DenseNet_cifar10

April 22, 2021

[ ]:
```
# import keras
# from keras.datasets import cifar10
# from keras.models import Model, Sequential
# from keras.layers import Dense, Dropout, Flatten, Input, AveragePooling2D,␣
 ↪merge, Activation
# from keras.layers import Conv2D, MaxPooling2D, BatchNormalization
# from keras.layers import Concatenate
# from keras.optimizers import Adam
from tensorflow.keras import models, layers
from tensorflow.keras.models import Model
from tensorflow.keras.layers import BatchNormalization, Activation, Flatten
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras import regularizers
import tensorboard
import numpy as np
import tensorflow as tf
%load_ext tensorboard
```

```
The tensorboard extension is already loaded. To reload it, use:
  %reload_ext tensorboard
```

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

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# Hyperparameters

batch_size = 64
num_classes = 10
epochs = 85
l = 6 # no of layers in dense block
num_filter = 35 # growth rate k
compression = 1.0
dropout_rate = 0.20
weight_decay = 0.001
```

[ ]:
```
# 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)
```

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# Dense Block
def denseblock(input, num_filter = 12, dropout_rate = 0.2):
    global compression
    temp = input
    for _ in range(l):
        BatchNorm = layers.BatchNormalization()(temp)
        relu = layers.Activation('relu')(BatchNorm)
        Conv2D_3_3 = layers.Conv2D(int(num_filter*compression), (3,3),␣
 ↪use_bias=False ,padding='same', kernel_initializer='he_normal',
                                   kernel_regularizer=tf.keras.regularizers.
 ↪l2(weight_decay))(relu)
        if dropout_rate>0:
            Conv2D_3_3 = layers.Dropout(dropout_rate)(Conv2D_3_3)
        concat = layers.Concatenate(axis=-1)([temp,Conv2D_3_3])

        temp = concat

    return temp

## transition Blosck
def transition(input, num_filter = 12, dropout_rate = 0.2):
    global compression
    BatchNorm = layers.BatchNormalization()(input)
    relu = layers.Activation('relu')(BatchNorm)
    Conv2D_BottleNeck = layers.Conv2D(int(num_filter*compression), (1,1),␣
 ↪use_bias=False ,padding='same', kernel_initializer='he_normal',
                                   kernel_regularizer=tf.keras.regularizers.
 ↪l2(weight_decay))(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(momentum=0.9, epsilon=0.00001)(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',␣
↪kernel_initializer='he_normal',
                      kernel_regularizer=regularizers.l2(weight_decay))(flat)
    return output
```

