CNN on CIFR Assignment:

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

In [0]:
```
# import keras
# from keras.datasets import cifar10
# from keras.models import Model, Sequential
# from keras.layers import Dense, Dropout, Flatten, Input, AveragePooling2D, m
erge, Activation
# from keras.layers import Conv2D, MaxPooling2D, BatchNormalization
# from keras.layers import Concatenate
# from keras.optimizers import Adam
from tensorflow.keras import models, layers
from tensorflow.keras.models import Model
from tensorflow.keras.layers import BatchNormalization, Activation, Flatten
from tensorflow.keras.optimizers import Adam
import matplotlib.pyplot as plt
import numpy as np
```

In [0]:
```
# this part will prevent tensorflow to allocate all the avaliable GPU Memory
# backend
import tensorflow as tf
# from tensorflow import keras

# from keras import backend as k

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

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

In [0]:
```
# Hyperparameters
batch_size = 64
num_classes = 10
epochs = 85
l = 6
num_filter = 35
compression = 1
dropout_rate = 0.2
```

In [4]:
```
# Load CIFAR10 Data
(X_train, y_train), (X_test, y_test) = tf.keras.datasets.cifar10.load_data()
img_height, img_width, channel = X_train.shape[1],X_train.shape[2],X_train.sha
pe[3]

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

```
Downloading data from https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz
170500096/170498071 [==============================] - 6s 0us/step
```

In [0]:
```
X_train.shape
```

Out[0]: (50000, 32, 32, 3)

In [0]:
```
X_test.shape
```

Out[0]: (10000, 32, 32, 3)

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

        temp = concat

    return temp

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

#output layer
def output_layer(input):
    global compression
    BatchNorm = layers.BatchNormalization()(input)
    relu = layers.Activation('relu')(BatchNorm)
    AvgPooling = layers.AveragePooling2D(pool_size=(3,3))(relu)
    #flat = layers.Flatten()(AvgPooling)
    #a=tf.keras.layers.Reshape((None,312,1), input_shape=(2,2,78))
    #model=tf.reshape(flat,[None,312,1])
    output = layers.Conv2D(10,(1,1),strides=(1,1),activation='softmax',padding
='valid')(AvgPooling)
    flat = layers.Flatten()(output)

