ML_Cifar10_1101124_SR

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1 Final project CIFAR10

– Network used VGG16

- **Pretrained VGG model (using weights of imageNet)**

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[1]:
```
from __future__ import absolute_import, division, print_function,␣
 ↪unicode_literals

import tensorflow as tf
from tensorflow.keras.preprocessing import image
from tensorflow.keras.models import Model,Sequential
from tensorflow.keras.layers import Flatten, Dense,␣
 ↪Dropout,concatenate,Activation
import numpy as np
import matplotlib.pyplot as plt
from tensorflow.keras import optimizers
from tensorflow.keras.callbacks import EarlyStopping
from tensorflow.keras.callbacks import CSVLogger
from sklearn.preprocessing import OneHotEncoder
from tensorflow.keras.datasets import cifar10
import timeit
import cv2
import gc
import random
from tensorflow.python.keras.callbacks import TensorBoard
from tensorflow.keras.applications.vgg16 import VGG16
from tensorflow.keras.regularizers import l1
from tensorflow.keras.callbacks import LearningRateScheduler
from keras.preprocessing.image import ImageDataGenerator

print("Setup Done..")
```

```
Setup Done..
```

```
Using TensorFlow backend.
```

1.1 Loading test and train data

- We use cifar10.load_data() to load our data

[2]:
```
(train_imgs, train_labels), (test_imgs, test_labels) = cifar10.load_data()
print("Data loaded")
```

```
Data loaded
```

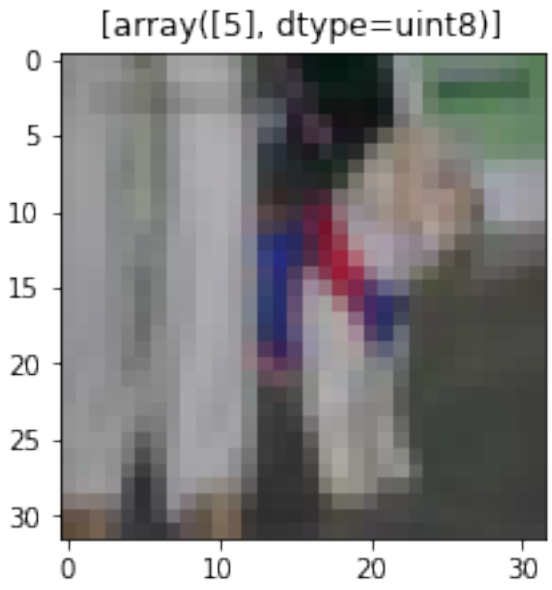
1.2 Checking data shape and size

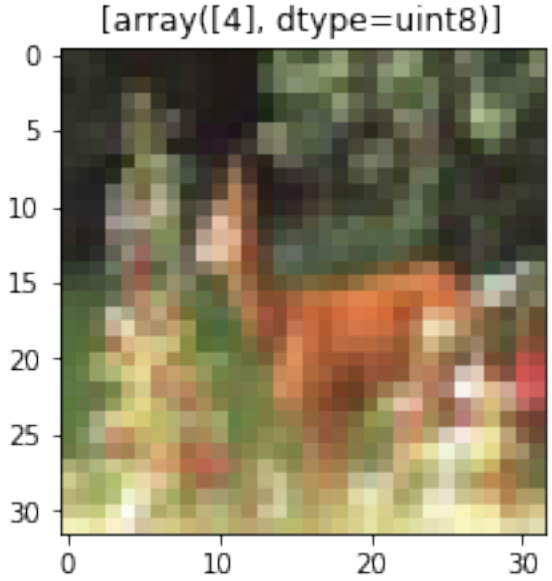
[3]:
```
print("Shape of train data: ",train_imgs.shape)
print("Shape of test data: ",test_imgs.shape)
print("Shape of train labels: ",train_labels.shape)
print("Shape of test labels: ",test_labels.shape)
```

