In [ ]:

```
from keras.layers import Input, Dense, Flatten, Dropout
from keras.models import Model
from keras.optimizers import Adam, SGD
from keras.utils import np_utils
from keras import backend as K
import numpy as np
import os
from keras.regularizers import l2
import tensorflow as tf
import time
import datetime
import argparse
import datetime
import socket
import keras
from sklearn import preprocessing
import scipy.io as sio
import numpy as np
import matplotlib.pyplot as plt
from sklearn import preprocessing
import time
from keras.preprocessing.image import ImageDataGenerator
from PIL import Image, ImageOps
from keras.preprocessing import image
from keras.preprocessing.image import ImageDataGenerator
##### For one-hot label
from keras.utils import np_utils
```

In [ ]:

```
nb_classes = 397
img_depth = 3
data_dir ='/content/drive/My Drive/Colab Notebooks/SUN_Practice/'+'SUN397'
train_img_file = '/content/drive/My Drive/Colab Notebooks/SUN_Practice/Part
test_img_file = '/content/drive/My Drive/Colab Notebooks/SUN_Practice/Parti
classes_name_list = '/content/drive/My Drive/Colab Notebooks/SUN_Practice/P
train_label_file ='/content/drive/My Drive/Colab Notebooks/SUN_Practice/Par
test_label_file = '/content/drive/My Drive/Colab Notebooks/SUN_Practice/Par

train_img_file_path='/content/drive/My Drive/Colab Notebooks/SUN_Practice/P
test_img_file_path='/content/drive/My Drive/Colab Notebooks/SUN_Practice/Pa
```

In [ ]:

```
print('Begin to create a map to tansfer the str label to int label...')
class_name_file =  classes_name_list
class_str = [str(line.strip()) for line in open(class_name_file).readlines(
class_count = len(class_str)
print('%d class names are loaded' % class_count)
        # begin to create the map
le = preprocessing.LabelEncoder()
le.fit(class_str)
print(list(le.classes_))
print('Label map created...')
```

load training data

In [ ]:

```
print('\nBegin to load training data...\n')
desired_img_dim=224
print('Loading image file %s' % train_img_file_path)
```

In [ ]:

```
start_time_ = time.time()
train_img_file_path = [str(line.strip()) for line in open(train_img_file_pa
nb_sample = len(train_img_file_path)
print('Image count: %d' % nb_sample)

data_resized_holder = np.empty([nb_sample, desired_img_dim, desired_img_dim

for idx in range(nb_sample):
    img_file1 = train_img_file_path[idx].replace("\\", "/")      # the image
    # print(str(img_file1))
    # 1. read the image
    img1 = image.load_img(data_dir+img_file1)

    # 2. resize
    img1 = img1.resize((desired_img_dim, desired_img_dim), resample=0)


    # 6. give to the holder
    data_resized_holder[idx] = img1
    if(idx % 1000==0):
        print('%d image loaded.' % idx)

print('\nImage file loaded, the shape is ' + str(data_resized_holder.shape)
```

loading the training labels text

In [ ]:

```
one_hot = True
print('Loading label file %s' % train_label_file)
label_str = [str(line.strip()) for line in open(train_label_file).readlines
nb_unique = len(label_str)
labels_unique = le.transform(label_str)
# print(labels_unique)
labels_holder = np.hstack((  [ labels_unique[i] ] * 50 for i in range(nb_un
# print(labels_holder)
nb_sample = len(labels_holder)
if one_hot == True:
    labels = np.array([[float(i == l) for i in range(nb_classes)] for l in 
else:
    labels = labels_holder
print('Labels loaded, shape is:' + str(labels.shape))
```

loading training data

In [ ]:
```
x_train, nb_train_sample_1 = data_resized_holder, nb_sample
```

In [ ]:
```
y_train, nb_train_sample_2 = labels, nb_sample
```

In [ ]:
```
del data_resized_holder
del labels
```

Saving train data and test data

Saving x_train y_train as .npy file

In [ ]:
```
np.save('/content/drive/My Drive/Colab Notebooks/SUN_Practice/x_tain.npy',x
```