    return flat
```

In [0]:
```
#https://www.kaggle.com/genesis16/densenet-93-accuracy
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 [11]:
```
model = Model(inputs=[input], outputs=[output])
model.summary()
```

```
Model: "model"
__________________________________________________________________________________________________
Layer (type)                    Output Shape         Param #     Connected to
==================================================================================================
input_2 (InputLayer)            [(None, 32, 32, 3)]  0
__________________________________________________________________________________________________
conv2d_53 (Conv2D)              (None, 32, 32, 35)   945         input_2[0]
[0]
__________________________________________________________________________________________________
batch_normalization_52 (BatchNo (None, 32, 32, 35)   140         conv2d_53[0]
[0]
__________________________________________________________________________________________________
activation_52 (Activation)      (None, 32, 32, 35)   0           batch_normal
ization_52[0][0]
__________________________________________________________________________________________________
conv2d_54 (Conv2D)              (None, 32, 32, 35)   11025       activation_5
2[0][0]
__________________________________________________________________________________________________
dropout_51 (Dropout)            (None, 32, 32, 35)   0           conv2d_54[0]
[0]
__________________________________________________________________________________________________
concatenate_48 (Concatenate)    (None, 32, 32, 70)   0           conv2d_53[0]
[0]
                                                                 dropout_51
[0][0]
__________________________________________________________________________________________________
batch_normalization_53 (BatchNo (None, 32, 32, 70)   280         concatenate_
48[0][0]
__________________________________________________________________________________________________
activation_53 (Activation)      (None, 32, 32, 70)   0           batch_normal
ization_53[0][0]
__________________________________________________________________________________________________
conv2d_55 (Conv2D)              (None, 32, 32, 35)   22050       activation_5
3[0][0]
__________________________________________________________________________________________________
dropout_52 (Dropout)            (None, 32, 32, 35)   0           conv2d_55[0]
[0]
__________________________________________________________________________________________________
concatenate_49 (Concatenate)    (None, 32, 32, 105)  0           concatenate_
48[0][0]
                                                                 dropout_52
[0][0]
__________________________________________________________________________________________________
```

```
batch_normalization_54 (BatchNo (None, 32, 32, 105)  420         concatenate_
49[0][0]
__________________________________________________________________________
_____
activation_54 (Activation)      (None, 32, 32, 105)  0           batch_normal
ization_54[0][0]
__________________________________________________________________________
_____
conv2d_56 (Conv2D)              (None, 32, 32, 35)   33075       activation_5
4[0][0]
__________________________________________________________________________
_____
dropout_53 (Dropout)            (None, 32, 32, 35)   0           conv2d_56[0]
[0]
__________________________________________________________________________
_____
concatenate_50 (Concatenate)    (None, 32, 32, 140)  0           concatenate_
49[0][0]
                                                                 dropout_53
[0][0]
__________________________________________________________________________
_____
batch_normalization_55 (BatchNo (None, 32, 32, 140)  560         concatenate_
50[0][0]
__________________________________________________________________________
_____
activation_55 (Activation)      (None, 32, 32, 140)  0           batch_normal
ization_55[0][0]
__________________________________________________________________________
_____
conv2d_57 (Conv2D)              (None, 32, 32, 35)   44100       activation_5
5[0][0]
__________________________________________________________________________
_____
dropout_54 (Dropout)            (None, 32, 32, 35)   0           conv2d_57[0]
[0]
__________________________________________________________________________
_____
concatenate_51 (Concatenate)    (None, 32, 32, 175)  0           concatenate_
50[0][0]
                                                                 dropout_54
[0][0]
__________________________________________________________________________
_____
batch_normalization_56 (BatchNo (None, 32, 32, 175)  700         concatenate_
51[0][0]
__________________________________________________________________________
_____
activation_56 (Activation)      (None, 32, 32, 175)  0           batch_normal
ization_56[0][0]
__________________________________________________________________________
_____
conv2d_58 (Conv2D)              (None, 32, 32, 35)   55125       activation_5
6[0][0]
__________________________________________________________________________
_____
dropout_55 (Dropout)            (None, 32, 32, 35)   0           conv2d_58[0]
```

```
[0]
__________________________________________________________________________________________________
____________________
concatenate_52 (Concatenate)    (None, 32, 32, 210)  0           concatenate_
51[0][0]
                                                                 dropout_55
[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_57 (BatchNo (None, 32, 32, 210)  840         concatenate_
52[0][0]