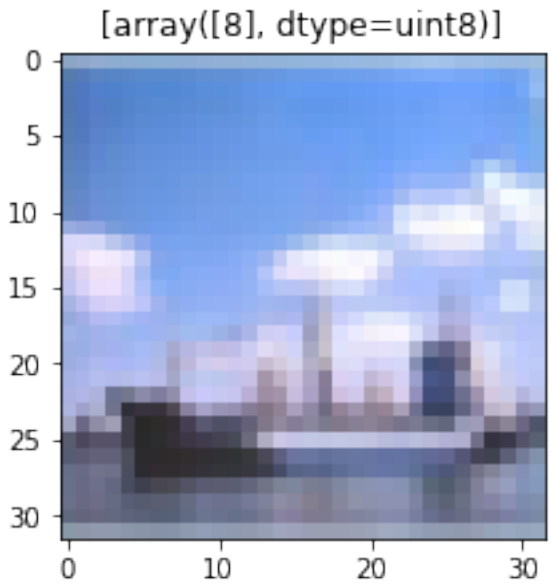
```
Shape of train data:  (50000, 32, 32, 3)
Shape of test data:  (10000, 32, 32, 3)
Shape of train labels:  (50000, 1)
Shape of test labels:  (10000, 1)
```

1.3 Plotting some random images

[4]:
```
val_index = []
for i in range(3):
    value = random.randint(0,3582)
    val_index.append(value)
    plt.figure( figsize=(15, 15))
    plt.subplot(1, 4, i+1)
    plt.title([train_labels[value]])
    plt.imshow(train_imgs[value])

plt.show()
```


[array([5], dtype=uint8)]
0
5
10
15
20
25
30
0
10
20
30


[array([4], dtype=uint8)]
0
5
10
15
20
25
30
0
10
20
30



2 Preprocess image using VGG function image

- The function is used to normalize image according to VGG16 network

[5]:
```
from tensorflow.keras.applications.vgg16 import preprocess_input
start = timeit.default_timer()
train_imgs = preprocess_input(train_imgs)
test_imgs = preprocess_input(test_imgs)
stop = timeit.default_timer()
print('Time taken to preprocess/normalize data : ', stop - start)
```

```
Time taken to preprocess/normalize data :  0.5072890070005087
```

2.1 Resize test and train images

- The images are resized to (224,244,3) format so that they can be used with VGG model
- The below code takes up lot of RAM so be sure to increase your ram on google cloud (otherwise you may get memory error)

[6]:
```
gc.collect()
start = timeit.default_timer()
train_imgs = np.array([cv2.resize(img, (224, 224), interpolation=cv2.
 ↪INTER_CUBIC) for img in train_imgs])
test_imgs = np.array([cv2.resize(img, (224, 224), interpolation=cv2.INTER_CUBIC)␣
 ↪for img in test_imgs])
stop = timeit.default_timer()
print('Time taken to resize data : ', stop - start)
```

```
print("Resize done")
```

```
Time taken to resize data :  27.60721833700154
Resize done
```

[7]:
```
#check shape of newly resiezed image
train_imgs.shape
```

[7]:
```
(50000, 224, 224, 3)
```

2.2 Applying one hot encoding on our labels

[8]:
```
onehot_encoder = OneHotEncoder(sparse=False)

train_labels = train_labels.reshape(-1,1)
test_labels = test_labels.reshape(-1,1)

train_labels = onehot_encoder.fit_transform(train_labels)
test_labels = onehot_encoder.transform(test_labels)
```

[9]:
```
print("Shape of train labels: ",train_labels.shape)
print("Shape of test labels: ",test_labels.shape)
```

```
Shape of train labels:  (50000, 10)
Shape of test labels:  (10000, 10)
```

2.3 Using model from keras–> VGG16

- we have used pretrained weights for imagenet and kept the top fully connected layers.

2.4 How we train our model:

- we freeze our layers of VGG16 so that they are not trained initially
- we only train our new Fully connected layers (so that they start extracting meanings from VGG16 network)
- we only use 2 epochs with high learning rate
- we then unfreeze VGG16 layers, and then train our model with a low variable learning rate for higher number of epoch.

2.4.1 Fully connected layers(Description):

- We use 2 fully connected layers and then add a drop out layer in between to reduce overfitting.
- We also add Reguralizer to prevent overfitting
- we have used Adam optimizer with learning rate of 0.0001 for training FC layers for 2 epochs
- for later traning of full model w ehave used variable Learning rates

2.4.2 Freezing VGG16 layers

- we freeze vgg16 model for our first 2 epoch (only new fully connected layer is trained)
- after these epoch we unfreeze the model and train it

[10]:
```
#define variable learning rates

def learning_rate_schedule(epoch):
    if epoch <= 3:
        return 1e-4 # 0.00001
    elif epoch <= 8:
        return 1e-5
    elif epoch <= 10:
        return 1e-6
    else:
        return 1e-7
    return LR
```

