321[0][0]                                                                                                                                                                       
                                                                 conv2d_34
9[0][0]                                                                                                                                                                       
__________________________________________________________________________
________________________
batch_normalization_349 (BatchN (None, 8, 8, 216)    864          concatena
te_322[0][0]                                                                                                                                                                       
__________________________________________________________________________
________________________
activation_349 (Activation)     (None, 8, 8, 216)    0            batch_nor
malization_349[0][0]                                                                                                                                                                       
__________________________________________________________________________
________________________
conv2d_350 (Conv2D)             (None, 8, 8, 18)     34992        activatio
n_349[0][0]                                                                                                                                                                       
__________________________________________________________________________
________________________
concatenate_323 (Concatenate)   (None, 8, 8, 234)    0            concatena
te_322[0][0]                                                                                                                                                                       
                                                                 conv2d_35
0[0][0]                                                                                                                                                                       
__________________________________________________________________________
________________________
batch_normalization_350 (BatchN (None, 8, 8, 234)    936          concatena
te_323[0][0]                                                                                                                                                                       
__________________________________________________________________________
________________________
activation_350 (Activation)     (None, 8, 8, 234)    0            batch_nor
malization_350[0][0]                                                                                                                                                                       
__________________________________________________________________________
________________________
conv2d_351 (Conv2D)             (None, 8, 8, 18)     4212         activatio
n_350[0][0]                                                                                                                                                                       
__________________________________________________________________________
________________________
average_pooling2d_26 (AveragePo (None, 4, 4, 18)     0            conv2d_35
1[0][0]                                                                                                                                                                       
__________________________________________________________________________
________________________
batch_normalization_351 (BatchN (None, 4, 4, 18)     72           average_p
ooling2d_26[0][0]                                                                                                                                                                       
__________________________________________________________________________
________________________
activation_351 (Activation)     (None, 4, 4, 18)     0            batch_nor
malization_351[0][0]                                                                                                                                                                       
__________________________________________________________________________
________________________
conv2d_352 (Conv2D)             (None, 4, 4, 18)     2916         activatio
n_351[0][0]                                                                                                                                                                       
__________________________________________________________________________
________________________
concatenate_324 (Concatenate)   (None, 4, 4, 36)     0            average_p
ooling2d_26[0][0]                                                                                                                                                                       
                                                                 conv2d_35
2[0][0]                                                                                                                                                                       
__________________________________________________________________________
________________________
batch_normalization_352 (BatchN (None, 4, 4, 36)     144          concatena
te_324[0][0]                                                                                                                                                                       