In [ ]:
```
np.save('/content/drive/My Drive/Colab Notebooks/SUN_Practice/y_train.npy',
```

loading testing data

load testing data

In [ ]:
```
print('Loading image file %s' % test_img_file_path )
start_time_ = time.time()
test_img_file_path = [str(line.strip()) for line in open(test_img_file_path
nb_sample = len(test_img_file_path)
print('Image count: %d' % nb_sample)

data_resized_holder = np.empty([nb_sample, desired_img_dim, desired_img_dim

for idx in range(nb_sample):
    img_file1 = data_dir + test_img_file_path[idx].replace("\\", "/")      #
    # print(str(img_file1))
    # 1. read the image
    img1 = image.load_img(img_file1)

    # 2. resize
    img1 = img1.resize((desired_img_dim, desired_img_dim), resample=0)


    # 6. give to the holder
    data_resized_holder[idx] = img1
    if(idx % 1000==0):
        print('%d image loaded.' % idx)

print('\nImage file loaded, the shape is ' + str(data_resized_holder.shape)
```

Load test labels

In [ ]:

```
one_hot = True
# loading the training labels
print('Loading label file %s' % test_label_file)
label_str = [str(line.strip()) for line in open(test_label_file).readlines(
nb_unique = len(label_str)
labels_unique = le.transform(label_str)
# print(labels_unique)
labels_holder = np.hstack((  [ labels_unique[i] ] * 50 for i in range(nb_un
# print(labels_holder)
nb_sample = len(labels_holder)
if one_hot == True:
    labels = np.array([[float(i == l) for i in range(nb_classes)] for l in
else:
    labels = labels_holder
print('Labels loaded, shape is:' + str(labels.shape))
```

In [ ]:

```
x_test, nb_test_sample_1 = data_resized_holder, nb_sample
```

In [ ]:

```
y_test, nb_test_sample_2 = labels, nb_sample
```

In [ ]:

```
del data_resized_holder
del labels
```

Saving x_test y_test .npy file

In [ ]:

```
np.save('/content/drive/My Drive/Colab Notebooks/SUN_Practice/x_test.npy',x
```

In [ ]:

```
np.save('/content/drive/My Drive/Colab Notebooks/SUN_Practice/y_test.npy',y
```

In [ ]:

```
del x_test
del y_test
```

Load train data and test data

Load train data

In [2]:

```
x_train = np.load('/root/Code_GCP/SUN_Practice/x_tain.npy')
```

In [3]:

```
y_train = np.load('/root/Code_GCP/SUN_Practice/y_train.npy')
```

Load test data

Load the training data and testing data from the npy file.X means input data and y means the label of the sample.

In [4]:

```
x_test = np.load('/root/Code_GCP/SUN_Practice/x_test.npy')
```

In [5]:

```
y_test = np.load('/root/Code_GCP/SUN_Practice/y_test.npy')
```

In [6]:

```
print(x_train.shape)
print(y_train.shape)
print(x_test.shape)
print(y_test.shape)
```

```
(19850, 224, 224, 3)
(19850, 397)
(19850, 224, 224, 3)
(19850, 397)
```

In [ ]:

```

```

In [ ]:

```
import os
os.environ["CUDA_VISIBLE_DEVICES"]="0";
```

In [1]:

```
import numpy as np
import keras
from keras.applications.vgg16 import VGG16
from keras.applications.densenet import DenseNet201
```

```
/root/anaconda3/lib/python3.6/site-packages/h5py/__init__.py:36: FutureWa
rning: Conversion of the second argument of issubdtype from `float` to `n
p.floating` is deprecated. In future, it will be treated as `np.float64 =
= np.dtype(float).type`.
  from ._conv import register_converters as _register_converters
Using TensorFlow backend.
```

In [2]:

```

# x_train=np.load("x_train.npy")
# x_test=np.load("x_test.npy")
# y_train=np.load("y_train.npy")
# y_test=np.load("y_test.npy")
# print(y_test.shape)
```

```
(19850, 397)
```

Data processing

In [3]:

```
from keras.applications.densenet import preprocess_input

x_test = preprocess_input(x_test)
x_train = preprocess_input(x_train)
```

Call the DenseNet model function of Keras. Use a pretrained weights on imagenet. We don't use the top layer of DenseNet, because in order to get a better perform we want to biuld FC layers by ourselves. The input shape is 2272273, 227*227 means resolution and 3 means number of channel.