[11]:
```
#Initilize vgg net
vgg_net = VGG16(include_top=True, weights='imagenet', input_shape=(224,224,3))

#Define our model
x = vgg_net.get_layer('fc2').output
x = Dense(900, activity_regularizer=l1(0.001),activation='relu',␣
 ↪name='my_fc3')(x)
x = Dropout(0.3)(x)
x = Dense(10, activation='softmax', name='predictions')(x)
model_updated = Model(inputs=vgg_net.input, outputs=x)


## save our model weights
model_updated.save_weights('CIFAR10_VGG16_model_updated_initial.h5')
print("Model_Updated saved")

history_fc_list = []
history_full_list = []
```

```
WARNING:tensorflow:From /opt/conda/lib/python3.7/site-
packages/tensorflow_core/python/ops/resource_variable_ops.py:1630: calling
BaseResourceVariable.__init__ (from tensorflow.python.ops.resource_variable_ops)
with constraint is deprecated and will be removed in a future version.
Instructions for updating:
If using Keras pass *_constraint arguments to layers.
Model_Updated saved
```

[12]:
```
# Function to free up keras memory

from keras.backend.tensorflow_backend import set_session
```

```
from keras.backend.tensorflow_backend import clear_session
from keras.backend.tensorflow_backend import get_session
import tensorflow

# Reset Keras Session
def reset_keras():
    sess = get_session()
    clear_session()
    sess.close()
    sess = get_session()

    try:
        del classifier # this is from global space - change this as you need
    except:
        pass

    print(gc.collect()) # if it's done something you should see a number being␣
 ↪outputted

    # use the same config as you used to create the session
    config = tensorflow.ConfigProto()
    config.gpu_options.per_process_gpu_memory_fraction = 1
    config.gpu_options.visible_device_list = "0"
    set_session(tensorflow.Session(config=config))
```

[13]:
```
EPOCHS = 2
BATCH_SIZE = 128

train_generator = ImageDataGenerator(horizontal_flip=True,rotation_range=45,\
                                     fill_mode='nearest').flow(train_imgs,␣
 ↪train_labels, batch_size=BATCH_SIZE)
validation_generator = ImageDataGenerator().flow(test_imgs, test_labels,␣
 ↪batch_size=BATCH_SIZE)

validation_steps = test_imgs.shape[0]//BATCH_SIZE

steps_per_epoch = train_imgs.shape[0]//BATCH_SIZE
```