__________________________________________________________________________
________________________
```

```
activation_352 (Activation)     (None, 4, 4, 36)     0           batch_nor
malization_352[0][0]
__________________________________________________________________________
________________________
conv2d_353 (Conv2D)             (None, 4, 4, 18)     5832        activatio
n_352[0][0]
__________________________________________________________________________
________________________
concatenate_325 (Concatenate)   (None, 4, 4, 54)     0           concatena
te_324[0][0]
                                                                 conv2d_35
3[0][0]
__________________________________________________________________________
________________________
batch_normalization_353 (BatchN (None, 4, 4, 54)     216         concatena
te_325[0][0]
__________________________________________________________________________
________________________
activation_353 (Activation)     (None, 4, 4, 54)     0           batch_nor
malization_353[0][0]
__________________________________________________________________________
________________________
conv2d_354 (Conv2D)             (None, 4, 4, 18)     8748        activatio
n_353[0][0]
__________________________________________________________________________
________________________
concatenate_326 (Concatenate)   (None, 4, 4, 72)     0           concatena
te_325[0][0]
                                                                 conv2d_35
4[0][0]
__________________________________________________________________________
________________________
batch_normalization_354 (BatchN (None, 4, 4, 72)     288         concatena
te_326[0][0]
__________________________________________________________________________
________________________
activation_354 (Activation)     (None, 4, 4, 72)     0           batch_nor
malization_354[0][0]
__________________________________________________________________________
________________________
conv2d_355 (Conv2D)             (None, 4, 4, 18)     11664       activatio
n_354[0][0]
__________________________________________________________________________
________________________
concatenate_327 (Concatenate)   (None, 4, 4, 90)     0           concatena
te_326[0][0]
                                                                 conv2d_35
5[0][0]
__________________________________________________________________________
________________________
batch_normalization_355 (BatchN (None, 4, 4, 90)     360         concatena
te_327[0][0]
__________________________________________________________________________
________________________
activation_355 (Activation)     (None, 4, 4, 90)     0           batch_nor
malization_355[0][0]
__________________________________________________________________________
________________________
conv2d_356 (Conv2D)             (None, 4, 4, 18)     14580       activatio
n_355[0][0]
__________________________________________________________________________
```

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________________________
concatenate_328 (Concatenate)   (None, 4, 4, 108)    0           concatena
te_327[0][0]
                                                                 conv2d_35
6[0][0]
__________________________________________________________________________
________________________
batch_normalization_356 (BatchN (None, 4, 4, 108)    432         concatena
te_328[0][0]
__________________________________________________________________________
________________________
activation_356 (Activation)     (None, 4, 4, 108)    0           batch_nor
malization_356[0][0]
__________________________________________________________________________
________________________
conv2d_357 (Conv2D)             (None, 4, 4, 18)     17496       activatio
n_356[0][0]
__________________________________________________________________________
________________________
concatenate_329 (Concatenate)   (None, 4, 4, 126)    0           concatena
te_328[0][0]
                                                                 conv2d_35
7[0][0]
__________________________________________________________________________
________________________
batch_normalization_357 (BatchN (None, 4, 4, 126)    504         concatena
te_329[0][0]
__________________________________________________________________________
________________________
activation_357 (Activation)     (None, 4, 4, 126)    0           batch_nor
malization_357[0][0]
__________________________________________________________________________
________________________
conv2d_358 (Conv2D)             (None, 4, 4, 18)     20412       activatio
n_357[0][0]
__________________________________________________________________________
________________________
concatenate_330 (Concatenate)   (None, 4, 4, 144)    0           concatena
te_329[0][0]
                                                                 conv2d_35
8[0][0]
__________________________________________________________________________
________________________
batch_normalization_358 (BatchN (None, 4, 4, 144)    576         concatena
te_330[0][0]
__________________________________________________________________________
________________________
activation_358 (Activation)     (None, 4, 4, 144)    0           batch_nor
malization_358[0][0]
__________________________________________________________________________
________________________
conv2d_359 (Conv2D)             (None, 4, 4, 18)     23328       activatio