[ ]:
```
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)
```

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#https://arxiv.org/pdf/1608.06993.pdf
from IPython.display import IFrame, YouTubeVideo
YouTubeVideo(id='-W6y8xnd--U', width=600)
```
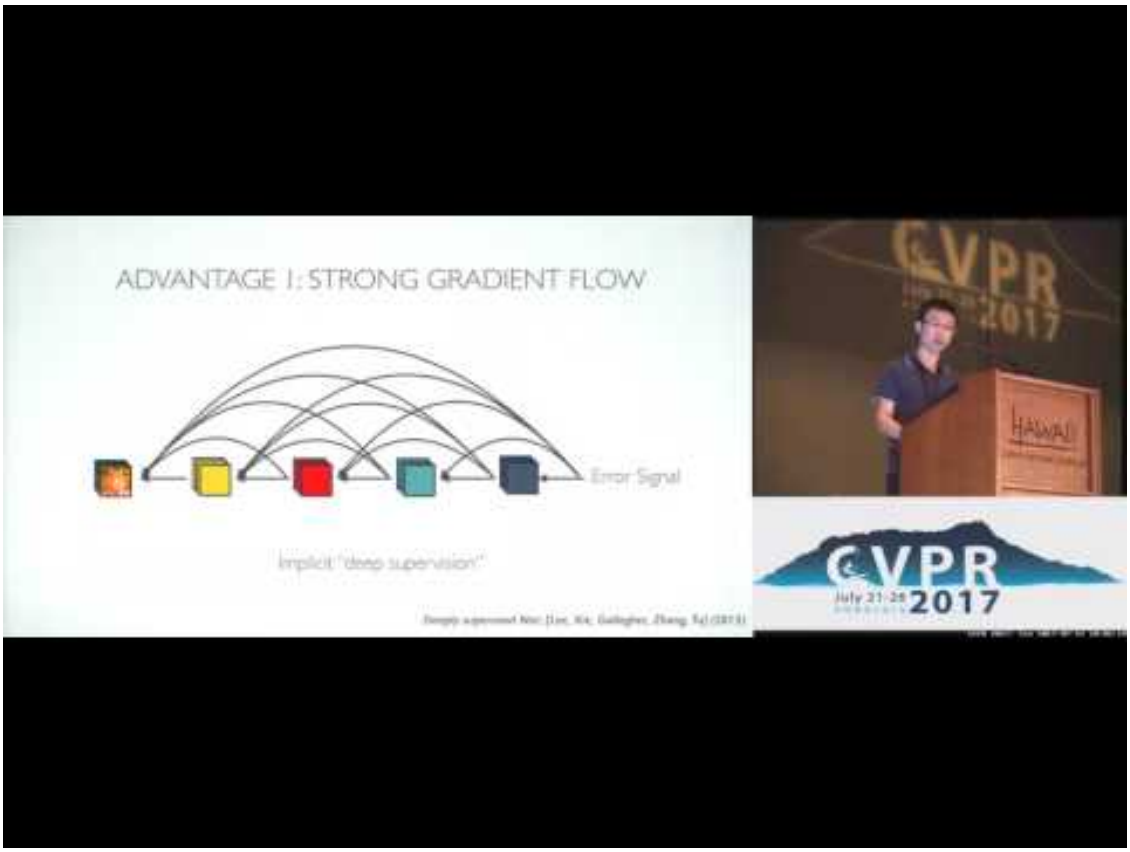

[ ]:



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