2.5 Run 1

[14]:
```
i=0
#Initilize vgg net
vgg_net = VGG16(include_top=True, weights='imagenet', input_shape=(224,224,3))

#Define our model
```

```
x = vgg_net.get_layer('fc2').output
x = Dense(900, activity_regularizer=l1(0.001),activation='relu',␣
 ↪name='my_fc3')(x)
x = Dropout(0.3)(x)
x = Dense(10, activation='softmax', name='predictions')(x)
model_updated = Model(inputs=vgg_net.input, outputs=x)

gc.collect()


model_updated.load_weights('CIFAR10_VGG16_model_updated_initial.h5')

print('------------------------New run started---------------------------------')
print('Initial model weights loaded , Started training run number ', i+1)
print('------------------------------------------------------------------------')

# Make the last Fully connected layers trainable and freezing the rest of VGG␣
 ↪model
for layer in model_updated.layers:
    layer.trainable = False
for layer in model_updated.layers[-3:]:
    layer.trainable = True

tensorboard = TensorBoard(log_dir="logs\{}".format('CIFAR10\FC_Layer'+str(i)))

model_updated.compile(loss='categorical_crossentropy', optimizer=optimizers.
 ↪Adam(lr=0.00005), metrics=['accuracy'])




print('--------------------------Starting Fully connected layer␣
 ↪training-------------------------------------')

# history_fc = model_updated.fit(train_imgs, train_labels, batch_size=128,\
# shuffle=True, epochs=2, validation_data=\
#                     (test_imgs, test_labels),callbacks =[tensorboard])

history_fc = model_updated.fit_generator(train_generator,␣
 ↪steps_per_epoch=steps_per_epoch, epochs=2,
                    validation_data=validation_generator,␣
 ↪validation_steps=validation_steps,
                    shuffle=True, callbacks=[tensorboard])
```

```
gc.collect()
##Unfreeze weights ------ Now full model will be trained
for layer in model_updated.layers:
    layer.trainable = True


no_epochs = 10
tensorboard = TensorBoard(log_dir="logs\{}".format('CIFAR10\FULL_Model'+str(i)))

opt2 = optimizers.Adam(lr=0.00001)

### Variable learning rate -----------------------
lrate = LearningRateScheduler(learning_rate_schedule)
callbacks_list = [lrate,tensorboard]




model_updated.compile(loss='categorical_crossentropy', optimizer=opt2,␣
 ↪metrics=['accuracy'])


print('--------------------------Starting Full model training -->after␣
 ↪unfreez-------------------------------------')

## Training full model
# history = model_updated.fit(train_imgs, train_labels, batch_size=128,\
# shuffle=True, epochs=no_epochs, validation_data=\
#                      (test_imgs, test_labels),callbacks =callbacks_list)

history = model_updated.fit_generator(train_generator,␣
 ↪steps_per_epoch=steps_per_epoch, epochs=no_epochs,
                    validation_data=validation_generator,␣
 ↪validation_steps=validation_steps,
                    shuffle=True, callbacks=[tensorboard])



## Timer for checking time taken
stop = timeit.default_timer()
print('Time taken for one run is : ', stop - start)

model_updated.save_weights('CIFAR10_VGG16_model_updated_fin.h5')
print("Model_Updated weights saved")

## saving history for plots
history_fc_list.append(history_fc)
```

```
history_full_list.append(history)
```

```
-----------------------New run started---------------------------------
Initial model weights loaded , Started training run number  1
-----------------------------------------------------------------------
-------------------------Starting Fully connected layer
training-----------------------------------
Epoch 1/2
389/390 [============================>.] - ETA: 1s - loss: 1.1098 - acc:
0.6951Epoch 1/2
390/390 [==============================] - 489s 1s/step - loss: 1.1094 - acc:
0.6950 - val_loss: 0.6827 - val_acc: 0.8271
Epoch 2/2
389/390 [============================>.] - ETA: 1s - loss: 0.7942 - acc:
0.7791Epoch 1/2
390/390 [==============================] - 485s 1s/step - loss: 0.7941 - acc:
0.7791 - val_loss: 0.6137 - val_acc: 0.8403
-------------------------Starting Full model training -->after
unfreez-------------------------------------
Epoch 1/10
389/390 [============================>.] - ETA: 1s - loss: 0.5375 - acc:
0.8636Epoch 1/10
390/390 [==============================] - 488s 1s/step - loss: 0.5373 - acc:
0.8636 - val_loss: 0.3662 - val_acc: 0.9199
Epoch 2/10
389/390 [============================>.] - ETA: 1s - loss: 0.3812 - acc:
0.9146Epoch 1/10
390/390 [==============================] - 478s 1s/step - loss: 0.3811 - acc:
0.9146 - val_loss: 0.3205 - val_acc: 0.9330
Epoch 3/10
389/390 [============================>.] - ETA: 1s - loss: 0.3135 - acc:
0.9352Epoch 1/10
390/390 [==============================] - 482s 1s/step - loss: 0.3135 - acc:
0.9351 - val_loss: 0.2872 - val_acc: 0.9411
Epoch 4/10
389/390 [============================>.] - ETA: 1s - loss: 0.2675 - acc:
0.9509Epoch 1/10
390/390 [==============================] - 476s 1s/step - loss: 0.2676 - acc:
0.9510 - val_loss: 0.2726 - val_acc: 0.9428
Epoch 5/10
389/390 [============================>.] - ETA: 1s - loss: 0.2304 - acc:
0.9616Epoch 1/10
390/390 [==============================] - 476s 1s/step - loss: 0.2305 - acc:
0.9616 - val_loss: 0.2636 - val_acc: 0.9464
Epoch 6/10
389/390 [============================>.] - ETA: 1s - loss: 0.2083 - acc:
0.9685Epoch 1/10
```

```
390/390 [==============================] - 463s 1s/step - loss: 0.2082 - acc:
0.9686 - val_loss: 0.2722 - val_acc: 0.9421
Epoch 7/10
389/390 [============================>.] - ETA: 1s - loss: 0.1849 - acc:
0.9750Epoch 1/10
390/390 [==============================] - 485s 1s/step - loss: 0.1849 - acc:
0.9750 - val_loss: 0.2544 - val_acc: 0.9471
Epoch 8/10
389/390 [============================>.] - ETA: 1s - loss: 0.1688 - acc:
0.9801Epoch 1/10
390/390 [==============================] - 495s 1s/step - loss: 0.1688 - acc:
0.9801 - val_loss: 0.2607 - val_acc: 0.9476
Epoch 9/10
389/390 [============================>.] - ETA: 1s - loss: 0.1543 - acc:
0.9839Epoch 1/10
390/390 [==============================] - 491s 1s/step - loss: 0.1544 - acc:
0.9838 - val_loss: 0.2485 - val_acc: 0.9470
Epoch 10/10
389/390 [============================>.] - ETA: 1s - loss: 0.1448 - acc:
0.9857Epoch 1/10
390/390 [==============================] - 490s 1s/step - loss: 0.1448 - acc:
0.9857 - val_loss: 0.2421 - val_acc: 0.9500
Time taken for one run is :  5839.472475565002
Model_Updated weights saved
```