n_358[0][0]
__________________________________________________________________________
________________________
concatenate_331 (Concatenate)   (None, 4, 4, 162)    0           concatena
te_330[0][0]
                                                                 conv2d_35
9[0][0]
__________________________________________________________________________
________________________
```

```
batch_normalization_359 (BatchN (None, 4, 4, 162)    648         concatena
te_331[0][0]
__________________________________________________________________________
________________________
activation_359 (Activation)     (None, 4, 4, 162)    0           batch_nor
malization_359[0][0]
__________________________________________________________________________
________________________
conv2d_360 (Conv2D)             (None, 4, 4, 18)     26244       activatio
n_359[0][0]
__________________________________________________________________________
________________________
concatenate_332 (Concatenate)   (None, 4, 4, 180)    0           concatena
te_331[0][0]
                                                                 conv2d_36
0[0][0]
__________________________________________________________________________
________________________
batch_normalization_360 (BatchN (None, 4, 4, 180)    720         concatena
te_332[0][0]
__________________________________________________________________________
________________________
activation_360 (Activation)     (None, 4, 4, 180)    0           batch_nor
malization_360[0][0]
__________________________________________________________________________
________________________
conv2d_361 (Conv2D)             (None, 4, 4, 18)     29160       activatio
n_360[0][0]
__________________________________________________________________________
________________________
concatenate_333 (Concatenate)   (None, 4, 4, 198)    0           concatena
te_332[0][0]
                                                                 conv2d_36
1[0][0]
__________________________________________________________________________
________________________
batch_normalization_361 (BatchN (None, 4, 4, 198)    792         concatena
te_333[0][0]
__________________________________________________________________________
________________________
activation_361 (Activation)     (None, 4, 4, 198)    0           batch_nor
malization_361[0][0]
__________________________________________________________________________
________________________
conv2d_362 (Conv2D)             (None, 4, 4, 18)     32076       activatio
n_361[0][0]
__________________________________________________________________________
________________________
concatenate_334 (Concatenate)   (None, 4, 4, 216)    0           concatena
te_333[0][0]
                                                                 conv2d_36
2[0][0]
__________________________________________________________________________
________________________
batch_normalization_362 (BatchN (None, 4, 4, 216)    864         concatena
te_334[0][0]
__________________________________________________________________________
________________________
activation_362 (Activation)     (None, 4, 4, 216)    0           batch_nor
malization_362[0][0]
__________________________________________________________________________
```

```
________________________
conv2d_363 (Conv2D)             (None, 4, 4, 18)     34992       activatio
n_362[0][0]

__________________________________________________________________________
________________________
concatenate_335 (Concatenate)   (None, 4, 4, 234)    0           concatena
te_334[0][0]

                                                                 conv2d_36
3[0][0]

__________________________________________________________________________
________________________
batch_normalization_363 (BatchN (None, 4, 4, 234)    936         concatena
te_335[0][0]

__________________________________________________________________________
________________________
activation_363 (Activation)     (None, 4, 4, 234)    0           batch_nor
malization_363[0][0]

__________________________________________________________________________
________________________
average_pooling2d_27 (AveragePo (None, 2, 2, 234)    0           activatio
n_363[0][0]

__________________________________________________________________________
________________________
flatten_5 (Flatten)             (None, 936)          0           average_p
ooling2d_27[0][0]

__________________________________________________________________________
________________________
dense_5 (Dense)                 (None, 10)           9370        flatten_5
[0][0]
==========================================================================
========================
Total params: 958,492
Trainable params: 945,388
Non-trainable params: 13,104

__________________________________________________________________________
________________________
```

In [21]:

```
print(len(model.layers))
```

```
263
```

In [49]:

```

```

In [51]:

```
aug = ImageDataGenerator(shear_range=0.2,
                         zoom_range=0.2,
                         height_shift_range=0.1,
                         horizontal_flip=True)

# determine Loss function and Optimizer
model.compile(loss='categorical_crossentropy',
              optimizer=Adam(learning_rate=0.001),
              metrics=['accuracy'])
```

In [52]:

```
cp_callback = tf.keras.callbacks.ModelCheckpoint(
    filepath="models/CNN_CIFR_APR_21_{epoch:04d}.hdf5",