```
Model: "functional_3"
_________________________________________________________________________________
__________________
Layer (type)                    Output Shape         Param #     Connected to
=================================================================================
==================
input_3 (InputLayer)            [(None, 32, 32, 3)]  0
_________________________________________________________________________________
__________________
conv2d_29 (Conv2D)              (None, 32, 32, 35)   945         input_3[0][0]
_________________________________________________________________________________
__________________
batch_normalization_29 (BatchNo (None, 32, 32, 35)   140         conv2d_29[0][0]
_________________________________________________________________________________
__________________
activation_29 (Activation)      (None, 32, 32, 35)   0
batch_normalization_29[0][0]
_________________________________________________________________________________
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------------------
conv2d_30 (Conv2D)              (None, 32, 32, 35)   11025
activation_29[0][0]
--------------------------------------------------------------------------------
------------------
dropout_27 (Dropout)            (None, 32, 32, 35)   0           conv2d_30[0][0]
--------------------------------------------------------------------------------
------------------
concatenate_24 (Concatenate)    (None, 32, 32, 70)   0           conv2d_29[0][0]
dropout_27[0][0]
--------------------------------------------------------------------------------
------------------
batch_normalization_30 (BatchNo (None, 32, 32, 70)   280
concatenate_24[0][0]
--------------------------------------------------------------------------------
------------------
activation_30 (Activation)      (None, 32, 32, 70)   0
batch_normalization_30[0][0]
--------------------------------------------------------------------------------
------------------
conv2d_31 (Conv2D)              (None, 32, 32, 35)   22050
activation_30[0][0]
--------------------------------------------------------------------------------
------------------
dropout_28 (Dropout)            (None, 32, 32, 35)   0           conv2d_31[0][0]
--------------------------------------------------------------------------------
------------------
concatenate_25 (Concatenate)    (None, 32, 32, 105)  0
concatenate_24[0][0]
dropout_28[0][0]
--------------------------------------------------------------------------------
------------------
batch_normalization_31 (BatchNo (None, 32, 32, 105)  420
concatenate_25[0][0]
--------------------------------------------------------------------------------
------------------
activation_31 (Activation)      (None, 32, 32, 105)  0
batch_normalization_31[0][0]
--------------------------------------------------------------------------------
------------------
conv2d_32 (Conv2D)              (None, 32, 32, 35)   33075
activation_31[0][0]
--------------------------------------------------------------------------------
------------------
dropout_29 (Dropout)            (None, 32, 32, 35)   0           conv2d_32[0][0]
--------------------------------------------------------------------------------
------------------
concatenate_26 (Concatenate)    (None, 32, 32, 140)  0
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concatenate_25[0][0]
dropout_29[0][0]
__________________________________________________________________________________
__________________
batch_normalization_32 (BatchNo (None, 32, 32, 140)  560
concatenate_26[0][0]
__________________________________________________________________________________
__________________
activation_32 (Activation)      (None, 32, 32, 140)  0
batch_normalization_32[0][0]
__________________________________________________________________________________
__________________
conv2d_33 (Conv2D)              (None, 32, 32, 35)   44100
activation_32[0][0]
__________________________________________________________________________________
__________________
dropout_30 (Dropout)            (None, 32, 32, 35)   0           conv2d_33[0][0]
__________________________________________________________________________________
__________________
concatenate_27 (Concatenate)    (None, 32, 32, 175)  0
concatenate_26[0][0]
dropout_30[0][0]
__________________________________________________________________________________
__________________
batch_normalization_33 (BatchNo (None, 32, 32, 175)  700
concatenate_27[0][0]
__________________________________________________________________________________
__________________
activation_33 (Activation)      (None, 32, 32, 175)  0
batch_normalization_33[0][0]
__________________________________________________________________________________
__________________
conv2d_34 (Conv2D)              (None, 32, 32, 35)   55125
activation_33[0][0]
__________________________________________________________________________________
__________________
dropout_31 (Dropout)            (None, 32, 32, 35)   0           conv2d_34[0][0]
__________________________________________________________________________________
__________________
concatenate_28 (Concatenate)    (None, 32, 32, 210)  0
concatenate_27[0][0]
dropout_31[0][0]
__________________________________________________________________________________
__________________
batch_normalization_34 (BatchNo (None, 32, 32, 210)  840
concatenate_28[0][0]
__________________________________________________________________________________
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activation_34 (Activation)      (None, 32, 32, 210)  0
batch_normalization_34[0][0]
__________________________________________________________________________________
__________________
conv2d_35 (Conv2D)              (None, 32, 32, 35)   66150
activation_34[0][0]
__________________________________________________________________________________
__________________
dropout_32 (Dropout)            (None, 32, 32, 35)   0           conv2d_35[0][0]
__________________________________________________________________________________
__________________
concatenate_29 (Concatenate)    (None, 32, 32, 245)  0
concatenate_28[0][0]
dropout_32[0][0]
__________________________________________________________________________________
__________________
batch_normalization_35 (BatchNo (None, 32, 32, 245)  980
concatenate_29[0][0]
__________________________________________________________________________________
__________________
activation_35 (Activation)      (None, 32, 32, 245)  0
batch_normalization_35[0][0]
__________________________________________________________________________________
__________________
conv2d_36 (Conv2D)              (None, 32, 32, 35)   8575
activation_35[0][0]
__________________________________________________________________________________
__________________
dropout_33 (Dropout)            (None, 32, 32, 35)   0           conv2d_36[0][0]
__________________________________________________________________________________
__________________
average_pooling2d_4 (AveragePoo (None, 16, 16, 35)   0
dropout_33[0][0]
__________________________________________________________________________________
__________________
batch_normalization_36 (BatchNo (None, 16, 16, 35)   140