2.6 Run 2

[15]:
```
i=1
#Initilize vgg net
vgg_net = VGG16(include_top=True, weights='imagenet', input_shape=(224,224,3))

#Define our model
x = vgg_net.get_layer('fc2').output
x = Dense(900, activity_regularizer=l1(0.001),activation='relu',␣
 ↪name='my_fc3')(x)
x = Dropout(0.3)(x)
x = Dense(10, activation='softmax', name='predictions')(x)
model_updated = Model(inputs=vgg_net.input, outputs=x)

gc.collect()


model_updated.load_weights('CIFAR10_VGG16_model_updated_initial.h5')

print('------------------------New run started--------------------------------')
print('Initial model weights loaded , Started training run number ', i+1)
print('-----------------------------------------------------------------------')
```

```
# Make the last Fully connected layers trainable and freezing the rest of VGG␣
 ↪model
for layer in model_updated.layers:
    layer.trainable = False
for layer in model_updated.layers[-3:]:
    layer.trainable = True

tensorboard = TensorBoard(log_dir="logs\{}".format('CIFAR10\FC_Layer'+str(i)))

model_updated.compile(loss='categorical_crossentropy', optimizer=optimizers.
 ↪Adam(lr=0.00005), metrics=['accuracy'])




print('-------------------------Starting Fully connected layer␣
 ↪training-------------------------------------')

# history_fc = model_updated.fit(train_imgs, train_labels, batch_size=128,\
# shuffle=True, epochs=2, validation_data=\
#                      (test_imgs, test_labels),callbacks =[tensorboard])

history_fc = model_updated.fit_generator(train_generator,␣
 ↪steps_per_epoch=steps_per_epoch, epochs=2,
                    validation_data=validation_generator,␣
 ↪validation_steps=validation_steps,
                    shuffle=True, callbacks=[tensorboard])


gc.collect()
##Unfreeze weights ------ Now full model will be trained
for layer in model_updated.layers:
    layer.trainable = True


no_epochs = 10
tensorboard = TensorBoard(log_dir="logs\{}".format('CIFAR10\FULL_Model'+str(i)))

opt2 = optimizers.Adam(lr=0.00001)

### Variable learning rate -----------------------
lrate = LearningRateScheduler(learning_rate_schedule)
callbacks_list = [lrate,tensorboard]
```

```
model_updated.compile(loss='categorical_crossentropy', optimizer=opt2,␣
 ↪metrics=['accuracy'])


print('-------------------------Starting Full model training -->after␣
 ↪unfreez-----------------------------------')

## Training full model
# history = model_updated.fit(train_imgs, train_labels, batch_size=128,\
# shuffle=True, epochs=no_epochs, validation_data=\
#                      (test_imgs, test_labels),callbacks =callbacks_list)

history = model_updated.fit_generator(train_generator,␣
 ↪steps_per_epoch=steps_per_epoch, epochs=no_epochs,
                    validation_data=validation_generator,␣
 ↪validation_steps=validation_steps,
                    shuffle=True, callbacks=[tensorboard])



## Timer for checking time taken
stop = timeit.default_timer()
print('Time taken for one run is : ', stop - start)

model_updated.save_weights('CIFAR10_VGG16_model_updated_fin.h5')
print("Model_Updated weights saved")

## saving history for plots
history_fc_list.append(history_fc)
history_full_list.append(history)
```

```
------------------------New run started---------------------------------
Initial model weights loaded , Started training run number  2
--------------------------------------------------------------------------------
-------------------------Starting Fully connected layer
training-----------------------------------
Epoch 1/2
389/390 [============================>.] - ETA: 1s - loss: 1.1066 - acc:
0.6968Epoch 1/2
390/390 [==============================] - 491s 1s/step - loss: 1.1058 - acc:
0.6972 - val_loss: 0.6891 - val_acc: 0.8275
Epoch 2/2
389/390 [============================>.] - ETA: 1s - loss: 0.7980 - acc:
0.7752Epoch 1/2
390/390 [==============================] - 489s 1s/step - loss: 0.7980 - acc:
```

```
0.7752 - val_loss: 0.6191 - val_acc: 0.8394
-------------------------Starting Full model training -->after
unfreez-----------------------------------
Epoch 1/10
389/390 [============================>.] - ETA: 1s - loss: 0.5374 - acc:
0.8647Epoch 1/10
390/390 [==============================] - 483s 1s/step - loss: 0.5370 - acc:
0.8649 - val_loss: 0.3706 - val_acc: 0.9202
Epoch 2/10
389/390 [============================>.] - ETA: 1s - loss: 0.3834 - acc:
0.9123Epoch 1/10
390/390 [==============================] - 492s 1s/step - loss: 0.3834 - acc:
0.9122 - val_loss: 0.3252 - val_acc: 0.9309
Epoch 3/10
389/390 [============================>.] - ETA: 1s - loss: 0.3130 - acc:
0.9374Epoch 1/10
390/390 [==============================] - 480s 1s/step - loss: 0.3129 - acc:
0.9374 - val_loss: 0.2856 - val_acc: 0.9409
Epoch 4/10
389/390 [============================>.] - ETA: 1s - loss: 0.2665 - acc:
0.9516Epoch 1/10
390/390 [==============================] - 478s 1s/step - loss: 0.2664 - acc:
0.9516 - val_loss: 0.2709 - val_acc: 0.9456
Epoch 5/10
389/390 [============================>.] - ETA: 1s - loss: 0.2297 - acc:
0.9620Epoch 1/10
390/390 [==============================] - 477s 1s/step - loss: 0.2296 - acc:
0.9621 - val_loss: 0.2676 - val_acc: 0.9455
Epoch 6/10
389/390 [============================>.] - ETA: 1s - loss: 0.2067 - acc:
0.9693Epoch 1/10
390/390 [==============================] - 475s 1s/step - loss: 0.2067 - acc:
0.9692 - val_loss: 0.2613 - val_acc: 0.9473
Epoch 7/10
389/390 [============================>.] - ETA: 1s - loss: 0.1850 - acc:
0.9752Epoch 1/10
390/390 [==============================] - 476s 1s/step - loss: 0.1850 - acc:
0.9752 - val_loss: 0.2457 - val_acc: 0.9509
Epoch 8/10
389/390 [============================>.] - ETA: 1s - loss: 0.1674 - acc:
0.9805Epoch 1/10
390/390 [==============================] - 473s 1s/step - loss: 0.1674 - acc:
0.9804 - val_loss: 0.2542 - val_acc: 0.9478
Epoch 9/10
389/390 [============================>.] - ETA: 1s - loss: 0.1569 - acc:
0.9824Epoch 1/10
390/390 [==============================] - 473s 1s/step - loss: 0.1568 - acc:
0.9824 - val_loss: 0.2445 - val_acc: 0.9512
```

```
Epoch 10/10
389/390 [============================>.] - ETA: 1s - loss: 0.1442 - acc:
0.9861Epoch 1/10
390/390 [==============================] - 483s 1s/step - loss: 0.1442 - acc:
0.9861 - val_loss: 0.2444 - val_acc: 0.9500
Time taken for one run is :  11614.747509958
Model_Updated weights saved
```