    verbose=1,
    save_weights_only=True,
    period=10)


res_model = model.fit(
                    x = aug.flow(X_train, y_train, batch_size=batch_size,),
                    epochs=150,
                    verbose=1,
                    validation_data=(X_test, y_test),
                    callbacks = [cp_callback])
```

```
WARNING:tensorflow:`period` argument is deprecated. Please use `save_freq`
to specify the frequency in number of batches seen.
Epoch 1/150
1563/1563 [==============================] - 73s 44ms/step - loss: 2.0559
- accuracy: 0.2771 - val_loss: 1.4818 - val_accuracy: 0.4724
Epoch 2/150
1563/1563 [==============================] - 67s 43ms/step - loss: 1.3637
- accuracy: 0.5087 - val_loss: 1.3150 - val_accuracy: 0.5554
Epoch 3/150
1563/1563 [==============================] - 67s 43ms/step - loss: 1.0332
- accuracy: 0.6286 - val_loss: 1.2683 - val_accuracy: 0.5775
Epoch 4/150
1563/1563 [==============================] - 66s 43ms/step - loss: 0.8787
- accuracy: 0.6897 - val_loss: 1.5207 - val_accuracy: 0.5580
Epoch 5/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.7662
- accuracy: 0.7294 - val_loss: 1.2011 - val_accuracy: 0.6211
Epoch 6/150
1563/1563 [==============================] - 66s 42ms/step - loss: 0.6816
- accuracy: 0.7630 - val_loss: 0.9039 - val_accuracy: 0.7009
Epoch 7/150
1563/1563 [==============================] - 66s 43ms/step - loss: 0.6421
- accuracy: 0.7774 - val_loss: 0.7522 - val_accuracy: 0.7519
Epoch 8/150
1563/1563 [==============================] - 66s 43ms/step - loss: 0.5894
- accuracy: 0.7970 - val_loss: 0.8303 - val_accuracy: 0.7195
Epoch 9/150
1563/1563 [==============================] - 66s 43ms/step - loss: 0.5542
- accuracy: 0.8095 - val_loss: 0.7475 - val_accuracy: 0.7489
Epoch 10/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.5222
- accuracy: 0.8192 - val_loss: 0.5490 - val_accuracy: 0.8099

Epoch 00010: saving model to models/CNN_CIFR_APR_21_0010.hdf5
Epoch 11/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.4958
- accuracy: 0.8288 - val_loss: 0.6702 - val_accuracy: 0.7814
Epoch 12/150
1563/1563 [==============================] - 66s 43ms/step - loss: 0.4779
- accuracy: 0.8363 - val_loss: 0.7194 - val_accuracy: 0.7740
Epoch 13/150
1563/1563 [==============================] - 66s 43ms/step - loss: 0.4561
- accuracy: 0.8430 - val_loss: 0.7384 - val_accuracy: 0.7725
Epoch 14/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.4260
- accuracy: 0.8521 - val_loss: 0.5619 - val_accuracy: 0.8110
Epoch 15/150
1563/1563 [==============================] - 66s 43ms/step - loss: 0.4232
- accuracy: 0.8553 - val_loss: 0.5817 - val_accuracy: 0.8151
Epoch 16/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.4044
- accuracy: 0.8586 - val_loss: 0.6623 - val_accuracy: 0.7926
Epoch 17/150
1563/1563 [==============================] - 66s 43ms/step - loss: 0.3934
- accuracy: 0.8630 - val_loss: 0.5560 - val_accuracy: 0.8214
Epoch 18/150
1563/1563 [==============================] - 66s 43ms/step - loss: 0.3824
- accuracy: 0.8664 - val_loss: 0.5246 - val_accuracy: 0.8287
Epoch 19/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.3637
- accuracy: 0.8727 - val_loss: 0.8526 - val_accuracy: 0.7577
```

```
Epoch 20/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.3529
- accuracy: 0.8789 - val_loss: 0.4970 - val_accuracy: 0.8354

Epoch 00020: saving model to models/CNN_CIFR_APR_21_0020.hdf5
Epoch 21/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.3473
- accuracy: 0.8799 - val_loss: 0.5231 - val_accuracy: 0.8289
Epoch 22/150
1563/1563 [==============================] - 66s 43ms/step - loss: 0.3314
- accuracy: 0.8862 - val_loss: 0.4715 - val_accuracy: 0.8472
Epoch 23/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.3326
- accuracy: 0.8844 - val_loss: 0.4497 - val_accuracy: 0.8522
Epoch 24/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.3136
- accuracy: 0.8887 - val_loss: 0.4620 - val_accuracy: 0.8558
Epoch 25/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.3057
- accuracy: 0.8926 - val_loss: 0.5079 - val_accuracy: 0.8368
Epoch 26/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.2968
- accuracy: 0.8960 - val_loss: 0.5256 - val_accuracy: 0.8370
Epoch 27/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.2956
- accuracy: 0.8980 - val_loss: 0.3803 - val_accuracy: 0.8746
Epoch 28/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.2905
- accuracy: 0.9009 - val_loss: 0.4478 - val_accuracy: 0.8580
Epoch 29/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.2867
- accuracy: 0.9000 - val_loss: 0.4346 - val_accuracy: 0.8596
Epoch 30/150
1563/1563 [==============================] - 68s 43ms/step - loss: 0.2743
- accuracy: 0.9045 - val_loss: 0.4546 - val_accuracy: 0.8608

Epoch 00030: saving model to models/CNN_CIFR_APR_21_0030.hdf5
Epoch 31/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.2683
- accuracy: 0.9080 - val_loss: 0.5228 - val_accuracy: 0.8428
Epoch 32/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.2710
- accuracy: 0.9055 - val_loss: 0.4431 - val_accuracy: 0.8633
Epoch 33/150
1563/1563 [==============================] - 66s 42ms/step - loss: 0.2574
- accuracy: 0.9113 - val_loss: 0.5754 - val_accuracy: 0.8269
Epoch 34/150
1563/1563 [==============================] - 66s 43ms/step - loss: 0.2561
- accuracy: 0.9081 - val_loss: 0.3920 - val_accuracy: 0.8749
Epoch 35/150
1563/1563 [==============================] - 66s 43ms/step - loss: 0.2506
- accuracy: 0.9132 - val_loss: 0.5423 - val_accuracy: 0.8452