average_pooling2d_4[0][0]
__________________________________________________________________________________
__________________
activation_36 (Activation)      (None, 16, 16, 35)   0
batch_normalization_36[0][0]
__________________________________________________________________________________
__________________
conv2d_37 (Conv2D)              (None, 16, 16, 35)   11025
activation_36[0][0]
__________________________________________________________________________________
__________________
dropout_34 (Dropout)            (None, 16, 16, 35)   0           conv2d_37[0][0]
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__________________________________________________________________________________
__________________
concatenate_30 (Concatenate)    (None, 16, 16, 70)   0
average_pooling2d_4[0][0]
dropout_34[0][0]
__________________________________________________________________________________
__________________
batch_normalization_37 (BatchNo (None, 16, 16, 70)   280
concatenate_30[0][0]
__________________________________________________________________________________
__________________
activation_37 (Activation)      (None, 16, 16, 70)   0
batch_normalization_37[0][0]
__________________________________________________________________________________
__________________
conv2d_38 (Conv2D)              (None, 16, 16, 35)   22050
activation_37[0][0]
__________________________________________________________________________________
__________________
dropout_35 (Dropout)            (None, 16, 16, 35)   0           conv2d_38[0][0]
__________________________________________________________________________________
__________________
concatenate_31 (Concatenate)    (None, 16, 16, 105)  0
concatenate_30[0][0]
dropout_35[0][0]
__________________________________________________________________________________
__________________
batch_normalization_38 (BatchNo (None, 16, 16, 105)  420
concatenate_31[0][0]
__________________________________________________________________________________
__________________
activation_38 (Activation)      (None, 16, 16, 105)  0
batch_normalization_38[0][0]
__________________________________________________________________________________
__________________
conv2d_39 (Conv2D)              (None, 16, 16, 35)   33075
activation_38[0][0]
__________________________________________________________________________________
__________________
dropout_36 (Dropout)            (None, 16, 16, 35)   0           conv2d_39[0][0]
__________________________________________________________________________________
__________________
concatenate_32 (Concatenate)    (None, 16, 16, 140)  0
concatenate_31[0][0]
dropout_36[0][0]
__________________________________________________________________________________
__________________
batch_normalization_39 (BatchNo (None, 16, 16, 140)  560
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concatenate_32[0][0]
__________________________________________________________________________________
__________________
activation_39 (Activation)      (None, 16, 16, 140)  0
batch_normalization_39[0][0]
__________________________________________________________________________________
__________________
conv2d_40 (Conv2D)              (None, 16, 16, 35)   44100
activation_39[0][0]
__________________________________________________________________________________
__________________
dropout_37 (Dropout)            (None, 16, 16, 35)   0           conv2d_40[0][0]
__________________________________________________________________________________
__________________
concatenate_33 (Concatenate)    (None, 16, 16, 175)  0
concatenate_32[0][0]
dropout_37[0][0]
__________________________________________________________________________________
__________________
batch_normalization_40 (BatchNo (None, 16, 16, 175)  700
concatenate_33[0][0]
__________________________________________________________________________________
__________________
activation_40 (Activation)      (None, 16, 16, 175)  0
batch_normalization_40[0][0]
__________________________________________________________________________________
__________________
conv2d_41 (Conv2D)              (None, 16, 16, 35)   55125
activation_40[0][0]
__________________________________________________________________________________
__________________
dropout_38 (Dropout)            (None, 16, 16, 35)   0           conv2d_41[0][0]
__________________________________________________________________________________
__________________
concatenate_34 (Concatenate)    (None, 16, 16, 210)  0
concatenate_33[0][0]
dropout_38[0][0]
__________________________________________________________________________________
__________________
batch_normalization_41 (BatchNo (None, 16, 16, 210)  840
concatenate_34[0][0]
__________________________________________________________________________________
__________________
activation_41 (Activation)      (None, 16, 16, 210)  0
batch_normalization_41[0][0]
__________________________________________________________________________________
__________________
conv2d_42 (Conv2D)              (None, 16, 16, 35)   66150
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activation_41[0][0]
__________________________________________________________________________________________________
dropout_39 (Dropout)            (None, 16, 16, 35)   0           conv2d_42[0][0]
__________________________________________________________________________________________________
concatenate_35 (Concatenate)    (None, 16, 16, 245)  0
concatenate_34[0][0]
dropout_39[0][0]
__________________________________________________________________________________________________
batch_normalization_42 (BatchNo (None, 16, 16, 245)  980
concatenate_35[0][0]
__________________________________________________________________________________________________
activation_42 (Activation)      (None, 16, 16, 245)  0
batch_normalization_42[0][0]
__________________________________________________________________________________________________
conv2d_43 (Conv2D)              (None, 16, 16, 35)   8575
activation_42[0][0]
__________________________________________________________________________________________________
dropout_40 (Dropout)            (None, 16, 16, 35)   0           conv2d_43[0][0]
__________________________________________________________________________________________________
average_pooling2d_5 (AveragePoo (None, 8, 8, 35)     0
dropout_40[0][0]
__________________________________________________________________________________________________
batch_normalization_43 (BatchNo (None, 8, 8, 35)     140
average_pooling2d_5[0][0]
__________________________________________________________________________________________________
activation_43 (Activation)      (None, 8, 8, 35)     0
batch_normalization_43[0][0]
__________________________________________________________________________________________________
conv2d_44 (Conv2D)              (None, 8, 8, 35)     11025
activation_43[0][0]
__________________________________________________________________________________________________
dropout_41 (Dropout)            (None, 8, 8, 35)     0           conv2d_44[0][0]