2.7 Run 3

[17]:
```
reset_keras()
i=2
#Initilize vgg net
vgg_net = VGG16(include_top=True, weights='imagenet', input_shape=(224,224,3))

#Define our model
x = vgg_net.get_layer('fc2').output
x = Dense(900, activity_regularizer=l1(0.001),activation='relu',␣
 ↪name='my_fc3')(x)
x = Dropout(0.3)(x)
x = Dense(10, activation='softmax', name='predictions')(x)
model_updated = Model(inputs=vgg_net.input, outputs=x)

gc.collect()


model_updated.load_weights('CIFAR10_VGG16_model_updated_initial.h5')

print('------------------------New run started--------------------------------')
print('Initial model weights loaded , Started training run number ', i+1)
print('-----------------------------------------------------------------------')

# Make the last Fully connected layers trainable and freezing the rest of VGG␣
 ↪model
for layer in model_updated.layers:
    layer.trainable = False
for layer in model_updated.layers[-3:]:
    layer.trainable = True

tensorboard = TensorBoard(log_dir="logs\{}".format('CIFAR10\FC_Layer'+str(i)))

model_updated.compile(loss='categorical_crossentropy', optimizer=optimizers.
 ↪Adam(lr=0.00005), metrics=['accuracy'])
```

```
print('-------------------------Starting Fully connected layer␣
 ↪training-----------------------------------')

# history_fc = model_updated.fit(train_imgs, train_labels, batch_size=128,\
# shuffle=True, epochs=2, validation_data=\
#                      (test_imgs, test_labels),callbacks =[tensorboard])

history_fc = model_updated.fit_generator(train_generator,␣
 ↪steps_per_epoch=steps_per_epoch, epochs=2,
                    validation_data=validation_generator,␣
 ↪validation_steps=validation_steps,
                    shuffle=True, callbacks=[tensorboard])


gc.collect()
##Unfreeze weights ------ Now full model will be trained
for layer in model_updated.layers:
    layer.trainable = True


no_epochs = 10
tensorboard = TensorBoard(log_dir="logs\{}".format('CIFAR10\FULL_Model'+str(i)))

opt2 = optimizers.Adam(lr=0.00001)

### Variable learning rate -----------------------
lrate = LearningRateScheduler(learning_rate_schedule)
callbacks_list = [lrate,tensorboard]




model_updated.compile(loss='categorical_crossentropy', optimizer=opt2,␣
 ↪metrics=['accuracy'])


print('-------------------------Starting Full model training -->after␣
 ↪unfreez-------------------------------------')

## Training full model
# history = model_updated.fit(train_imgs, train_labels, batch_size=128,\
# shuffle=True, epochs=no_epochs, validation_data=\
#                      (test_imgs, test_labels),callbacks =callbacks_list)

history = model_updated.fit_generator(train_generator,␣
 ↪steps_per_epoch=steps_per_epoch, epochs=no_epochs,
```

```
                    validation_data=validation_generator,␣
 ↪validation_steps=validation_steps,
                    shuffle=True, callbacks=[tensorboard])



## Timer for checking time taken
stop = timeit.default_timer()
print('Time taken for one run is : ', stop - start)

model_updated.save_weights('CIFAR10_VGG16_model_updated_fin.h5')
print("Model_Updated weights saved")

## saving history for plots
history_fc_list.append(history_fc)
history_full_list.append(history)
```