Epoch 36/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.2508
- accuracy: 0.9131 - val_loss: 0.3805 - val_accuracy: 0.8788
Epoch 37/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.2439
- accuracy: 0.9164 - val_loss: 0.4357 - val_accuracy: 0.8644
Epoch 38/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.2356
- accuracy: 0.9168 - val_loss: 0.4718 - val_accuracy: 0.8556
```

```
Epoch 39/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.2350
- accuracy: 0.9178 - val_loss: 0.4460 - val_accuracy: 0.8666
Epoch 40/150
1563/1563 [==============================] - 66s 42ms/step - loss: 0.2256
- accuracy: 0.9202 - val_loss: 0.4293 - val_accuracy: 0.8715

Epoch 00040: saving model to models/CNN_CIFR_APR_21_0040.hdf5
Epoch 41/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.2238
- accuracy: 0.9221 - val_loss: 0.3896 - val_accuracy: 0.8797
Epoch 42/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.2212
- accuracy: 0.9235 - val_loss: 0.4427 - val_accuracy: 0.8668
Epoch 43/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.2175
- accuracy: 0.9235 - val_loss: 0.3910 - val_accuracy: 0.8836
Epoch 44/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.2178
- accuracy: 0.9247 - val_loss: 0.5024 - val_accuracy: 0.8535
Epoch 45/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.2113
- accuracy: 0.9260 - val_loss: 0.4228 - val_accuracy: 0.8630
Epoch 46/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.2051
- accuracy: 0.9284 - val_loss: 0.3894 - val_accuracy: 0.8773
Epoch 47/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.2042
- accuracy: 0.9309 - val_loss: 0.3584 - val_accuracy: 0.8906
Epoch 48/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1979
- accuracy: 0.9295 - val_loss: 0.4130 - val_accuracy: 0.8801
Epoch 49/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.2004
- accuracy: 0.9297 - val_loss: 0.3788 - val_accuracy: 0.8801
Epoch 50/150
1563/1563 [==============================] - 66s 43ms/step - loss: 0.1926
- accuracy: 0.9327 - val_loss: 0.3910 - val_accuracy: 0.8810

Epoch 00050: saving model to models/CNN_CIFR_APR_21_0050.hdf5
Epoch 51/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1924
- accuracy: 0.9326 - val_loss: 0.3595 - val_accuracy: 0.8904
Epoch 52/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1893
- accuracy: 0.9343 - val_loss: 0.4073 - val_accuracy: 0.8819
Epoch 53/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1886
- accuracy: 0.9343 - val_loss: 0.3884 - val_accuracy: 0.8874
Epoch 54/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1835
- accuracy: 0.9357 - val_loss: 0.4128 - val_accuracy: 0.8698
Epoch 55/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1859
- accuracy: 0.9356 - val_loss: 0.4159 - val_accuracy: 0.8852
Epoch 56/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1787
- accuracy: 0.9351 - val_loss: 0.4618 - val_accuracy: 0.8741
Epoch 57/150
1563/1563 [==============================] - 66s 42ms/step - loss: 0.1783
- accuracy: 0.9356 - val_loss: 0.3833 - val_accuracy: 0.8864
```

```
Epoch 58/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1774
- accuracy: 0.9395 - val_loss: 0.4322 - val_accuracy: 0.8756
Epoch 59/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1746
- accuracy: 0.9386 - val_loss: 0.5668 - val_accuracy: 0.8438
Epoch 60/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1712
- accuracy: 0.9403 - val_loss: 0.5007 - val_accuracy: 0.8572

Epoch 00060: saving model to models/CNN_CIFR_APR_21_0060.hdf5
Epoch 61/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1727
- accuracy: 0.9412 - val_loss: 0.4146 - val_accuracy: 0.8800
Epoch 62/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1606
- accuracy: 0.9448 - val_loss: 0.3966 - val_accuracy: 0.8819
Epoch 63/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1624
- accuracy: 0.9431 - val_loss: 0.4694 - val_accuracy: 0.8750
Epoch 64/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1657
- accuracy: 0.9416 - val_loss: 0.3988 - val_accuracy: 0.8865
Epoch 65/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1577
- accuracy: 0.9452 - val_loss: 0.4243 - val_accuracy: 0.8873
Epoch 66/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1551
- accuracy: 0.9465 - val_loss: 0.3759 - val_accuracy: 0.8915
Epoch 67/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1589
- accuracy: 0.9436 - val_loss: 0.3728 - val_accuracy: 0.8912
Epoch 68/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1544
- accuracy: 0.9466 - val_loss: 0.4373 - val_accuracy: 0.8815
Epoch 69/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1531
- accuracy: 0.9462 - val_loss: 0.3604 - val_accuracy: 0.8975
Epoch 70/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1528
- accuracy: 0.9475 - val_loss: 0.4536 - val_accuracy: 0.8818

Epoch 00070: saving model to models/CNN_CIFR_APR_21_0070.hdf5
Epoch 71/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1522
- accuracy: 0.9464 - val_loss: 0.4337 - val_accuracy: 0.8819
Epoch 72/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1503
- accuracy: 0.9469 - val_loss: 0.3924 - val_accuracy: 0.8940
Epoch 73/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1411
- accuracy: 0.9512 - val_loss: 0.4700 - val_accuracy: 0.8790
Epoch 74/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1460
- accuracy: 0.9487 - val_loss: 0.3794 - val_accuracy: 0.8947
Epoch 75/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1416
- accuracy: 0.9499 - val_loss: 0.4935 - val_accuracy: 0.8671