__________________________________________________________________________________________________
____________________
activation_57 (Activation)      (None, 32, 32, 210)  0           batch_normal
ization_57[0][0]
__________________________________________________________________________________________________
____________________
conv2d_59 (Conv2D)              (None, 32, 32, 35)   66150       activation_5
7[0][0]
__________________________________________________________________________________________________
____________________
dropout_56 (Dropout)            (None, 32, 32, 35)   0           conv2d_59[0]
[0]
__________________________________________________________________________________________________
____________________
concatenate_53 (Concatenate)    (None, 32, 32, 245)  0           concatenate_
52[0][0]
                                                                 dropout_56
[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_58 (BatchNo (None, 32, 32, 245)  980         concatenate_
53[0][0]
__________________________________________________________________________________________________
____________________
activation_58 (Activation)      (None, 32, 32, 245)  0           batch_normal
ization_58[0][0]
__________________________________________________________________________________________________
____________________
conv2d_60 (Conv2D)              (None, 32, 32, 35)   8575        activation_5
8[0][0]
__________________________________________________________________________________________________
____________________
dropout_57 (Dropout)            (None, 32, 32, 35)   0           conv2d_60[0]
[0]
__________________________________________________________________________________________________
____________________
average_pooling2d_4 (AveragePoo (None, 16, 16, 35)   0           dropout_57
[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_59 (BatchNo (None, 16, 16, 35)   140         average_pool
ing2d_4[0][0]
__________________________________________________________________________________________________
____________________
activation_59 (Activation)      (None, 16, 16, 35)   0           batch_normal
ization_59[0][0]
```

```
__________________________________________________________________________________________________
_____________________
conv2d_61 (Conv2D)              (None, 16, 16, 35)   11025       activation_5
9[0][0]
__________________________________________________________________________________________________
_____________________
dropout_58 (Dropout)            (None, 16, 16, 35)   0           conv2d_61[0]
[0]
__________________________________________________________________________________________________
_____________________
concatenate_54 (Concatenate)    (None, 16, 16, 70)   0           average_pool
ing2d_4[0][0]
                                                                 dropout_58
[0][0]
__________________________________________________________________________________________________
_____________________
batch_normalization_60 (BatchNo (None, 16, 16, 70)   280         concatenate_
54[0][0]
__________________________________________________________________________________________________
_____________________
activation_60 (Activation)      (None, 16, 16, 70)   0           batch_normal
ization_60[0][0]
__________________________________________________________________________________________________
_____________________
conv2d_62 (Conv2D)              (None, 16, 16, 35)   22050       activation_6
0[0][0]
__________________________________________________________________________________________________
_____________________
dropout_59 (Dropout)            (None, 16, 16, 35)   0           conv2d_62[0]
[0]
__________________________________________________________________________________________________
_____________________
concatenate_55 (Concatenate)    (None, 16, 16, 105)  0           concatenate_
54[0][0]
                                                                 dropout_59
[0][0]
__________________________________________________________________________________________________
_____________________
batch_normalization_61 (BatchNo (None, 16, 16, 105)  420         concatenate_
55[0][0]
__________________________________________________________________________________________________
_____________________
activation_61 (Activation)      (None, 16, 16, 105)  0           batch_normal
ization_61[0][0]
__________________________________________________________________________________________________
_____________________
conv2d_63 (Conv2D)              (None, 16, 16, 35)   33075       activation_6
1[0][0]
__________________________________________________________________________________________________
_____________________
dropout_60 (Dropout)            (None, 16, 16, 35)   0           conv2d_63[0]
[0]
__________________________________________________________________________________________________
_____________________
concatenate_56 (Concatenate)    (None, 16, 16, 140)  0           concatenate_
55[0][0]
                                                                 dropout_60
```

```
[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_62 (BatchNo (None, 16, 16, 140)  560         concatenate_
56[0][0]
__________________________________________________________________________________________________
____________________
activation_62 (Activation)      (None, 16, 16, 140)  0           batch_normal
ization_62[0][0]
__________________________________________________________________________________________________
____________________
conv2d_64 (Conv2D)              (None, 16, 16, 35)   44100       activation_6
2[0][0]