__________________________________________________________________________________________________
concatenate_36 (Concatenate)    (None, 8, 8, 70)     0
average_pooling2d_5[0][0]
dropout_41[0][0]
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__________________________________________________________________________________
__________________
batch_normalization_44 (BatchNo (None, 8, 8, 70)     280
concatenate_36[0][0]
__________________________________________________________________________________
__________________
activation_44 (Activation)      (None, 8, 8, 70)     0
batch_normalization_44[0][0]
__________________________________________________________________________________
__________________
conv2d_45 (Conv2D)              (None, 8, 8, 35)     22050
activation_44[0][0]
__________________________________________________________________________________
__________________
dropout_42 (Dropout)            (None, 8, 8, 35)     0           conv2d_45[0][0]
__________________________________________________________________________________
__________________
concatenate_37 (Concatenate)    (None, 8, 8, 105)    0
concatenate_36[0][0]
dropout_42[0][0]
__________________________________________________________________________________
__________________
batch_normalization_45 (BatchNo (None, 8, 8, 105)    420
concatenate_37[0][0]
__________________________________________________________________________________
__________________
activation_45 (Activation)      (None, 8, 8, 105)    0
batch_normalization_45[0][0]
__________________________________________________________________________________
__________________
conv2d_46 (Conv2D)              (None, 8, 8, 35)     33075
activation_45[0][0]
__________________________________________________________________________________
__________________
dropout_43 (Dropout)            (None, 8, 8, 35)     0           conv2d_46[0][0]
__________________________________________________________________________________
__________________
concatenate_38 (Concatenate)    (None, 8, 8, 140)    0
concatenate_37[0][0]
dropout_43[0][0]
__________________________________________________________________________________
__________________
batch_normalization_46 (BatchNo (None, 8, 8, 140)    560
concatenate_38[0][0]
__________________________________________________________________________________
__________________
activation_46 (Activation)      (None, 8, 8, 140)    0
batch_normalization_46[0][0]
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__________________________________________________________________________________
__________________
conv2d_47 (Conv2D)              (None, 8, 8, 35)     44100
activation_46[0][0]
__________________________________________________________________________________
__________________
dropout_44 (Dropout)            (None, 8, 8, 35)     0           conv2d_47[0][0]
__________________________________________________________________________________
__________________
concatenate_39 (Concatenate)    (None, 8, 8, 175)    0
concatenate_38[0][0]
dropout_44[0][0]
__________________________________________________________________________________
__________________
batch_normalization_47 (BatchNo (None, 8, 8, 175)    700
concatenate_39[0][0]
__________________________________________________________________________________
__________________
activation_47 (Activation)      (None, 8, 8, 175)    0
batch_normalization_47[0][0]
__________________________________________________________________________________
__________________
conv2d_48 (Conv2D)              (None, 8, 8, 35)     55125
activation_47[0][0]
__________________________________________________________________________________
__________________
dropout_45 (Dropout)            (None, 8, 8, 35)     0           conv2d_48[0][0]
__________________________________________________________________________________
__________________
concatenate_40 (Concatenate)    (None, 8, 8, 210)    0
concatenate_39[0][0]
dropout_45[0][0]
__________________________________________________________________________________
__________________
batch_normalization_48 (BatchNo (None, 8, 8, 210)    840
concatenate_40[0][0]
__________________________________________________________________________________
__________________
activation_48 (Activation)      (None, 8, 8, 210)    0
batch_normalization_48[0][0]
__________________________________________________________________________________
__________________
conv2d_49 (Conv2D)              (None, 8, 8, 35)     66150
activation_48[0][0]
__________________________________________________________________________________
__________________
dropout_46 (Dropout)            (None, 8, 8, 35)     0           conv2d_49[0][0]
__________________________________________________________________________________
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__________________
concatenate_41 (Concatenate)    (None, 8, 8, 245)    0
concatenate_40[0][0]
dropout_46[0][0]
__________________________________________________________________________________
__________________
batch_normalization_49 (BatchNo (None, 8, 8, 245)    980
concatenate_41[0][0]
__________________________________________________________________________________
__________________
activation_49 (Activation)      (None, 8, 8, 245)    0
batch_normalization_49[0][0]
__________________________________________________________________________________
__________________
conv2d_50 (Conv2D)              (None, 8, 8, 35)     8575
activation_49[0][0]
__________________________________________________________________________________
__________________
dropout_47 (Dropout)            (None, 8, 8, 35)     0           conv2d_50[0][0]
__________________________________________________________________________________
__________________
average_pooling2d_6 (AveragePoo (None, 4, 4, 35)     0
dropout_47[0][0]
__________________________________________________________________________________
__________________
batch_normalization_50 (BatchNo (None, 4, 4, 35)     140
average_pooling2d_6[0][0]
__________________________________________________________________________________
__________________
activation_50 (Activation)      (None, 4, 4, 35)     0
batch_normalization_50[0][0]
__________________________________________________________________________________
__________________
conv2d_51 (Conv2D)              (None, 4, 4, 35)     11025
activation_50[0][0]
__________________________________________________________________________________
__________________
dropout_48 (Dropout)            (None, 4, 4, 35)     0           conv2d_51[0][0]
__________________________________________________________________________________
__________________
concatenate_42 (Concatenate)    (None, 4, 4, 70)     0
average_pooling2d_6[0][0]
dropout_48[0][0]
__________________________________________________________________________________
__________________
batch_normalization_51 (BatchNo (None, 4, 4, 70)     280
concatenate_42[0][0]
__________________________________________________________________________________
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__________________
activation_51 (Activation)      (None, 4, 4, 70)     0
batch_normalization_51[0][0]