Epoch 76/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1380
- accuracy: 0.9512 - val_loss: 0.3925 - val_accuracy: 0.8887
```

```
Epoch 77/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1455
- accuracy: 0.9503 - val_loss: 0.4475 - val_accuracy: 0.8886
Epoch 78/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1444
- accuracy: 0.9488 - val_loss: 0.4721 - val_accuracy: 0.8780
Epoch 79/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1383
- accuracy: 0.9532 - val_loss: 0.3739 - val_accuracy: 0.8961
Epoch 80/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1349
- accuracy: 0.9513 - val_loss: 0.4277 - val_accuracy: 0.8823

Epoch 00080: saving model to models/CNN_CIFR_APR_21_0080.hdf5
Epoch 81/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1345
- accuracy: 0.9530 - val_loss: 0.4701 - val_accuracy: 0.8802
Epoch 82/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1338
- accuracy: 0.9542 - val_loss: 0.4273 - val_accuracy: 0.8848
Epoch 83/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1376
- accuracy: 0.9516 - val_loss: 0.4584 - val_accuracy: 0.8809
Epoch 84/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1360
- accuracy: 0.9516 - val_loss: 0.3975 - val_accuracy: 0.8937
Epoch 85/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1304
- accuracy: 0.9536 - val_loss: 0.3940 - val_accuracy: 0.8953
Epoch 86/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1279
- accuracy: 0.9555 - val_loss: 0.4143 - val_accuracy: 0.8899
Epoch 87/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1232
- accuracy: 0.9564 - val_loss: 0.5233 - val_accuracy: 0.8780
Epoch 88/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1300
- accuracy: 0.9547 - val_loss: 0.3722 - val_accuracy: 0.8982
Epoch 89/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1255
- accuracy: 0.9556 - val_loss: 0.3879 - val_accuracy: 0.8980
Epoch 90/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1246
- accuracy: 0.9557 - val_loss: 0.4095 - val_accuracy: 0.8980

Epoch 00090: saving model to models/CNN_CIFR_APR_21_0090.hdf5
Epoch 91/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1215
- accuracy: 0.9573 - val_loss: 0.4667 - val_accuracy: 0.8832
Epoch 92/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1265
- accuracy: 0.9553 - val_loss: 0.4134 - val_accuracy: 0.8881
Epoch 93/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1178
- accuracy: 0.9585 - val_loss: 0.4407 - val_accuracy: 0.8924
Epoch 94/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1252
- accuracy: 0.9555 - val_loss: 0.4126 - val_accuracy: 0.8945
Epoch 95/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1240
- accuracy: 0.9578 - val_loss: 0.5021 - val_accuracy: 0.8775
```

```
Epoch 96/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1123
- accuracy: 0.9608 - val_loss: 0.4373 - val_accuracy: 0.8861
Epoch 97/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1188
- accuracy: 0.9590 - val_loss: 0.3692 - val_accuracy: 0.9013
Epoch 98/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1124
- accuracy: 0.9609 - val_loss: 0.4346 - val_accuracy: 0.8933
Epoch 99/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1223
- accuracy: 0.9584 - val_loss: 0.3783 - val_accuracy: 0.8982
Epoch 100/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1120
- accuracy: 0.9611 - val_loss: 0.3999 - val_accuracy: 0.8988

Epoch 00100: saving model to models/CNN_CIFR_APR_21_0100.hdf5
Epoch 101/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1081
- accuracy: 0.9615 - val_loss: 0.4202 - val_accuracy: 0.8976
Epoch 102/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1173
- accuracy: 0.9598 - val_loss: 0.4964 - val_accuracy: 0.8828
Epoch 103/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1106
- accuracy: 0.9610 - val_loss: 0.3922 - val_accuracy: 0.9002
Epoch 104/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1069
- accuracy: 0.9627 - val_loss: 0.3959 - val_accuracy: 0.8936
Epoch 105/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1078
- accuracy: 0.9615 - val_loss: 0.5215 - val_accuracy: 0.8794
Epoch 106/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1123
- accuracy: 0.9612 - val_loss: 0.3960 - val_accuracy: 0.9014
Epoch 107/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1150
- accuracy: 0.9598 - val_loss: 0.5091 - val_accuracy: 0.8793
Epoch 108/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1043
- accuracy: 0.9639 - val_loss: 0.4140 - val_accuracy: 0.8966
Epoch 109/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1090
- accuracy: 0.9628 - val_loss: 0.3764 - val_accuracy: 0.8987
Epoch 110/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1075
- accuracy: 0.9625 - val_loss: 0.4183 - val_accuracy: 0.8998

Epoch 00110: saving model to models/CNN_CIFR_APR_21_0110.hdf5
Epoch 111/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1094
- accuracy: 0.9617 - val_loss: 0.4139 - val_accuracy: 0.8919
Epoch 112/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1040
- accuracy: 0.9642 - val_loss: 0.4082 - val_accuracy: 0.8986
Epoch 113/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1005
- accuracy: 0.9640 - val_loss: 0.4627 - val_accuracy: 0.8895
Epoch 114/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0984
- accuracy: 0.9657 - val_loss: 0.4565 - val_accuracy: 0.8856
```

```
Epoch 115/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1029
- accuracy: 0.9643 - val_loss: 0.4881 - val_accuracy: 0.8857
Epoch 116/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1068
- accuracy: 0.9624 - val_loss: 0.4593 - val_accuracy: 0.8909