__________________________________________________________________________________________________
____________________
dropout_61 (Dropout)            (None, 16, 16, 35)   0           conv2d_64[0]
[0]
__________________________________________________________________________________________________
____________________
concatenate_57 (Concatenate)    (None, 16, 16, 175)  0           concatenate_
56[0][0]
                                                                 dropout_61
[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_63 (BatchNo (None, 16, 16, 175)  700         concatenate_
57[0][0]
__________________________________________________________________________________________________
____________________
activation_63 (Activation)      (None, 16, 16, 175)  0           batch_normal
ization_63[0][0]
__________________________________________________________________________________________________
____________________
conv2d_65 (Conv2D)              (None, 16, 16, 35)   55125       activation_6
3[0][0]
__________________________________________________________________________________________________
____________________
dropout_62 (Dropout)            (None, 16, 16, 35)   0           conv2d_65[0]
[0]
__________________________________________________________________________________________________
____________________
concatenate_58 (Concatenate)    (None, 16, 16, 210)  0           concatenate_
57[0][0]
                                                                 dropout_62
[0][0]
__________________________________________________________________________________________________
____________________
batch_normalization_64 (BatchNo (None, 16, 16, 210)  840         concatenate_
58[0][0]
__________________________________________________________________________________________________
____________________
activation_64 (Activation)      (None, 16, 16, 210)  0           batch_normal
ization_64[0][0]
__________________________________________________________________________________________________
____________________
conv2d_66 (Conv2D)              (None, 16, 16, 35)   66150       activation_6
4[0][0]
```

```
__________________________________________________________________________________________
__________________________
dropout_63 (Dropout)            (None, 16, 16, 35)   0           conv2d_66[0]
[0]
__________________________________________________________________________________________
__________________________
concatenate_59 (Concatenate)    (None, 16, 16, 245)  0           concatenate_
58[0][0]
                                                                 dropout_63
[0][0]
__________________________________________________________________________________________
__________________________
batch_normalization_65 (BatchNo (None, 16, 16, 245)  980         concatenate_
59[0][0]
__________________________________________________________________________________________
__________________________
activation_65 (Activation)      (None, 16, 16, 245)  0           batch_normal
ization_65[0][0]
__________________________________________________________________________________________
__________________________
conv2d_67 (Conv2D)              (None, 16, 16, 35)   8575        activation_6
5[0][0]
__________________________________________________________________________________________
__________________________
dropout_64 (Dropout)            (None, 16, 16, 35)   0           conv2d_67[0]
[0]
__________________________________________________________________________________________
__________________________
average_pooling2d_5 (AveragePoo (None, 8, 8, 35)     0           dropout_64
[0][0]
__________________________________________________________________________________________
__________________________
batch_normalization_66 (BatchNo (None, 8, 8, 35)     140         average_pool
ing2d_5[0][0]
__________________________________________________________________________________________
__________________________
activation_66 (Activation)      (None, 8, 8, 35)     0           batch_normal
ization_66[0][0]
__________________________________________________________________________________________
__________________________
conv2d_68 (Conv2D)              (None, 8, 8, 35)     11025       activation_6
6[0][0]
__________________________________________________________________________________________
__________________________
dropout_65 (Dropout)            (None, 8, 8, 35)     0           conv2d_68[0]
[0]
__________________________________________________________________________________________
__________________________
concatenate_60 (Concatenate)    (None, 8, 8, 70)     0           average_pool
ing2d_5[0][0]
                                                                 dropout_65
[0][0]
__________________________________________________________________________________________
__________________________
batch_normalization_67 (BatchNo (None, 8, 8, 70)     280         concatenate_
60[0][0]
__________________________________________________________________________________________
```

```
_____________________
activation_67 (Activation)      (None, 8, 8, 70)     0           batch_normal
ization_67[0][0]
_____________________________________________________________________________
_____________________
conv2d_69 (Conv2D)              (None, 8, 8, 35)     22050       activation_6
7[0][0]
_____________________________________________________________________________
_____________________
dropout_66 (Dropout)            (None, 8, 8, 35)     0           conv2d_69[0]
[0]
_____________________________________________________________________________
_____________________
concatenate_61 (Concatenate)    (None, 8, 8, 105)    0           concatenate_
60[0][0]
                                                                 dropout_66
[0][0]