In [4]:
```
model = DenseNet201(weights="imagenet", include_top=False, classes=397, inp
print(model.summary())
```

```
_________________________
conv4_block27_0_relu (Activatio (None, 14, 14, 1088) 0           conv4_bl
ock27_0_bn[0][0]

_________________________________________________________________________
_________________________
conv4_block27_1_conv (Conv2D)   (None, 14, 14, 128)  139264      conv4_bl
ock27_0_relu[0][0]

_________________________________________________________________________
_________________________
conv4_block27_1_bn (BatchNormal (None, 14, 14, 128)  512         conv4_bl
ock27_1_conv[0][0]

_________________________________________________________________________
_________________________
conv4_block27_1_relu (Activatio (None, 14, 14, 128)  0           conv4_bl
ock27_1_bn[0][0]

_________________________________________________________________________
_________________________
conv4_block27_2_conv (Conv2D)   (None, 14, 14, 32)   36864       conv4_bl
ock27_1_relu[0][0]

_________________________________________________________________________
```

We add a average pooling layer after the relu layer. And we add a softmax layer to predict the 397 classes.

In [5]:
```
from keras.layers import Flatten, Dense, Dropout
from keras.models import Model
from keras.layers.pooling import GlobalAveragePooling2D

x = model.get_layer('relu').output
x = GlobalAveragePooling2D(name='pool')(x)
x = Dense(397, activation='softmax', name='fc1')(x)

model_updated = Model(inputs=model.input, outputs=x)
```

Its more convenient to save the pretrained weights because we need to repeat the experiment for 3 times.

In [6]:
```
model_updated.save_weights('model_initial.h5')
```

In [7]:
```
def learning_rate_schedule(epoch):
    if epoch <= 10:
        return 1e-4 # 0.00001
    elif epoch <= 20:
        return 1e-5
    elif epoch <= 30:
        return 1e-6
    else:
        return 1e-7
    return LR
```

Train the DenseNet. Use categorical crossentropy as loss function and use the learning rate schedule we have defined. Use the data we have loaded and set the batch size as 32 and train for 7 epochs. Repeat the experiment for 3 times and save the weight we trained.

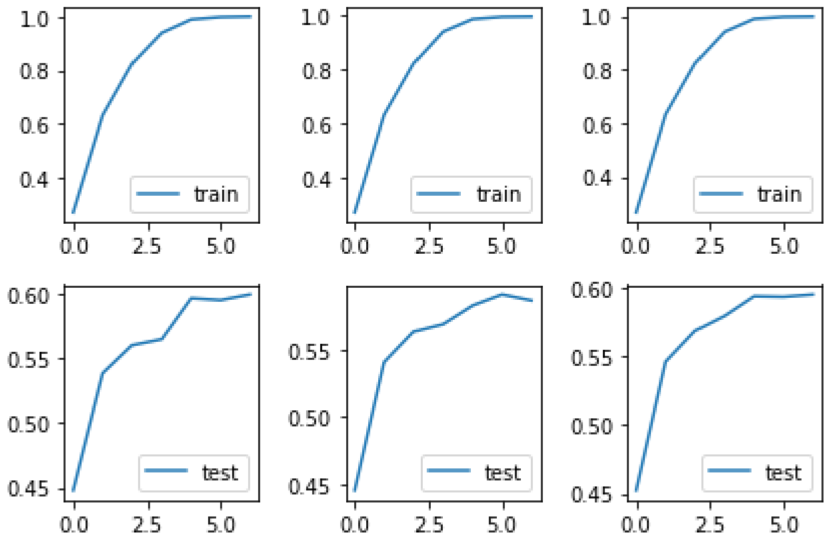
In [10]:
```
from keras import optimizers
from keras.callbacks import EarlyStopping

model_updated.load_weights('model_initial.h5')
training_runs = []
for i in range(3):
    model_updated.compile(loss='categorical_crossentropy', optimizer=optimi
    keras.callbacks.LearningRateScheduler(learning_rate_schedule)
    history = model_updated.fit(x_train, y_train, batch_size=32, shuffle=Tr
    training_runs.append(history)
    model_updated.get_weights()
    if i == 2:
        model_updated.save_weights('model1_from_scratch.h5')
    else:
        model_updated.load_weights('model_initial.h5')
```

```
Train on 19850 samples, validate on 19850 samples
Epoch 1/7
19850/19850 [==============================] - 395s 20ms/step - loss: 3.7
642 - acc: 0.2728 - val_loss: 2.3402 - val_acc: 0.4478
Epoch 2/7
19850/19850 [==============================] - 342s 17ms/step - loss: 1.6
678 - acc: 0.6327 - val_loss: 1.8257 - val_acc: 0.5383
Epoch 3/7
19850/19850 [==============================] - 342s 17ms/step - loss: 0.8
549 - acc: 0.8254 - val_loss: 1.7113 - val_acc: 0.5602
Epoch 4/7
19850/19850 [==============================] - 342s 17ms/step - loss: 0.3
837 - acc: 0.9392 - val_loss: 1.6612 - val_acc: 0.5647
Epoch 5/7
19850/19850 [==============================] - 343s 17ms/step - loss: 0.1
469 - acc: 0.9891 - val_loss: 1.5617 - val_acc: 0.5966
Epoch 6/7
19850/19850 [==============================] - 343s 17ms/step - loss: 0.0
596 - acc: 0.9980 - val_loss: 1.5687 - val_acc: 0.5951
Epoch 7/7
19850/19850 [==============================] - 343s 17ms/step - loss: 0.0
278 - acc: 0.9999 - val_loss: 1.5764 - val_acc: 0.5994
Train on 19850 samples, validate on 19850 samples
Epoch 1/7
19850/19850 [==============================] - 400s 20ms/step - loss: 3.7
664 - acc: 0.2697 - val_loss: 2.3580 - val_acc: 0.4453
Epoch 2/7
19850/19850 [==============================] - 345s 17ms/step - loss: 1.6
818 - acc: 0.6310 - val_loss: 1.8470 - val_acc: 0.5408
Epoch 3/7
19850/19850 [==============================] - 345s 17ms/step - loss: 0.8
589 - acc: 0.8225 - val_loss: 1.6958 - val_acc: 0.5637
Epoch 4/7
19850/19850 [==============================] - 345s 17ms/step - loss: 0.3
886 - acc: 0.9412 - val_loss: 1.6553 - val_acc: 0.5693
Epoch 5/7
19850/19850 [==============================] - 345s 17ms/step - loss: 0.1
514 - acc: 0.9877 - val_loss: 1.6090 - val_acc: 0.5832
Epoch 6/7
19850/19850 [==============================] - 345s 17ms/step - loss: 0.0
689 - acc: 0.9961 - val_loss: 1.6137 - val_acc: 0.5914
```

