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 DropOut layers.
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. Maximum of 1 million parameters
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]:
```
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 tensorflow as tf
import tensorflow.keras as K
```

In [2]:
```
# Hyperparameters
batch_size = 128
num_classes = 10
epochs = 10
l = 40
num_filter = 12
compression = 0.5
dropout_rate = 0.2
```

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

```
Downloading data from https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz
(https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz)
170500096/170498071 [==============================] - 2s 0us/step
```

In [4]:
```
X_train.shape
```

Out[4]:
```
(50000, 32, 32, 3)
```

In [5]:
```
X_test.shape
```

Out[5]:
```
(10000, 32, 32, 3)
```

In [6]:
```
# 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')(r
        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'
    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=(2,2))(relu)
    flat = layers.Flatten()(AvgPooling)
    output = layers.Dense(num_classes, activation='softmax')(flat)
    return output
```

In [7]:
```
num_filter = 12
dropout_rate = 0.2
l = 12
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 [ ]:
```
model = Model(inputs=[input], outputs=[output])
model.summary()
```

```
Model: "model"
_____________________________________________________________________________________________
Layer (type)                    Output Shape         Param #     Connected to
=============================================================================================
input_1 (InputLayer)            [(None, 32, 32, 3)]  0
_____________________________________________________________________________________________
conv2d (Conv2D)                 (None, 32, 32, 12)   324         input_1[0][0]
_____________________________________________________________________________________________
batch_normalization (BatchNorma (None, 32, 32, 12)   48          conv2d[0][0]
_____________________________________________________________________________________________
activation (Activation)         (None, 32, 32, 12)   0           batch_normalization[0][0]
_____________________________________________________________________________________________
conv2d_1 (Conv2D)               (None, 32, 32, 6)    648         activation[0][0]
_____________________________________________________________________________________________
dropout (Dropout)               (None, 32, 32, 6)    0           conv2d_1[0][0]
_____________________________________________________________________________________________
concatenate (Concatenate)       (None, 32, 32, 18)   0           conv2d[0][0]
                                                                 dropout[0][0]
_____________________________________________________________________________________________
batch_normalization_1 (BatchNor (None, 32, 32, 18)   72          concatenate[0][0]
```

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

```
262
```

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

In [ ]:
```
model.fit(X_train, y_train,
                    batch_size=batch_size,
                    epochs=epochs,
                    verbose=1,
                    validation_data=(X_test, y_test))
```

```
Epoch 1/10
391/391 [==============================] - 80s 106ms/step - loss: 1.6921 - accuracy: 0.3635 - val_loss:
2.2382 - val_accuracy: 0.3487
Epoch 2/10
391/391 [==============================] - 39s 100ms/step - loss: 1.3750 - accuracy: 0.4932 - val_loss:
1.5767 - val_accuracy: 0.4525
Epoch 3/10
391/391 [==============================] - 38s 97ms/step - loss: 1.2392 - accuracy: 0.5498 - val_loss:
1.4586 - val_accuracy: 0.5184
Epoch 4/10
391/391 [==============================] - 38s 98ms/step - loss: 1.1385 - accuracy: 0.5859 - val_loss:
1.3950 - val_accuracy: 0.5613
Epoch 5/10
391/391 [==============================] - 39s 100ms/step - loss: 1.0582 - accuracy: 0.6186 - val_loss:
1.3705 - val_accuracy: 0.5627
Epoch 6/10
391/391 [==============================] - 38s 98ms/step - loss: 1.0017 - accuracy: 0.6375 - val_loss:
1.0920 - val_accuracy: 0.6249
Epoch 7/10
391/391 [==============================] - 38s 98ms/step - loss: 0.9527 - accuracy: 0.6583 - val_loss:
1.1976 - val_accuracy: 0.6167
Epoch 8/10
391/391 [==============================] - 38s 98ms/step - loss: 0.9155 - accuracy: 0.6705 - val_loss:
1.0936 - val_accuracy: 0.6266
Epoch 9/10
391/391 [==============================] - 38s 98ms/step - loss: 0.8790 - accuracy: 0.6857 - val_loss:
1.3293 - val_accuracy: 0.5663
Epoch 10/10
391/391 [==============================] - 38s 98ms/step - loss: 0.8586 - accuracy: 0.6915 - val_loss:
1.2386 - val_accuracy: 0.6239
```

Out[11]:
```
<tensorflow.python.keras.callbacks.History at 0x7fc9644e2b10>
```

In [ ]:
```
# 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 9ms/step - loss: 1.2386 - accuracy: 0.6239
Test loss: 1.2385536432266235
Test accuracy: 0.6238999962806702
```

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