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__________________
conv2d_52 (Conv2D)              (None, 4, 4, 35)     22050
activation_51[0][0]

____________________________________________________________________________
__________________
dropout_49 (Dropout)            (None, 4, 4, 35)     0           conv2d_52[0][0]

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__________________
concatenate_43 (Concatenate)    (None, 4, 4, 105)    0
concatenate_42[0][0]
dropout_49[0][0]

____________________________________________________________________________
__________________
batch_normalization_52 (BatchNo (None, 4, 4, 105)    420
concatenate_43[0][0]

____________________________________________________________________________
__________________
activation_52 (Activation)      (None, 4, 4, 105)    0
batch_normalization_52[0][0]

____________________________________________________________________________
__________________
conv2d_53 (Conv2D)              (None, 4, 4, 35)     33075
activation_52[0][0]

____________________________________________________________________________
__________________
dropout_50 (Dropout)            (None, 4, 4, 35)     0           conv2d_53[0][0]

____________________________________________________________________________
__________________
concatenate_44 (Concatenate)    (None, 4, 4, 140)    0
concatenate_43[0][0]
dropout_50[0][0]

____________________________________________________________________________
__________________
batch_normalization_53 (BatchNo (None, 4, 4, 140)    560
concatenate_44[0][0]

____________________________________________________________________________
__________________
activation_53 (Activation)      (None, 4, 4, 140)    0
batch_normalization_53[0][0]

____________________________________________________________________________
__________________
conv2d_54 (Conv2D)              (None, 4, 4, 35)     44100
activation_53[0][0]