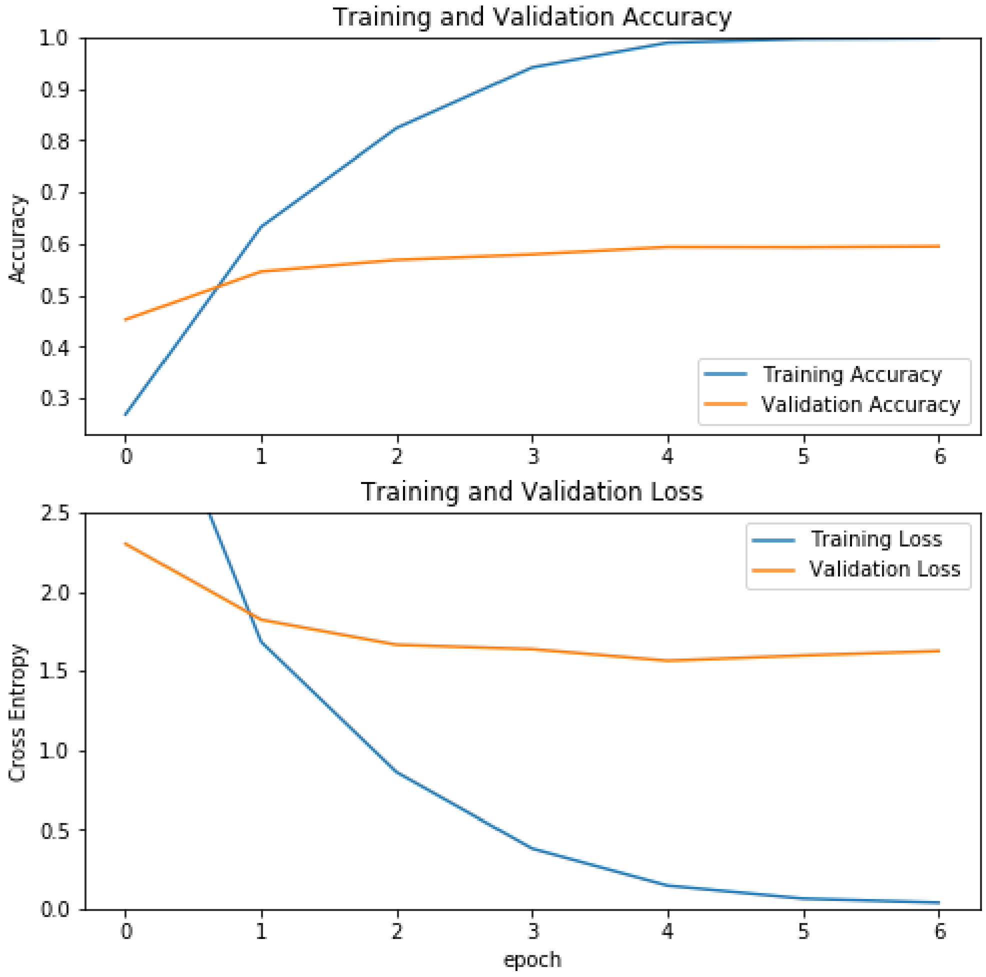
```
Epoch 7/7
19850/19850 [==============================] - 345s 17ms/step - loss: 0.0
488 - acc: 0.9972 - val_loss: 1.6596 - val_acc: 0.5870
Train on 19850 samples, validate on 19850 samples
Epoch 1/7
19850/19850 [==============================] - 403s 20ms/step - loss: 3.7
982 - acc: 0.2681 - val_loss: 2.3037 - val_acc: 0.4523
Epoch 2/7
19850/19850 [==============================] - 343s 17ms/step - loss: 1.6
832 - acc: 0.6327 - val_loss: 1.8241 - val_acc: 0.5457
Epoch 3/7
19850/19850 [==============================] - 340s 17ms/step - loss: 0.8
602 - acc: 0.8238 - val_loss: 1.6659 - val_acc: 0.5683
Epoch 4/7
19850/19850 [==============================] - 344s 17ms/step - loss: 0.3
793 - acc: 0.9416 - val_loss: 1.6379 - val_acc: 0.5791
Epoch 5/7
19850/19850 [==============================] - 339s 17ms/step - loss: 0.1
456 - acc: 0.9896 - val_loss: 1.5647 - val_acc: 0.5934
Epoch 6/7
19850/19850 [==============================] - 344s 17ms/step - loss: 0.0
634 - acc: 0.9970 - val_loss: 1.5982 - val_acc: 0.5930
Epoch 7/7
19850/19850 [==============================] - 340s 17ms/step - loss: 0.0
377 - acc: 0.9983 - val_loss: 1.6261 - val_acc: 0.5947
```