```
Saved model to disk
```

Assignment

In [16]:
```
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 tensorflow as tf
import tensorflow.keras as K
```

In [2]:
```
# Hyperparameters
batch_size = 128
num_classes = 10
l = 6
num_filter = 35
compression = 1
dropout_rate = 0.2
```

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

```
Downloading data from https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz
(https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz)
170500096/170498071 [==============================] - 4s 0us/step
```

In [4]:
```
y_train
```

Out[4]:
```
array([[0., 0., 0., ..., 0., 0., 0.],
       [0., 0., 0., ..., 0., 0., 1.],
       [0., 0., 0., ..., 0., 0., 1.],
       ...,
       [0., 0., 0., ..., 0., 0., 1.],
       [0., 1., 0., ..., 0., 0., 0.],
       [0., 1., 0., ..., 0., 0., 0.]], dtype=float32)
```

In [5]:
```
def normalize_pixels(train, test):
    train_norm = train.astype('float32')
    test_norm  = test.astype('float32')

    train_norm /= 255
    test_norm /= 255

    return (train_norm, test_norm)
```

In [6]:
```
X_train,X_test=normalize_pixels(X_train,X_test)
```

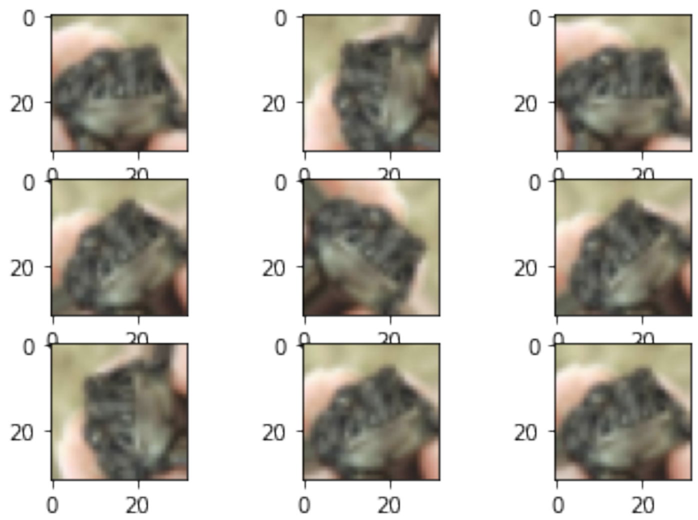
In [7]:
```
sample=X_train[25]
sample.shape
```

Out[7]:
```
(32, 32, 3)
```

In [8]:
```
from numpy import expand_dims
from keras.preprocessing.image import ImageDataGenerator
from matplotlib import pyplot

sample_images = expand_dims(sample, 0)
# image data augmentation
datagen = ImageDataGenerator(rotation_range=90)
# prepare iterator
it = datagen.flow(sample_images, batch_size=1)
# generate sample images and plot
for i in range(9):
    pyplot.subplot(330 + 1 + i)
    # generate batch of images
    batch = it.next()
    image = batch[0];
    # plot raw pixel data
    pyplot.imshow(image)