```
204
-----------------------New run started---------------------------------
Initial model weights loaded , Started training run number  3
-----------------------------------------------------------------------
-------------------------Starting Fully connected layer
training-----------------------------------
Epoch 1/2
389/390 [============================>.] - ETA: 1s - loss: 1.1022 - acc:
0.6979Epoch 1/2
390/390 [==============================] - 511s 1s/step - loss: 1.1014 - acc:
0.6980 - val_loss: 0.6788 - val_acc: 0.8275
Epoch 2/2
389/390 [============================>.] - ETA: 1s - loss: 0.7916 - acc:
0.7803Epoch 1/2
390/390 [==============================] - 507s 1s/step - loss: 0.7917 - acc:
0.7802 - val_loss: 0.6074 - val_acc: 0.8429
-------------------------Starting Full model training -->after
unfreez-------------------------------------
Epoch 1/10
389/390 [============================>.] - ETA: 1s - loss: 0.5347 - acc:
0.8637Epoch 1/10
390/390 [==============================] - 509s 1s/step - loss: 0.5344 - acc:
0.8638 - val_loss: 0.3776 - val_acc: 0.9149
Epoch 2/10
389/390 [============================>.] - ETA: 1s - loss: 0.3815 - acc:
0.9144Epoch 1/10
390/390 [==============================] - 505s 1s/step - loss: 0.3815 - acc:
0.9143 - val_loss: 0.3207 - val_acc: 0.9323
Epoch 3/10
389/390 [============================>.] - ETA: 1s - loss: 0.3125 - acc:
```

```
0.9366Epoch 1/10
390/390 [==============================] - 508s 1s/step - loss: 0.3123 - acc:
0.9367 - val_loss: 0.3010 - val_acc: 0.9368
Epoch 4/10
389/390 [============================>.] - ETA: 1s - loss: 0.2676 - acc:
0.9497Epoch 1/10
390/390 [==============================] - 512s 1s/step - loss: 0.2678 - acc:
0.9497 - val_loss: 0.2792 - val_acc: 0.9396
Epoch 5/10
389/390 [============================>.] - ETA: 1s - loss: 0.2334 - acc:
0.9603Epoch 1/10
390/390 [==============================] - 511s 1s/step - loss: 0.2334 - acc:
0.9603 - val_loss: 0.2713 - val_acc: 0.9421
Epoch 6/10
389/390 [============================>.] - ETA: 1s - loss: 0.2072 - acc:
0.9682Epoch 1/10
390/390 [==============================] - 510s 1s/step - loss: 0.2072 - acc:
0.9682 - val_loss: 0.2658 - val_acc: 0.9440
Epoch 7/10
389/390 [============================>.] - ETA: 1s - loss: 0.1842 - acc:
0.9758Epoch 1/10
390/390 [==============================] - 509s 1s/step - loss: 0.1842 - acc:
0.9757 - val_loss: 0.2631 - val_acc: 0.9464
Epoch 8/10
389/390 [============================>.] - ETA: 1s - loss: 0.1679 - acc:
0.9805Epoch 1/10
390/390 [==============================] - 507s 1s/step - loss: 0.1680 - acc:
0.9805 - val_loss: 0.2551 - val_acc: 0.9472
Epoch 9/10
389/390 [============================>.] - ETA: 1s - loss: 0.1545 - acc:
0.9830Epoch 1/10
390/390 [==============================] - 506s 1s/step - loss: 0.1545 - acc:
0.9830 - val_loss: 0.2525 - val_acc: 0.9464
Epoch 10/10
389/390 [============================>.] - ETA: 1s - loss: 0.1443 - acc:
0.9855Epoch 1/10
390/390 [==============================] - 507s 1s/step - loss: 0.1444 - acc:
0.9855 - val_loss: 0.2427 - val_acc: 0.9489
Time taken for one run is :  23796.115679282
Model_Updated weights saved
```