_____________________________________________________________________________
_____________________
batch_normalization_68 (BatchNo (None, 8, 8, 105)    420         concatenate_
61[0][0]
_____________________________________________________________________________
_____________________
activation_68 (Activation)      (None, 8, 8, 105)    0           batch_normal
ization_68[0][0]
_____________________________________________________________________________
_____________________
conv2d_70 (Conv2D)              (None, 8, 8, 35)     33075       activation_6
8[0][0]
_____________________________________________________________________________
_____________________
dropout_67 (Dropout)            (None, 8, 8, 35)     0           conv2d_70[0]
[0]
_____________________________________________________________________________
_____________________
concatenate_62 (Concatenate)    (None, 8, 8, 140)    0           concatenate_
61[0][0]
                                                                 dropout_67
[0][0]
_____________________________________________________________________________
_____________________
batch_normalization_69 (BatchNo (None, 8, 8, 140)    560         concatenate_
62[0][0]
_____________________________________________________________________________
_____________________
activation_69 (Activation)      (None, 8, 8, 140)    0           batch_normal
ization_69[0][0]
_____________________________________________________________________________
_____________________
conv2d_71 (Conv2D)              (None, 8, 8, 35)     44100       activation_6
9[0][0]
_____________________________________________________________________________
_____________________
dropout_68 (Dropout)            (None, 8, 8, 35)     0           conv2d_71[0]
[0]
_____________________________________________________________________________
_____________________
```

```
concatenate_63 (Concatenate)    (None, 8, 8, 175)    0           concatenate_
62[0][0]
                                                                 dropout_68
[0][0]
__________________________________________________________________________
_____________________
batch_normalization_70 (BatchNo (None, 8, 8, 175)    700         concatenate_
63[0][0]
__________________________________________________________________________
_____________________
activation_70 (Activation)      (None, 8, 8, 175)    0           batch_normal
ization_70[0][0]
__________________________________________________________________________
_____________________
conv2d_72 (Conv2D)              (None, 8, 8, 35)     55125       activation_7
0[0][0]
__________________________________________________________________________
_____________________
dropout_69 (Dropout)            (None, 8, 8, 35)     0           conv2d_72[0]
[0]
__________________________________________________________________________
_____________________
concatenate_64 (Concatenate)    (None, 8, 8, 210)    0           concatenate_
63[0][0]
                                                                 dropout_69
[0][0]
__________________________________________________________________________
_____________________
batch_normalization_71 (BatchNo (None, 8, 8, 210)    840         concatenate_
64[0][0]
__________________________________________________________________________
_____________________
activation_71 (Activation)      (None, 8, 8, 210)    0           batch_normal
ization_71[0][0]
__________________________________________________________________________
_____________________
conv2d_73 (Conv2D)              (None, 8, 8, 35)     66150       activation_7
1[0][0]
__________________________________________________________________________
_____________________
dropout_70 (Dropout)            (None, 8, 8, 35)     0           conv2d_73[0]
[0]
__________________________________________________________________________
_____________________
concatenate_65 (Concatenate)    (None, 8, 8, 245)    0           concatenate_
64[0][0]
                                                                 dropout_70
[0][0]
__________________________________________________________________________
_____________________
batch_normalization_72 (BatchNo (None, 8, 8, 245)    980         concatenate_
65[0][0]
__________________________________________________________________________
_____________________
activation_72 (Activation)      (None, 8, 8, 245)    0           batch_normal
ization_72[0][0]
__________________________________________________________________________
```

```
_____________________
conv2d_74 (Conv2D)              (None, 8, 8, 35)     8575        activation_7
2[0][0]
_____________________
_____________________
dropout_71 (Dropout)            (None, 8, 8, 35)     0           conv2d_74[0]
[0]
_____________________
_____________________
average_pooling2d_6 (AveragePoo (None, 4, 4, 35)     0           dropout_71
[0][0]
_____________________
_____________________
batch_normalization_73 (BatchNo (None, 4, 4, 35)     140         average_pool
ing2d_6[0][0]
_____________________
_____________________
activation_73 (Activation)      (None, 4, 4, 35)     0           batch_normal
ization_73[0][0]
_____________________
_____________________
conv2d_75 (Conv2D)              (None, 4, 4, 35)     11025       activation_7
3[0][0]
_____________________
_____________________
dropout_72 (Dropout)            (None, 4, 4, 35)     0           conv2d_75[0]
[0]
_____________________
_____________________
concatenate_66 (Concatenate)    (None, 4, 4, 70)     0           average_pool
ing2d_6[0][0]
                                                                 dropout_72
[0][0]
_____________________
_____________________
batch_normalization_74 (BatchNo (None, 4, 4, 70)     280         concatenate_
66[0][0]