# show the figure
pyplot.show()
```



In [9]:
```
def model_summarize(history):
    # plot loss
    pyplot.subplot(121)
    pyplot.title('Cross Entropy Loss')
    pyplot.plot(history.history['loss'], color='blue', label='train loss')
    pyplot.plot(history.history['val_loss'], color='orange', label='test loss')
    pyplot.show()
```

In [11]:
```
def model_train(X_train, y_train, X_test, y_test, batch_size, step_size, no_epochs):
    # image augmentation
    datagen = ImageDataGenerator(width_shift_range=0.1, height_shift_range=0.1, horizontal_flip=True, sh
    # prepare iterator
    train_iterator = datagen.flow(X_train, y_train, batch_size=batch_size)
    # fit model
    steps = int(X_train.shape[0] / step_size)
    checkpoint = K.callbacks.ModelCheckpoint('model1.h5', monitor='val_accuracy', verbose=1, save_weight
    lr_reduce = K.callbacks.ReduceLROnPlateau(monitor='val_accuracy', factor=0.2, patience=5, verbose=1)
    callback_list = [checkpoint, lr_reduce]
    history = model.fit_generator(train_iterator, steps_per_epoch=steps, epochs=no_epochs, validation_da
    # evaluate model
    _, acc = model.evaluate(X_test, y_test, verbose=1)
    print('Test Accuracy : > %.3f' % (acc * 100.0))
    model_summarize(history)
```

In [12]:
```
# 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')(r
        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'
    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=(2,2))(relu)
    flat = layers.Flatten()(AvgPooling)
    output = layers.Dense(num_classes, activation='softmax')(flat)
    return output
```

In [13]:
```
num_filter = 35
dropout_rate = 0
l = 6
input = layers.Input(shape=(img_height, img_width, channel))
First_Conv2D = layers.Conv2D(32, (3,3), use_bias=False ,padding='same')(input)
BatchNorm = layers.BatchNormalization()(First_Conv2D)

First_Block = denseblock(BatchNorm,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 [14]:
```
model = Model(inputs=[input], outputs=[output])
model.summary()
```

```
Model: "model"
__________________________________________________________________________________________________
Layer (type)                    Output Shape         Param #     Connected to
==================================================================================================
input_1 (InputLayer)            [(None, 32, 32, 3)]  0
__________________________________________________________________________________________________
conv2d (Conv2D)                 (None, 32, 32, 32)   864         input_1[0][0]
__________________________________________________________________________________________________
batch_normalization (BatchNorma (None, 32, 32, 32)   128         conv2d[0][0]
__________________________________________________________________________________________________
batch_normalization_1 (BatchNor (None, 32, 32, 32)   128         batch_normalization[0][0]
__________________________________________________________________________________________________
activation (Activation)         (None, 32, 32, 32)   0           batch_normalization_1[0][0]
__________________________________________________________________________________________________
conv2d_1 (Conv2D)               (None, 32, 32, 35)   10080       activation[0][0]
__________________________________________________________________________________________________
concatenate (Concatenate)       (None, 32, 32, 67)   0           batch_normalization[0][0]
                                                                 conv2d_1[0][0]
__________________________________________________________________________________________________
```

In [17]:
```
opt = K.optimizers.Adam(learning_rate=0.01, beta_1=0.9, beta_2=0.999, epsilon=1e-07)
model.compile(loss='categorical_crossentropy', optimizer=opt, metrics=['accuracy'])
```

In [18]:
```
# steps = int(X_train.shape[0] / step_size)
model_train(X_train, y_train, X_test, y_test, 128, 128, 50)
```

```
Epoch 00040: val_accuracy did not improve from 0.90530
Epoch 41/50
390/390 [==============================] - 58s 150ms/step - loss: 0.0921 - accuracy: 0.9674 - val_loss:
0.3594 - val_accuracy: 0.9052

Epoch 00041: val_accuracy did not improve from 0.90530
Epoch 42/50
390/390 [==============================] - 59s 150ms/step - loss: 0.0931 - accuracy: 0.9681 - val_loss:
0.3552 - val_accuracy: 0.9058

Epoch 00042: val_accuracy improved from 0.90530 to 0.90580, saving model to model1.h5
Epoch 43/50
390/390 [==============================] - 59s 150ms/step - loss: 0.0888 - accuracy: 0.9689 - val_loss:
0.3626 - val_accuracy: 0.9064

Epoch 00043: val_accuracy improved from 0.90580 to 0.90640, saving model to model1.h5
Epoch 44/50
390/390 [==============================] - 60s 154ms/step - loss: 0.0892 - accuracy: 0.9690 - val_loss:
```

In [19]:
```
from google.colab import drive
drive.mount('/content/drive')

model.save('/content/model_batch1/',save_format='tf')
model.save('/content/drive/My Drive/CNN_CIFR/model/model_batch1/',save_format='tf')
```

```
Mounted at /content/drive
INFO:tensorflow:Assets written to: /content/model_batch1/assets
INFO:tensorflow:Assets written to: /content/drive/My Drive/CNN_CIFR/model/model_batch1/assets
```

In [ ]:
```
# loading the saved model
del model
model = tf.keras.models.load_model('/content/drive/My Drive/CNN_CIFR/model/model_batch1/')
```