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__________________
dropout_51 (Dropout)            (None, 4, 4, 35)     0           conv2d_54[0][0]
____________________________________________________________________________________
__________________
concatenate_45 (Concatenate)    (None, 4, 4, 175)    0
concatenate_44[0][0]
dropout_51[0][0]
____________________________________________________________________________________
__________________
batch_normalization_54 (BatchNo (None, 4, 4, 175)    700
concatenate_45[0][0]
____________________________________________________________________________________
__________________
activation_54 (Activation)      (None, 4, 4, 175)    0
batch_normalization_54[0][0]
____________________________________________________________________________________
__________________
conv2d_55 (Conv2D)              (None, 4, 4, 35)     55125
activation_54[0][0]
____________________________________________________________________________________
__________________
dropout_52 (Dropout)            (None, 4, 4, 35)     0           conv2d_55[0][0]
____________________________________________________________________________________
__________________
concatenate_46 (Concatenate)    (None, 4, 4, 210)    0
concatenate_45[0][0]
dropout_52[0][0]
____________________________________________________________________________________
__________________
batch_normalization_55 (BatchNo (None, 4, 4, 210)    840
concatenate_46[0][0]
____________________________________________________________________________________
__________________
activation_55 (Activation)      (None, 4, 4, 210)    0
batch_normalization_55[0][0]
____________________________________________________________________________________
__________________
conv2d_56 (Conv2D)              (None, 4, 4, 35)     66150
activation_55[0][0]
____________________________________________________________________________________
__________________
dropout_53 (Dropout)            (None, 4, 4, 35)     0           conv2d_56[0][0]
____________________________________________________________________________________
__________________
concatenate_47 (Concatenate)    (None, 4, 4, 245)    0
concatenate_46[0][0]
dropout_53[0][0]
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batch_normalization_56 (BatchNo (None, 4, 4, 245)    980
concatenate_47[0][0]
------------------------------------------------------------------------------
------------------
activation_56 (Activation)      (None, 4, 4, 245)    0
batch_normalization_56[0][0]
------------------------------------------------------------------------------
------------------
average_pooling2d_7 (AveragePoo (None, 2, 2, 245)    0
activation_56[0][0]
------------------------------------------------------------------------------
------------------
flatten_1 (Flatten)             (None, 980)          0
average_pooling2d_7[0][0]
------------------------------------------------------------------------------
------------------
dense_1 (Dense)                 (None, 10)           9810        flatten_1[0][0]
==============================================================================
==================
Total params: 978,260
Trainable params: 970,420
Non-trainable params: 7,840
------------------------------------------------------------------------------
------------------
```

[ ]:
```
print(len(model.layers))
```

```
142
```

[ ]:
```
X_train = X_train.astype('float32')
X_test = X_test.astype('float32')

def preprocess_data(data_set):
    mean = np.array([125.3, 123.0, 113.9])
    std = np.array([63.0, 62.1, 66.7])

    data_set -= mean
    data_set /= std
    return data_set

X_train = preprocess_data(X_train)
# X_test = preprocess_data(X_test)
```

[ ]:
```
# optimizer = tf.keras.optimizers.Adam()
optimizer = tf.keras.optimizers.Adam()
```

```
model.compile(loss='categorical_crossentropy', optimizer=optimizer,␣
↪metrics=['accuracy'])

# set callback
tensorboardb_callback = tf.keras.callbacks.TensorBoard(log_dir='logs/fit',␣
↪histogram_freq=0)
modelCheckpoint_callback = tf.keras.callbacks.ModelCheckpoint('./ckpt.h5',␣
↪save_best_only=False, mode='auto', period=10)
earlyStopping_callback = tf.keras.callbacks.EarlyStopping(monitor='val_loss',␣
↪mode="min", patience=10, verbose=1)
# redule_lr_on_plataeu_callback = tf.keras.callbacks.
↪ReduceLROnPlateau(monitor='val_loss',patience=2, mode='min', factor=0.1)
callBacks = [tensorboardb_callback, modelCheckpoint_callback,␣
↪earlyStopping_callback]
```

```
WARNING:tensorflow:`period` argument is deprecated. Please use `save_freq` to
specify the frequency in number of batches seen.
```

[ ]:

[ ]:
```
# Data augementation

datagen = ImageDataGenerator(
    rotation_range=20,
    width_shift_range=0.125,
    height_shift_range=0.125,
    horizontal_flip=True,
    fill_mode='nearest',
    zoom_range=0.10
)

datagen.fit(X_train)
```

[ ]:
```
model.fit_generator(datagen.flow(X_train,y_train,batch_size=batch_size),
                     epochs=epochs,
                    callbacks=callBacks,
                    validation_data=(X_test, y_test),
                    verbose=1)

model.save('densenet.h5')
```

```
Epoch 1/85
  2/782 […] - ETA: 2:34 - loss: 4.4031 - accuracy:
0.0625WARNING:tensorflow:Callbacks method `on_train_batch_end` is slow compared
to the batch time (batch time: 0.0552s vs `on_train_batch_end` time: 0.3418s).
Check your callbacks.
782/782 [==============================] - 69s 88ms/step - loss: 2.6310 -
```