_____________________
_____________________
activation_74 (Activation)      (None, 4, 4, 70)     0           batch_normal
ization_74[0][0]
_____________________
_____________________
conv2d_76 (Conv2D)              (None, 4, 4, 35)     22050       activation_7
4[0][0]
_____________________
_____________________
dropout_73 (Dropout)            (None, 4, 4, 35)     0           conv2d_76[0]
[0]
_____________________
_____________________
concatenate_67 (Concatenate)    (None, 4, 4, 105)    0           concatenate_
66[0][0]
                                                                 dropout_73
[0][0]
_____________________
_____________________
```

```
batch_normalization_75 (BatchNo (None, 4, 4, 105)    420         concatenate_
67[0][0]
__________________________________________________________________________
_____
activation_75 (Activation)      (None, 4, 4, 105)    0           batch_normal
ization_75[0][0]
__________________________________________________________________________
_____
conv2d_77 (Conv2D)              (None, 4, 4, 35)     33075       activation_7
5[0][0]
__________________________________________________________________________
_____
dropout_74 (Dropout)            (None, 4, 4, 35)     0           conv2d_77[0]
[0]
__________________________________________________________________________
_____
concatenate_68 (Concatenate)    (None, 4, 4, 140)    0           concatenate_
67[0][0]
                                                                 dropout_74
[0][0]
__________________________________________________________________________
_____
batch_normalization_76 (BatchNo (None, 4, 4, 140)    560         concatenate_
68[0][0]
__________________________________________________________________________
_____
activation_76 (Activation)      (None, 4, 4, 140)    0           batch_normal
ization_76[0][0]
__________________________________________________________________________
_____
conv2d_78 (Conv2D)              (None, 4, 4, 35)     44100       activation_7
6[0][0]
__________________________________________________________________________
_____
dropout_75 (Dropout)            (None, 4, 4, 35)     0           conv2d_78[0]
[0]
__________________________________________________________________________
_____
concatenate_69 (Concatenate)    (None, 4, 4, 175)    0           concatenate_
68[0][0]
                                                                 dropout_75
[0][0]
__________________________________________________________________________
_____
batch_normalization_77 (BatchNo (None, 4, 4, 175)    700         concatenate_
69[0][0]
__________________________________________________________________________
_____
activation_77 (Activation)      (None, 4, 4, 175)    0           batch_normal
ization_77[0][0]
__________________________________________________________________________
_____
conv2d_79 (Conv2D)              (None, 4, 4, 35)     55125       activation_7
7[0][0]
__________________________________________________________________________
_____
dropout_76 (Dropout)            (None, 4, 4, 35)     0           conv2d_79[0]
```

```
[0]
__________________________________________________________________________________________
_____________________
concatenate_70 (Concatenate)    (None, 4, 4, 210)    0           concatenate_
69[0][0]
                                                                 dropout_76
[0][0]
__________________________________________________________________________________________
_____________________
batch_normalization_78 (BatchNo (None, 4, 4, 210)    840         concatenate_
70[0][0]
__________________________________________________________________________________________
_____________________
activation_78 (Activation)      (None, 4, 4, 210)    0           batch_normal
ization_78[0][0]
__________________________________________________________________________________________
_____________________
conv2d_80 (Conv2D)              (None, 4, 4, 35)     66150       activation_7
8[0][0]
__________________________________________________________________________________________
_____________________
dropout_77 (Dropout)            (None, 4, 4, 35)     0           conv2d_80[0]
[0]
__________________________________________________________________________________________
_____________________
concatenate_71 (Concatenate)    (None, 4, 4, 245)    0           concatenate_
70[0][0]
                                                                 dropout_77
[0][0]
__________________________________________________________________________________________
_____________________
batch_normalization_79 (BatchNo (None, 4, 4, 245)    980         concatenate_
71[0][0]
__________________________________________________________________________________________
_____________________
activation_79 (Activation)      (None, 4, 4, 245)    0           batch_normal
ization_79[0][0]
__________________________________________________________________________________________
_____________________
average_pooling2d_7 (AveragePoo (None, 1, 1, 245)    0           activation_7
9[0][0]
__________________________________________________________________________________________
_____________________
conv2d_81 (Conv2D)              (None, 1, 1, 10)     2460        average_pool
ing2d_7[0][0]
__________________________________________________________________________________________
_____________________
flatten_1 (Flatten)             (None, 10)           0           conv2d_81[0]
[0]
==========================================================================
======================
Total params: 970,910
Trainable params: 963,070
Non-trainable params: 7,840
__________________________________________________________________________________________
_____________________
```