Epoch 117/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1031
- accuracy: 0.9639 - val_loss: 0.3854 - val_accuracy: 0.9030
Epoch 118/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0920
- accuracy: 0.9669 - val_loss: 0.4358 - val_accuracy: 0.8948
Epoch 119/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0980
- accuracy: 0.9661 - val_loss: 0.4369 - val_accuracy: 0.8930
Epoch 120/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0976
- accuracy: 0.9659 - val_loss: 0.4985 - val_accuracy: 0.8838

Epoch 00120: saving model to models/CNN_CIFR_APR_21_0120.hdf5
Epoch 121/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0970
- accuracy: 0.9671 - val_loss: 0.4758 - val_accuracy: 0.8839
Epoch 122/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0973
- accuracy: 0.9666 - val_loss: 0.4733 - val_accuracy: 0.8850
Epoch 123/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0940
- accuracy: 0.9672 - val_loss: 0.4737 - val_accuracy: 0.8935
Epoch 124/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0987
- accuracy: 0.9650 - val_loss: 0.4241 - val_accuracy: 0.9002
Epoch 125/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0959
- accuracy: 0.9671 - val_loss: 0.3767 - val_accuracy: 0.9051
Epoch 126/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0937
- accuracy: 0.9664 - val_loss: 0.4093 - val_accuracy: 0.9036
Epoch 127/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0913
- accuracy: 0.9687 - val_loss: 0.4677 - val_accuracy: 0.8884
Epoch 128/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0913
- accuracy: 0.9687 - val_loss: 0.4663 - val_accuracy: 0.8896
Epoch 129/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0961
- accuracy: 0.9660 - val_loss: 0.5348 - val_accuracy: 0.8726
Epoch 130/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0934
- accuracy: 0.9675 - val_loss: 0.4149 - val_accuracy: 0.8986

Epoch 00130: saving model to models/CNN_CIFR_APR_21_0130.hdf5
Epoch 131/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0895
- accuracy: 0.9691 - val_loss: 0.4354 - val_accuracy: 0.8897
Epoch 132/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0887
- accuracy: 0.9684 - val_loss: 0.4052 - val_accuracy: 0.9012
Epoch 133/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0890
- accuracy: 0.9693 - val_loss: 0.4147 - val_accuracy: 0.8941
```

```
Epoch 134/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0966
- accuracy: 0.9674 - val_loss: 0.3841 - val_accuracy: 0.9030
Epoch 135/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0865
- accuracy: 0.9701 - val_loss: 0.4504 - val_accuracy: 0.8951
Epoch 136/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0887
- accuracy: 0.9691 - val_loss: 0.4288 - val_accuracy: 0.8986
Epoch 137/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0901
- accuracy: 0.9685 - val_loss: 0.4134 - val_accuracy: 0.9014
Epoch 138/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0831
- accuracy: 0.9711 - val_loss: 0.4349 - val_accuracy: 0.8948
Epoch 139/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0841
- accuracy: 0.9712 - val_loss: 0.3907 - val_accuracy: 0.9019
Epoch 140/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0858
- accuracy: 0.9708 - val_loss: 0.4171 - val_accuracy: 0.9001

Epoch 00140: saving model to models/CNN_CIFR_APR_21_0140.hdf5
Epoch 141/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0846
- accuracy: 0.9700 - val_loss: 0.4477 - val_accuracy: 0.8952
Epoch 142/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0903
- accuracy: 0.9689 - val_loss: 0.4104 - val_accuracy: 0.9055
Epoch 143/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0849
- accuracy: 0.9711 - val_loss: 0.4430 - val_accuracy: 0.8979
Epoch 144/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0805
- accuracy: 0.9714 - val_loss: 0.4034 - val_accuracy: 0.9084
Epoch 145/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0850
- accuracy: 0.9699 - val_loss: 0.4622 - val_accuracy: 0.8938
Epoch 146/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0870
- accuracy: 0.9697 - val_loss: 0.3974 - val_accuracy: 0.8989
Epoch 147/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0787
- accuracy: 0.9721 - val_loss: 0.4772 - val_accuracy: 0.8939
Epoch 148/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0839
- accuracy: 0.9712 - val_loss: 0.3918 - val_accuracy: 0.9041
Epoch 149/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0790
- accuracy: 0.9730 - val_loss: 0.4260 - val_accuracy: 0.9013
Epoch 150/150
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0799
- accuracy: 0.9726 - val_loss: 0.4882 - val_accuracy: 0.8944

Epoch 00150: saving model to models/CNN_CIFR_APR_21_0150.hdf5
```

In [57]:

```
# Continue Trainin from 150th epoch + train for 50 more epochs

model.load_weights("/content/CNN_CIFR_APR_21_0150.hdf5")
model.compile(loss='categorical_crossentropy',
              optimizer=Adam(learning_rate=0.001),
              metrics=['accuracy'])
cp_callback = tf.keras.callbacks.ModelCheckpoint(
    filepath="models/CNN_CIFR_APR_21_{epoch:04d}.hdf5",
    verbose=1,
    save_weights_only=True,
    period=10)


res_model = model.fit(
                    x = aug.flow(X_train, y_train, batch_size=batch_size,),
                    epochs=20,
                    verbose=1,
                    validation_data=(X_test, y_test),
                    callbacks = [cp_callback])
```

```
WARNING:tensorflow:`period` argument is deprecated. Please use `save_freq`
to specify the frequency in number of batches seen.