In [15]:

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

plt.subplot(2, 3, 1)
plt.plot(training_runs[0].history['acc'])
plt.legend(['train'], loc='lower right')

plt.subplot(2, 3, 2)
plt.plot(training_runs[1].history['acc'])
plt.legend(['train'], loc='lower right')

plt.subplot(2, 3, 3)
plt.plot(training_runs[2].history['acc'])
plt.legend(['train'], loc='lower right')

plt.subplot(2, 3, 4)
plt.plot(training_runs[0].history['val_acc'])
plt.legend(['test'], loc='lower right')

plt.subplot(2, 3, 5)
plt.plot(training_runs[1].history['val_acc'])
plt.legend(['test'], loc='lower right')

plt.subplot(2, 3, 6)
plt.plot(training_runs[2].history['val_acc'])
plt.legend(['test'], loc='lower right')

plt.tight_layout()

plt.show()
```



In [19]:
```
acc = history.history['acc']
val_acc = history.history['val_acc']

loss = history.history['loss']
val_loss = history.history['val_loss']

plt.figure(figsize=(8, 8))
plt.subplot(2, 1, 1)
plt.plot(acc, label='Training Accuracy')
plt.plot(val_acc, label='Validation Accuracy')
plt.legend(loc='lower right')
plt.ylabel('Accuracy')
plt.ylim([min(plt.ylim()),1])
plt.title('Training and Validation Accuracy')

plt.subplot(2, 1, 2)
plt.plot(loss, label='Training Loss')
plt.plot(val_loss, label='Validation Loss')
plt.legend(loc='upper right')
plt.ylabel('Cross Entropy')
plt.ylim([0,2.5])
plt.title('Training and Validation Loss')
plt.xlabel('epoch')
plt.show()
```



In [13]:
```
print("Average training accuracy: {}".format(np.mean([training_runs[0].hist
                                                      training_runs[1].histo
print("Average testing accuracy: {}".format(np.mean([training_runs[0].histo
                                                     training_runs[1].histo
```

```
Average training accuracy: 0.9984550797649034
Average testing accuracy: 0.5937027707793551
```

In [ ]: