In [1]:
```
from google.colab import drive
drive.mount('/content/drive')
```

```
Go to this URL in a browser: https://accounts.google.com/o/oauth2/auth?client_id=947318989803-6bn6qk8qdgf4n4g3pfee6491hc0brc4i.apps.googleusercontent.com&redirect_uri=urn%3Aietf%3Awg%3Aoauth%3A2.0%3Aoob&scope=email%20https%3A%2F%2Fwww.googleapis.com%2Fauth%2Fdocs.test%20https%3A%2F%2Fwww.googleapis.com%2Fauth%2Fdrive%20https%3A%2F%2Fwww.googleapis.com%2Fauth%2Fdrive.photos.readonly%20https%3A%2F%2Fwww.googleapis.com%2Fauth%2Fpeopleapi.readonly&response_type=code (https://accounts.google.com/o/oauth2/auth?client_id=947318989803-6bn6qk8qdgf4n4g3pfee6491hc0brc4i.apps.googleusercontent.com&redirect_uri=urn%3Aietf%3Awg%3Aoauth%3A2.0%3Aoob&scope=email%20https%3A%2F%2Fwww.googleapis.com%2Fauth%2Fdocs.test%20https%3A%2F%2Fwww.googleapis.com%2Fauth%2Fdrive%20https%3A%2F%2Fwww.googleapis.com%2Fauth%2Fdrive.photos.readonly%20https%3A%2F%2Fwww.googleapis.com%2Fauth%2Fpeopleapi.readonly&response_type=code)

Enter your authorization code:
··········
Mounted at /content/drive
```

In this task, I use 15-Scene to train VGG16 from-scretch and pre-trained.And I found that from-scretech is not good even drop in local-minimum situation,but for pre-trained is good ,the accuracy is %

VGG16---15-Scene dataset

import necessary package and vgg16

In [0]:
```
import tensorflow as tf
import numpy as np
import keras
import matplotlib.pyplot as plt
from keras.models import Model
from keras.layers import Dense,Flatten,Dropout
import cv2
from keras.applications.vgg16 import VGG16
from keras.optimizers import SGD
from tqdm import tqdm_notebook as tqdm
import os
from keras import optimizers
from keras.callbacks import EarlyStopping
```

process dataset and split it to training dataset,testing dataset

In [0]:
```
img_size = 224
num_classes = 15
maxepoches = 30
batch_size = 50

DATASET_PATH = '/content/drive/My Drive/Colab Notebooks/VGG16_Practice/15-S
one_hot_lookup = np.eye(num_classes)
dataset_x = []
dataset_y = []
for category in sorted(os.listdir(DATASET_PATH)):
    for fname in os.listdir(DATASET_PATH+"/"+category):
        img = cv2.imread(DATASET_PATH+"/"+category+'/'+fname, 2)
        img = cv2.resize(img, (img_size,img_size))
        dataset_x.append(np.reshape(img, [img_size,img_size,1]))
        dataset_y.append(np.reshape(one_hot_lookup[int(category)], [num_cla



# train_y = keras.utils.to_categorical(train_y).astype('float32')
# test_y = keras.utils.to_categorical(test_y).astype('float32')
```

In [0]:
```
dataset_x = np.array(dataset_x)
dataset_y = np.array(dataset_y)
```

In [0]:
```

"""shuffle dataset"""
p = np.random.permutation(len(dataset_x))
dataset_x = dataset_x[p]
dataset_y = dataset_y[p]

test_x = dataset_x[:int(len(dataset_x)/10)]
test_y = dataset_y[:int(len(dataset_x)/10)]
train_x = dataset_x[int(len(dataset_x)/10):]
train_y = dataset_y[int(len(dataset_x)/10):]
```

print train_x train_y test_x test_y shape , founding those part is one channel beacuse they are gray image

In [7]:
```
print(train_x.shape)
print(train_y.shape)
print(test_x.shape)
print(test_y.shape)
```

```
(4037, 224, 224, 1)
(4037, 15)
(448, 224, 224, 1)
(448, 15)
```

In order fit with VGG16 network , I convert one channel to three channel

In [8]:
```
train_x = [cv2.cvtColor(cv2.resize(i,(224,224)), cv2.COLOR_GRAY2BGR) for i
train_x = np.concatenate([arr[np.newaxis] for arr in train_x]).astype('floa

test_x  = [cv2.cvtColor(cv2.resize(i,(224,224)), cv2.COLOR_GRAY2BGR) for i
test_x  = np.concatenate([arr[np.newaxis] for arr in test_x] ).astype('floa

print("train_x shape :",train_x.shape)
print("test_x shape:",test_x.shape)
```

```
train_x shape : (4037, 224, 224, 3)
test_x shape: (448, 224, 224, 3)
```

In [0]:
```
train_x /= 255
test_x /= 255
```

VGG16 from Scretch

This part is VGG16 from scrtech : weights=None and layer.trainable=True

In [10]:
```
model_vgg =VGG16(include_top=False,input_shape=(224,224,3),weights=None)
for layer in model_vgg.layers:
  layer.trainable=True
#model=Flatten(name='Flatten')(model_vgg.output)
x = model_vgg.get_layer('block5_pool').output
x = Flatten(name='flatten')(x)
x = Dense(512, activation='relu', name='fc1')(x)
x = Dense(4096, activation='relu', name='fc2')(x)
x = Dense(15, activation='softmax', name='predictions')(x)
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/back
end/tensorflow_backend.py:66: The name tf.get_default_graph is deprecate
d. Please use tf.compat.v1.get_default_graph instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/back
end/tensorflow_backend.py:541: The name tf.placeholder is deprecated. Ple
ase use tf.compat.v1.placeholder instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/back
end/tensorflow_backend.py:4432: The name tf.random_uniform is deprecated.
Please use tf.random.uniform instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/back
end/tensorflow_backend.py:4267: The name tf.nn.max_pool is deprecated. Pl
ease use tf.nn.max_pool2d instead.
```

In [11]:
```
#model=Dense(15,activation='softmax')(model)
model_vgg_scene=Model(inputs=model_vgg.input, outputs=x)
model_vgg_scene.summary()
```

```
Model: "model_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_1 (InputLayer)         (None, 224, 224, 3)       0
_________________________________________________________________
block1_conv1 (Conv2D)        (None, 224, 224, 64)      1792
_________________________________________________________________
block1_conv2 (Conv2D)        (None, 224, 224, 64)      36928
_________________________________________________________________
block1_pool (MaxPooling2D)   (None, 112, 112, 64)      0
_________________________________________________________________
block2_conv1 (Conv2D)        (None, 112, 112, 128)     73856
_________________________________________________________________
block2_conv2 (Conv2D)        (None, 112, 112, 128)     147584
_________________________________________________________________
block2_pool (MaxPooling2D)   (None, 56, 56, 128)       0
_________________________________________________________________
block3_conv1 (Conv2D)        (None, 56, 56, 256)       295168
_________________________________________________________________
block3_conv2 (Conv2D)        (None, 56, 56, 256)       590080
_________________________________________________________________
block3_conv3 (Conv2D)        (None, 56, 56, 256)       590080
_________________________________________________________________
block3_pool (MaxPooling2D)   (None, 28, 28, 256)       0
_________________________________________________________________
block4_conv1 (Conv2D)        (None, 28, 28, 512)       1180160
_________________________________________________________________
block4_conv2 (Conv2D)        (None, 28, 28, 512)       2359808
_________________________________________________________________
block4_conv3 (Conv2D)        (None, 28, 28, 512)       2359808
_________________________________________________________________
block4_pool (MaxPooling2D)   (None, 14, 14, 512)       0
_________________________________________________________________
block5_conv1 (Conv2D)        (None, 14, 14, 512)       2359808
_________________________________________________________________
block5_conv2 (Conv2D)        (None, 14, 14, 512)       2359808
_________________________________________________________________
block5_conv3 (Conv2D)        (None, 14, 14, 512)       2359808
_________________________________________________________________
block5_pool (MaxPooling2D)   (None, 7, 7, 512)         0
_________________________________________________________________
flatten (Flatten)            (None, 25088)             0
_________________________________________________________________
fc1 (Dense)                  (None, 512)               12845568
_________________________________________________________________
fc2 (Dense)                  (None, 4096)              2101248
_________________________________________________________________
predictions (Dense)          (None, 15)                61455
=================================================================
Total params: 29,722,959
Trainable params: 29,722,959
```

```
Non-trainable params: 0
_________________________________________________________________
```

In [0]:
```
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
```

In [0]:
```
#sgd=SGD(lr=0.05,decay=1e-5)
```

In [14]:
```
model_vgg_scene.compile(loss='categorical_crossentropy',optimizer=optimizer
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/opti
mizers.py:793: The name tf.train.Optimizer is deprecated. Please use tf.c
ompat.v1.train.Optimizer instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/back
end/tensorflow_backend.py:3576: The name tf.log is deprecated. Please use
tf.math.log instead.
```

In [15]:
```
keras.callbacks.LearningRateScheduler(learning_rate_schedule)
```

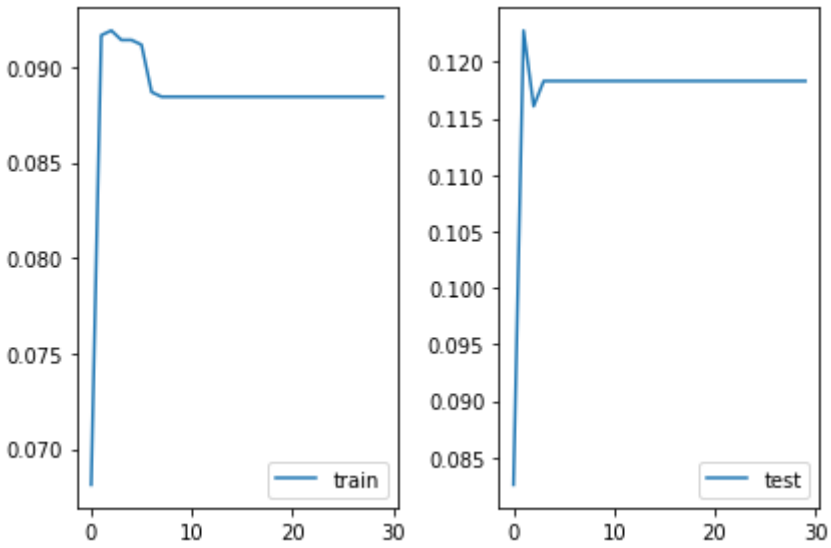
Out[15]:
```
<keras.callbacks.LearningRateScheduler at 0x7efe0201a780>
```

In [16]:
```
history=model_vgg_scene.fit(train_x, train_y, validation_data=(test_x, test
```

```
Epoch 21/30
4037/4037 [==============================] - 114s 28ms/step - loss: 2.706
7 - acc: 0.0884 - val_loss: 2.7064 - val_acc: 0.1183
Epoch 22/30
4037/4037 [==============================] - 114s 28ms/step - loss: 2.706
7 - acc: 0.0884 - val_loss: 2.7063 - val_acc: 0.1183
Epoch 23/30
4037/4037 [==============================] - 114s 28ms/step - loss: 2.706
6 - acc: 0.0884 - val_loss: 2.7062 - val_acc: 0.1183
Epoch 24/30
4037/4037 [==============================] - 114s 28ms/step - loss: 2.706
6 - acc: 0.0884 - val_loss: 2.7062 - val_acc: 0.1183
Epoch 25/30
4037/4037 [==============================] - 114s 28ms/step - loss: 2.706
5 - acc: 0.0884 - val_loss: 2.7061 - val_acc: 0.1183
Epoch 26/30
4037/4037 [==============================] - 114s 28ms/step - loss: 2.706
4 - acc: 0.0884 - val_loss: 2.7060 - val_acc: 0.1183
Epoch 27/30
4037/4037 [==============================] - 114s 28ms/step - loss: 2.706
```

In [0]:
```
import matplotlib.pyplot as plt
import numpy as np
from keras import optimizers
from keras.callbacks import EarlyStopping
```

In [18]:
```
plt.subplot(1, 2, 1)
plt.plot(history.history['acc'])
plt.legend(['train'], loc='lower right')
plt.subplot(1, 2, 2)

plt.plot(history.history['val_acc'])
plt.legend(['test'], loc='lower right')

plt.tight_layout()

plt.show()
```



VGG16 Pre-trained

This part using Pre-trained model ,and I design two parts. First is run 1 times and second is run 3 times .it is clearly that perform one times the accuracy increase a lot, even perform three times the model drop in local-minium

Perform Training one times

By using VGG16 pre-trained model run one time ,the accuracy increased to 78.1%

In [19]:
```
ishape=224
model_vgg = VGG16(include_top=False, weights='imagenet', input_shape=(ishap
for layer in model_vgg.layers:
    layer.trainable = False
```

```
Downloading data from https://github.com/fchollet/deep-learning-models/re
leases/download/v0.1/vgg16_weights_tf_dim_ordering_tf_kernels_notop.h5 (h
ttps://github.com/fchollet/deep-learning-models/releases/download/v0.1/vg
g16_weights_tf_dim_ordering_tf_kernels_notop.h5)
58892288/58889256 [==============================] - 3s 0us/step
```

In [0]:
```
x = model_vgg.get_layer('block5_pool').output
x = Flatten(name='flatten')(x)
x = Dense(512, activation='relu', name='fc1')(x)
x = Dense(4096, activation='relu', name='fc2')(x)
x = Dense(15, activation='softmax', name='predictions')(x)
```

In [21]:
```
#model=Dense(15,activation='softmax')(model)
model_vgg_pre_scene=Model(inputs=model_vgg.input, outputs=x)
model_vgg_pre_scene.summary()
```

```
Model: "model_2"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_2 (InputLayer)         (None, 224, 224, 3)       0
_________________________________________________________________
block1_conv1 (Conv2D)        (None, 224, 224, 64)      1792
_________________________________________________________________
block1_conv2 (Conv2D)        (None, 224, 224, 64)      36928
_________________________________________________________________
block1_pool (MaxPooling2D)   (None, 112, 112, 64)      0
_________________________________________________________________
block2_conv1 (Conv2D)        (None, 112, 112, 128)     73856
_________________________________________________________________
block2_conv2 (Conv2D)        (None, 112, 112, 128)     147584
_________________________________________________________________
block2_pool (MaxPooling2D)   (None, 56, 56, 128)       0
_________________________________________________________________
block3_conv1 (Conv2D)        (None, 56, 56, 256)       295168
_________________________________________________________________
block3_conv2 (Conv2D)        (None, 56, 56, 256)       590080
_________________________________________________________________
block3_conv3 (Conv2D)        (None, 56, 56, 256)       590080
_________________________________________________________________
block3_pool (MaxPooling2D)   (None, 28, 28, 256)       0
_________________________________________________________________
block4_conv1 (Conv2D)        (None, 28, 28, 512)       1180160
_________________________________________________________________
block4_conv2 (Conv2D)        (None, 28, 28, 512)       2359808
_________________________________________________________________
block4_conv3 (Conv2D)        (None, 28, 28, 512)       2359808
_________________________________________________________________
block4_pool (MaxPooling2D)   (None, 14, 14, 512)       0
_________________________________________________________________
block5_conv1 (Conv2D)        (None, 14, 14, 512)       2359808
_________________________________________________________________
block5_conv2 (Conv2D)        (None, 14, 14, 512)       2359808
_________________________________________________________________
block5_conv3 (Conv2D)        (None, 14, 14, 512)       2359808
_________________________________________________________________
block5_pool (MaxPooling2D)   (None, 7, 7, 512)         0
_________________________________________________________________
flatten (Flatten)            (None, 25088)             0
_________________________________________________________________
fc1 (Dense)                  (None, 512)               12845568
_________________________________________________________________
fc2 (Dense)                  (None, 4096)              2101248
_________________________________________________________________
predictions (Dense)          (None, 15)                61455
=================================================================
Total params: 29,722,959
Trainable params: 15,008,271
```

```
Non-trainable params: 14,714,688
_________________________________________________________________
```

In [0]:
```
# model = Dense(15, activation="softmax")(model)
# model_vgg_scene_pretrain = Model(model_vgg.input, model, name='vgg_16_pre
# model_vgg_scene_pretrain.summary()
```

In [0]:
```
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
```

In [0]:
```
#sgd = SGD(lr = 0.01, decay = 1e-5)
model_vgg_pre_scene.compile(loss='categorical_crossentropy', optimizer=opti
```

In [25]:
```
keras.callbacks.LearningRateScheduler(learning_rate_schedule)
```

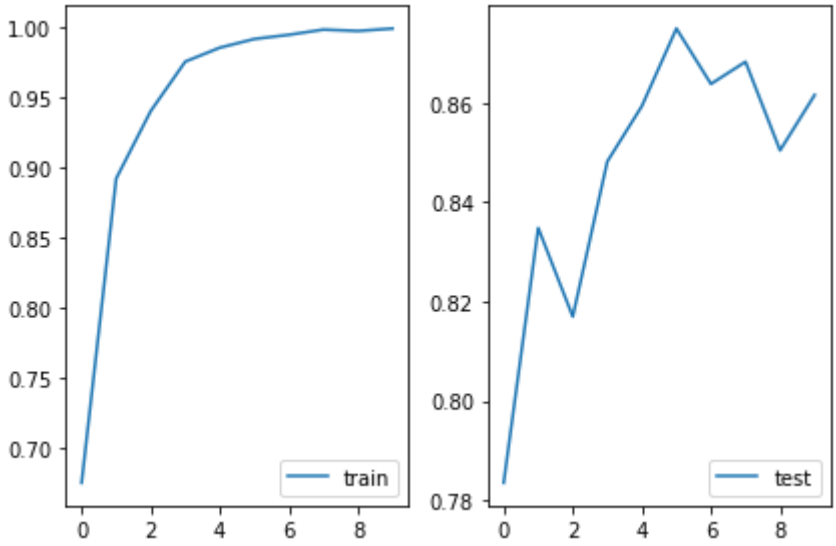
Out[25]:
```
<keras.callbacks.LearningRateScheduler at 0x7efdf01c5e80>
```

In [26]:
```
model_vgg_pre_scene.fit(train_x, train_y, validation_data=(test_x, test_y),
```

```
Train on 4037 samples, validate on 448 samples
Epoch 1/10
4037/4037 [==============================] - 44s 11ms/step - loss: 1.0449
- acc: 0.6757 - val_loss: 0.5533 - val_acc: 0.7835
Epoch 2/10
4037/4037 [==============================] - 43s 11ms/step - loss: 0.3380
- acc: 0.8922 - val_loss: 0.4819 - val_acc: 0.8348
Epoch 3/10
4037/4037 [==============================] - 43s 11ms/step - loss: 0.1855
- acc: 0.9403 - val_loss: 0.4864 - val_acc: 0.8170
Epoch 4/10
4037/4037 [==============================] - 43s 11ms/step - loss: 0.0925
- acc: 0.9755 - val_loss: 0.4586 - val_acc: 0.8482
Epoch 5/10
4037/4037 [==============================] - 43s 11ms/step - loss: 0.0614
- acc: 0.9854 - val_loss: 0.4389 - val_acc: 0.8594
Epoch 6/10
4037/4037 [==============================] - 43s 11ms/step - loss: 0.0324
- acc: 0.9916 - val_loss: 0.4209 - val_acc: 0.8750
Epoch 7/10
4037/4037 [==============================] - 43s 11ms/step - loss: 0.0238
- acc: 0.9946 - val_loss: 0.4572 - val_acc: 0.8638
Epoch 8/10
4037/4037 [==============================] - 43s 11ms/step - loss: 0.0155
- acc: 0.9983 - val_loss: 0.4562 - val_acc: 0.8683
Epoch 9/10
4037/4037 [==============================] - 43s 11ms/step - loss: 0.0151
- acc: 0.9973 - val_loss: 0.4828 - val_acc: 0.8504
Epoch 10/10
4037/4037 [==============================] - 43s 11ms/step - loss: 0.0103
- acc: 0.9990 - val_loss: 0.4548 - val_acc: 0.8616
```

Out[26]:
```
<keras.callbacks.History at 0x7efdf018d6d8>
```

In [27]:
```
plt.subplot(1, 2, 1)
plt.plot(model_vgg_pre_scene.history.history['acc'])
plt.legend(['train'], loc='lower right')
plt.subplot(1, 2, 2)

plt.plot(model_vgg_pre_scene.history.history['val_acc'])
plt.legend(['test'], loc='lower right')

plt.tight_layout()

plt.show()
```



Perform Training Three Times

The code which show below is not good way to normlization data in this dataset

In [0]:
```
# from tensorflow.keras.applications.vgg16 import preprocess_input
# x_test = preprocess_input(test_x)
# x_train = preprocess_input(train_x)
```

In [29]:
```
ishape=224

model = VGG16(weights='imagenet', include_top=False, input_shape=(ishape, i
for layer in model_vgg.layers:
    layer.trainable = False
print(model.summary())
```

```
Model: "vgg16"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_3 (InputLayer)         (None, 224, 224, 3)       0
_________________________________________________________________
block1_conv1 (Conv2D)        (None, 224, 224, 64)      1792
_________________________________________________________________
block1_conv2 (Conv2D)        (None, 224, 224, 64)      36928
_________________________________________________________________
block1_pool (MaxPooling2D)   (None, 112, 112, 64)      0
_________________________________________________________________
block2_conv1 (Conv2D)        (None, 112, 112, 128)     73856
_________________________________________________________________
block2_conv2 (Conv2D)        (None, 112, 112, 128)     147584
_________________________________________________________________
block2_pool (MaxPooling2D)   (None, 56, 56, 128)       0
_________________________________________________________________
block3_conv1 (Conv2D)        (None, 56, 56, 256)       295168
_________________________________________________________________
block3_conv2 (Conv2D)        (None, 56, 56, 256)       590080
_________________________________________________________________
block3_conv3 (Conv2D)        (None, 56, 56, 256)       590080
_________________________________________________________________
block3_pool (MaxPooling2D)   (None, 28, 28, 256)       0
_________________________________________________________________
block4_conv1 (Conv2D)        (None, 28, 28, 512)       1180160
_________________________________________________________________
block4_conv2 (Conv2D)        (None, 28, 28, 512)       2359808
_________________________________________________________________
block4_conv3 (Conv2D)        (None, 28, 28, 512)       2359808
_________________________________________________________________
block4_pool (MaxPooling2D)   (None, 14, 14, 512)       0
_________________________________________________________________
block5_conv1 (Conv2D)        (None, 14, 14, 512)       2359808
_________________________________________________________________
block5_conv2 (Conv2D)        (None, 14, 14, 512)       2359808
_________________________________________________________________
block5_conv3 (Conv2D)        (None, 14, 14, 512)       2359808
_________________________________________________________________
block5_pool (MaxPooling2D)   (None, 7, 7, 512)         0
=================================================================
Total params: 14,714,688
Trainable params: 14,714,688
Non-trainable params: 0
_________________________________________________________________
None
```

In [0]:
```
from keras.layers import Flatten, Dense
from keras.models import Model

x = model.get_layer('block5_pool').output
x = Flatten(name='flatten')(x)
x = Dense(512, activation='relu', name='fc1')(x)
#x = Dense(4096, activation='relu', name='fc2')(x)
x = Dense(15, activation='softmax', name='predictions')(x)

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

In [0]:
```
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
```

In [0]:
```
model_pre_updated.save_weights('model_initial.h5')
```

In [33]:
```
from keras import optimizers
from keras.callbacks import EarlyStopping

model_pre_updated.save_weights('model_initial.h5')
training_runs = []
for i in range(3):
    #model_updated.compile(loss='categorical_crossentropy', optimizer='sgd'

    model_pre_updated.compile(loss='categorical_crossentropy', optimizer=op
    keras.callbacks.LearningRateScheduler(learning_rate_schedule)
    history = model_pre_updated.fit(train_x, train_y, batch_size=32,  shuff
    training_runs.append(history)
    model_pre_updated.get_weights()
    if i == 2:
        model_pre_updated.save_weights('model1.h5')
    else:
        model_pre_updated.load_weights('model_initial.h5')
    print()
```

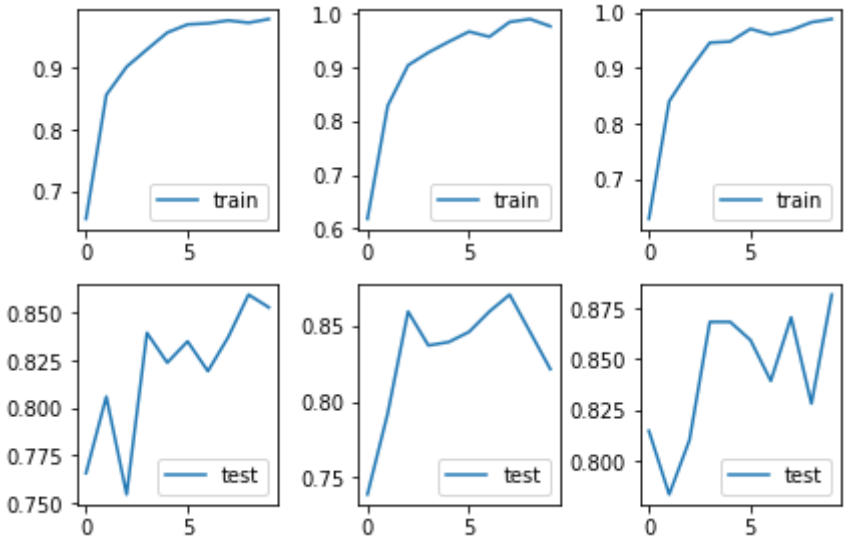
```
Train on 4037 samples, validate on 448 samples
Epoch 1/10
4037/4037 [==============================] - 119s 29ms/step - loss: 1.025
2 - acc: 0.6554 - val_loss: 0.6536 - val_acc: 0.7656
Epoch 2/10
4037/4037 [==============================] - 118s 29ms/step - loss: 0.425
8 - acc: 0.8556 - val_loss: 0.5316 - val_acc: 0.8058
Epoch 3/10
4037/4037 [==============================] - 118s 29ms/step - loss: 0.279
4 - acc: 0.9009 - val_loss: 0.7661 - val_acc: 0.7545
Epoch 4/10
4037/4037 [==============================] - 117s 29ms/step - loss: 0.211
7 - acc: 0.9289 - val_loss: 0.4589 - val_acc: 0.8393
Epoch 5/10
4037/4037 [==============================] - 117s 29ms/step - loss: 0.132
0 - acc: 0.9562 - val_loss: 0.6158 - val_acc: 0.8237
Epoch 6/10
4037/4037 [==============================] - 117s 29ms/step - loss: 0.095
8 - acc: 0.9693 - val_loss: 0.5353 - val_acc: 0.8348
Epoch 7/10
4037/4037 [==============================] - 117s 29ms/step - loss: 0.078
9 - acc: 0.9710 - val_loss: 0.6736 - val_acc: 0.8192
Epoch 8/10
4037/4037 [==============================] - 117s 29ms/step - loss: 0.072
4 - acc: 0.9757 - val_loss: 0.5754 - val_acc: 0.8371
Epoch 9/10
4037/4037 [==============================] - 117s 29ms/step - loss: 0.074
6 - acc: 0.9720 - val_loss: 0.5155 - val_acc: 0.8594
Epoch 10/10
4037/4037 [==============================] - 117s 29ms/step - loss: 0.068
7 - acc: 0.9780 - val_loss: 0.5576 - val_acc: 0.8527

Train on 4037 samples, validate on 448 samples
Epoch 1/10
4037/4037 [==============================] - 119s 30ms/step - loss: 1.160
0 - acc: 0.6178 - val_loss: 0.8131 - val_acc: 0.7388
Epoch 2/10
4037/4037 [==============================] - 118s 29ms/step - loss: 0.498
```

```
5 - acc: 0.8283 - val_loss: 0.5978 - val_acc: 0.7924
Epoch 3/10
4037/4037 [==============================] - 118s 29ms/step - loss: 0.272
4 - acc: 0.9036 - val_loss: 0.3909 - val_acc: 0.8594
Epoch 4/10
4037/4037 [==============================] - 117s 29ms/step - loss: 0.202
0 - acc: 0.9274 - val_loss: 0.5724 - val_acc: 0.8371
Epoch 5/10
4037/4037 [==============================] - 117s 29ms/step - loss: 0.147
7 - acc: 0.9475 - val_loss: 0.4733 - val_acc: 0.8393
Epoch 6/10
4037/4037 [==============================] - 117s 29ms/step - loss: 0.095
1 - acc: 0.9663 - val_loss: 0.5295 - val_acc: 0.8460
Epoch 7/10
4037/4037 [==============================] - 117s 29ms/step - loss: 0.122
8 - acc: 0.9567 - val_loss: 0.4194 - val_acc: 0.8594
Epoch 8/10
4037/4037 [==============================] - 117s 29ms/step - loss: 0.051
4 - acc: 0.9841 - val_loss: 0.4565 - val_acc: 0.8705
Epoch 9/10
4037/4037 [==============================] - 117s 29ms/step - loss: 0.031
4 - acc: 0.9896 - val_loss: 0.6239 - val_acc: 0.8460
Epoch 10/10
4037/4037 [==============================] - 117s 29ms/step - loss: 0.071
1 - acc: 0.9762 - val_loss: 0.7228 - val_acc: 0.8214

Train on 4037 samples, validate on 448 samples
Epoch 1/10
4037/4037 [==============================] - 120s 30ms/step - loss: 1.094
0 - acc: 0.6289 - val_loss: 0.5747 - val_acc: 0.8147
Epoch 2/10
4037/4037 [==============================] - 118s 29ms/step - loss: 0.477
1 - acc: 0.8400 - val_loss: 0.6016 - val_acc: 0.7835
Epoch 3/10
4037/4037 [==============================] - 118s 29ms/step - loss: 0.306
1 - acc: 0.8960 - val_loss: 0.5267 - val_acc: 0.8103
Epoch 4/10
4037/4037 [==============================] - 118s 29ms/step - loss: 0.166
6 - acc: 0.9453 - val_loss: 0.4529 - val_acc: 0.8683
Epoch 5/10
4037/4037 [==============================] - 118s 29ms/step - loss: 0.160
6 - acc: 0.9472 - val_loss: 0.3962 - val_acc: 0.8683
Epoch 6/10
4037/4037 [==============================] - 117s 29ms/step - loss: 0.088
6 - acc: 0.9700 - val_loss: 0.4773 - val_acc: 0.8594
Epoch 7/10
4037/4037 [==============================] - 117s 29ms/step - loss: 0.119
2 - acc: 0.9596 - val_loss: 0.5349 - val_acc: 0.8393
Epoch 8/10
4037/4037 [==============================] - 117s 29ms/step - loss: 0.095
5 - acc: 0.9678 - val_loss: 0.3961 - val_acc: 0.8705
Epoch 9/10
4037/4037 [==============================] - 117s 29ms/step - loss: 0.047
7 - acc: 0.9819 - val_loss: 0.7749 - val_acc: 0.8281
Epoch 10/10
4037/4037 [==============================] - 117s 29ms/step - loss: 0.038
```

```
1 - acc: 0.9876 - val_loss: 0.4519 - val_acc: 0.8817
```

In [0]:
```
import matplotlib.pyplot as plt
import numpy as np
```

In [35]:
```
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()

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: 0.9805961522631992
Average testing accuracy: 0.8519345238095237
```