In [0]:
```
# determine Loss function and Optimizer
model.compile(loss='categorical_crossentropy',
              optimizer=Adam(),
              metrics=['accuracy'])
```

In [0]:
```
from keras.preprocessing.image import ImageDataGenerator
generator = ImageDataGenerator(rotation_range=20,
                               width_shift_range=0.125,
                               height_shift_range=0.125,
                               horizontal_flip=True,
                               fill_mode='nearest',
                               zoom_range=0.10)

generator.fit(X_train)
```

In [22]:
```
#https://blog.keras.io/building-powerful-image-classification-models-using-very-little-data.html
model.fit_generator(generator.flow(X_train, y_train, batch_size=batch_size),
                    steps_per_epoch=(len(X_train)//batch_size)*5, epochs=20,
                    validation_data=(X_test, y_test))
```

```
Epoch 1/20
3905/3905 [==============================] - 410s 105ms/step - loss: 0.4277 -
acc: 0.8520 - val_loss: 0.8166 - val_acc: 0.7626
Epoch 2/20
3905/3905 [==============================] - 406s 104ms/step - loss: 0.3864 -
acc: 0.8654 - val_loss: 0.5648 - val_acc: 0.8379
Epoch 3/20
3905/3905 [==============================] - 409s 105ms/step - loss: 0.3513 -
acc: 0.8778 - val_loss: 0.4767 - val_acc: 0.8535
Epoch 4/20
3905/3905 [==============================] - 409s 105ms/step - loss: 0.3245 -
acc: 0.8873 - val_loss: 0.4529 - val_acc: 0.8631
Epoch 5/20
3905/3905 [==============================] - 407s 104ms/step - loss: 0.3051 -
acc: 0.8936 - val_loss: 0.3657 - val_acc: 0.8901
Epoch 6/20
3905/3905 [==============================] - 406s 104ms/step - loss: 0.2859 -
acc: 0.8998 - val_loss: 0.4397 - val_acc: 0.8722
Epoch 7/20
3905/3905 [==============================] - 407s 104ms/step - loss: 0.2689 -
acc: 0.9054 - val_loss: 0.4023 - val_acc: 0.8840
Epoch 8/20
3905/3905 [==============================] - 402s 103ms/step - loss: 0.2564 -
acc: 0.9105 - val_loss: 0.3955 - val_acc: 0.8888
Epoch 9/20
3905/3905 [==============================] - 400s 103ms/step - loss: 0.2447 -
acc: 0.9146 - val_loss: 0.3739 - val_acc: 0.8931
Epoch 10/20
3905/3905 [==============================] - 400s 102ms/step - loss: 0.2340 -
acc: 0.9180 - val_loss: 0.3771 - val_acc: 0.8959
Epoch 11/20
3905/3905 [==============================] - 400s 103ms/step - loss: 0.2259 -
acc: 0.9203 - val_loss: 0.4087 - val_acc: 0.8845
Epoch 12/20
3905/3905 [==============================] - 401s 103ms/step - loss: 0.2155 -
acc: 0.9244 - val_loss: 0.4331 - val_acc: 0.8867
Epoch 13/20
3905/3905 [==============================] - 400s 102ms/step - loss: 0.2092 -
acc: 0.9262 - val_loss: 0.3012 - val_acc: 0.9111
Epoch 14/20
3905/3905 [==============================] - 400s 102ms/step - loss: 0.2005 -
acc: 0.9293 - val_loss: 0.3843 - val_acc: 0.8952
Epoch 15/20
3905/3905 [==============================] - 399s 102ms/step - loss: 0.1950 -
acc: 0.9312 - val_loss: 0.3442 - val_acc: 0.9079
Epoch 16/20
3905/3905 [==============================] - 400s 102ms/step - loss: 0.1888 -
acc: 0.9331 - val_loss: 0.3730 - val_acc: 0.9056
Epoch 17/20
3905/3905 [==============================] - 400s 102ms/step - loss: 0.1847 -
acc: 0.9351 - val_loss: 0.3603 - val_acc: 0.8998
Epoch 18/20
3905/3905 [==============================] - 400s 102ms/step - loss: 0.1777 -
acc: 0.9373 - val_loss: 0.3620 - val_acc: 0.9038
Epoch 19/20
3905/3905 [==============================] - 400s 103ms/step - loss: 0.1722 -
acc: 0.9394 - val_loss: 0.3658 - val_acc: 0.9072
```

```
Epoch 20/20
3905/3905 [==============================] - 400s 102ms/step - loss: 0.1679 -
acc: 0.9407 - val_loss: 0.3436 - val_acc: 0.9071
```

Out[22]: <tensorflow.python.keras.callbacks.History at 0x7fb431f2aac8>

In [23]:
```
# Test the model
score = model.evaluate(X_test, y_test, verbose=1)
print('Test loss:', score[0])
print('Test accuracy:', score[1])
```

```
10000/10000 [==============================] - 4s 444us/sample - loss: 0.3447
- acc: 0.9071
Test loss: 0.3446852895885706
Test accuracy: 0.9071
```

In [0]:
```
# Save the trained weights in to .h5 format
model.save_weights("DNST_model.h5")
print("Saved model to disk")
```

```
Saved model to disk
```

Conclusions:

1- Used the given densenet to build the architecture of the model.

2- Used Image Augmentation techniques to make the model robust.

3- Used adam optimizer to optimize the loss.

4- Run the code for 20 epochs.

5- Test Loss=0.344

6- Test accuracy=90.71%