```
accuracy: 0.4355 - val_loss: 59.8250 - val_accuracy: 0.1857
Epoch 2/85
782/782 [==============================] - 68s 87ms/step - loss: 1.6475 -
accuracy: 0.5752 - val_loss: 60.2469 - val_accuracy: 0.1294
Epoch 3/85
782/782 [==============================] - 68s 87ms/step - loss: 1.3929 -
accuracy: 0.6285 - val_loss: 27.9607 - val_accuracy: 0.2448
Epoch 4/85
782/782 [==============================] - 68s 87ms/step - loss: 1.2716 -
accuracy: 0.6621 - val_loss: 32.9015 - val_accuracy: 0.1750
Epoch 5/85
782/782 [==============================] - 68s 87ms/step - loss: 1.2027 -
accuracy: 0.6845 - val_loss: 31.4301 - val_accuracy: 0.2376
Epoch 6/85
782/782 [==============================] - 68s 86ms/step - loss: 1.1526 -
accuracy: 0.6982 - val_loss: 69.3460 - val_accuracy: 0.2062
Epoch 7/85
782/782 [==============================] - 68s 86ms/step - loss: 1.1173 -
accuracy: 0.7081 - val_loss: 52.1518 - val_accuracy: 0.1108
Epoch 8/85
782/782 [==============================] - 68s 87ms/step - loss: 1.0835 -
accuracy: 0.7197 - val_loss: 35.3169 - val_accuracy: 0.1624
Epoch 9/85
782/782 [==============================] - 68s 87ms/step - loss: 1.0553 -
accuracy: 0.7272 - val_loss: 17.7513 - val_accuracy: 0.3071
Epoch 10/85
782/782 [==============================] - 68s 87ms/step - loss: 1.0381 -
accuracy: 0.7333 - val_loss: 69.4971 - val_accuracy: 0.1180
Epoch 11/85
782/782 [==============================] - 68s 87ms/step - loss: 1.0147 -
accuracy: 0.7402 - val_loss: 23.9153 - val_accuracy: 0.2038
Epoch 12/85
782/782 [==============================] - 68s 86ms/step - loss: 0.9960 -
accuracy: 0.7444 - val_loss: 31.7959 - val_accuracy: 0.2458
Epoch 13/85
782/782 [==============================] - 67s 86ms/step - loss: 0.9791 -
accuracy: 0.7503 - val_loss: 20.4676 - val_accuracy: 0.2682
Epoch 14/85
782/782 [==============================] - 67s 86ms/step - loss: 0.9703 -
accuracy: 0.7510 - val_loss: 65.6729 - val_accuracy: 0.1270
Epoch 15/85
782/782 [==============================] - 67s 86ms/step - loss: 0.9530 -
accuracy: 0.7556 - val_loss: 38.4958 - val_accuracy: 0.1216
Epoch 16/85
782/782 [==============================] - 67s 86ms/step - loss: 0.9429 -
accuracy: 0.7593 - val_loss: 21.9149 - val_accuracy: 0.1659
Epoch 17/85
782/782 [==============================] - 68s 86ms/step - loss: 0.9286 -
```

```
accuracy: 0.7617 - val_loss: 29.8570 - val_accuracy: 0.2042
Epoch 18/85
782/782 [==============================] - 68s 87ms/step - loss: 0.9197 -
accuracy: 0.7670 - val_loss: 31.2535 - val_accuracy: 0.1697
Epoch 19/85
782/782 [==============================] - 68s 87ms/step - loss: 0.9126 -
accuracy: 0.7675 - val_loss: 38.3681 - val_accuracy: 0.1559
Epoch 00019: early stopping
```

[ ]:
```
%tensorboard --logdir logs/fit
```

```
<IPython.core.display.Javascript object>
```

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

```
313/313 [==============================] - 4s 13ms/step - loss: 38.3681 -
accuracy: 0.1559
Test loss: 38.36806106567383
Test accuracy: 0.1559000015258789
```

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

```
Saved model to disk
```

[ ]:
```

```