Epoch 1/20
1563/1563 [==============================] - 71s 43ms/step - loss: 0.0626
- accuracy: 0.9779 - val_loss: 0.3811 - val_accuracy: 0.9143
Epoch 2/20
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0453
- accuracy: 0.9852 - val_loss: 0.3894 - val_accuracy: 0.9139
Epoch 3/20
1563/1563 [==============================] - 66s 43ms/step - loss: 0.0392
- accuracy: 0.9858 - val_loss: 0.3807 - val_accuracy: 0.9155
Epoch 4/20
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0362
- accuracy: 0.9869 - val_loss: 0.3820 - val_accuracy: 0.9192
Epoch 5/20
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0363
- accuracy: 0.9873 - val_loss: 0.3781 - val_accuracy: 0.9206
Epoch 6/20
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0321
- accuracy: 0.9885 - val_loss: 0.3949 - val_accuracy: 0.9164
Epoch 7/20
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0314
- accuracy: 0.9889 - val_loss: 0.3933 - val_accuracy: 0.9170
Epoch 8/20
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0310
- accuracy: 0.9898 - val_loss: 0.4028 - val_accuracy: 0.9185
Epoch 9/20
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0336
- accuracy: 0.9893 - val_loss: 0.4021 - val_accuracy: 0.9168
Epoch 10/20
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0290
- accuracy: 0.9898 - val_loss: 0.4029 - val_accuracy: 0.9173

Epoch 00010: saving model to models/CNN_CIFR_APR_21_0010.hdf5
Epoch 11/20
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0295
- accuracy: 0.9899 - val_loss: 0.3988 - val_accuracy: 0.9176
Epoch 12/20
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0279
- accuracy: 0.9905 - val_loss: 0.4015 - val_accuracy: 0.9204
Epoch 13/20
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0270
- accuracy: 0.9898 - val_loss: 0.4116 - val_accuracy: 0.9191
Epoch 14/20
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0273
- accuracy: 0.9903 - val_loss: 0.4094 - val_accuracy: 0.9182
Epoch 15/20
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0275
- accuracy: 0.9907 - val_loss: 0.4345 - val_accuracy: 0.9153
Epoch 16/20
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0266
- accuracy: 0.9915 - val_loss: 0.4220 - val_accuracy: 0.9180
Epoch 17/20
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0245
- accuracy: 0.9914 - val_loss: 0.4257 - val_accuracy: 0.9197
Epoch 18/20
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0248
- accuracy: 0.9915 - val_loss: 0.4091 - val_accuracy: 0.9231
Epoch 19/20
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0255
- accuracy: 0.9911 - val_loss: 0.4164 - val_accuracy: 0.9213
```

```
Epoch 20/20
1563/1563 [==============================] - 67s 43ms/step - loss: 0.0247
- accuracy: 0.9910 - val_loss: 0.4300 - val_accuracy: 0.9200

Epoch 00020: saving model to models/CNN_CIFR_APR_21_0020.hdf5
```

In [60]:

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

```
313/313 [==============================] - 3s 11ms/step - loss: 0.4300 - a
ccuracy: 0.9200
Test loss: 0.4300319254398346
Test accuracy: 0.9200000166893005
```

In [59]:

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

```
Saved model to disk
```