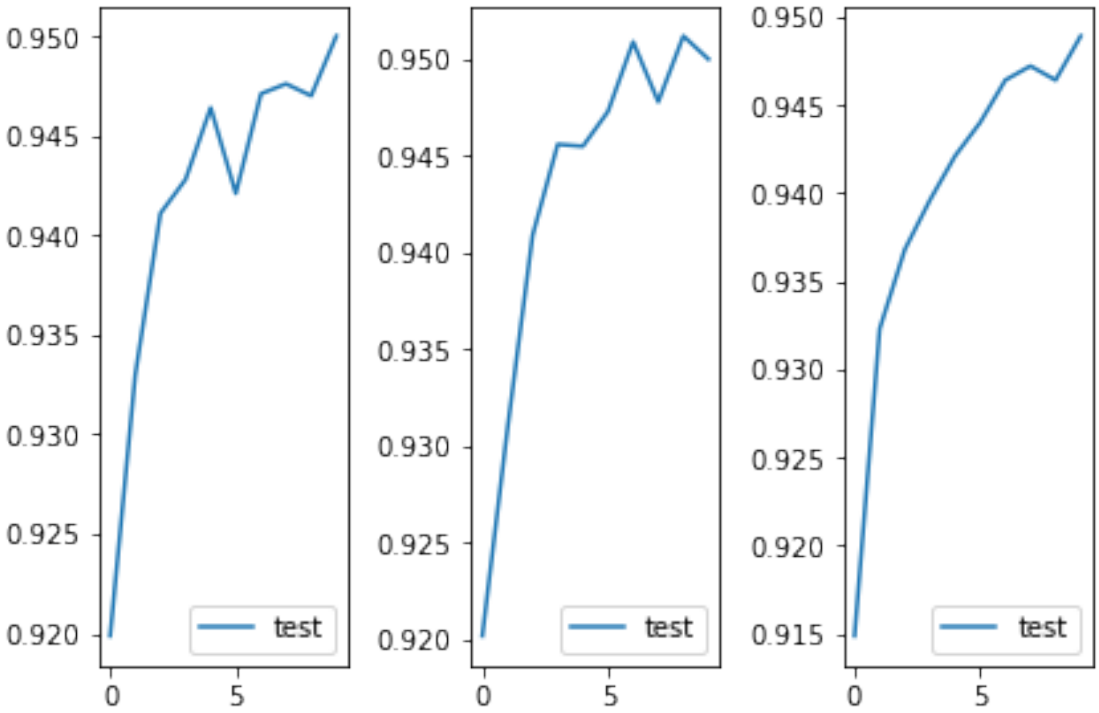
2.8 Tensorboard logs have been save to logs folder

- where "*_Layer" folder means logs where we train only our FC layers
- where "*_Model" folder means logs where we train all layers in our model

2.9 Plotting the graphs of testing accuracy

- Test accuracy
- Plotted for only FC_layer training
- Plotted for full model training

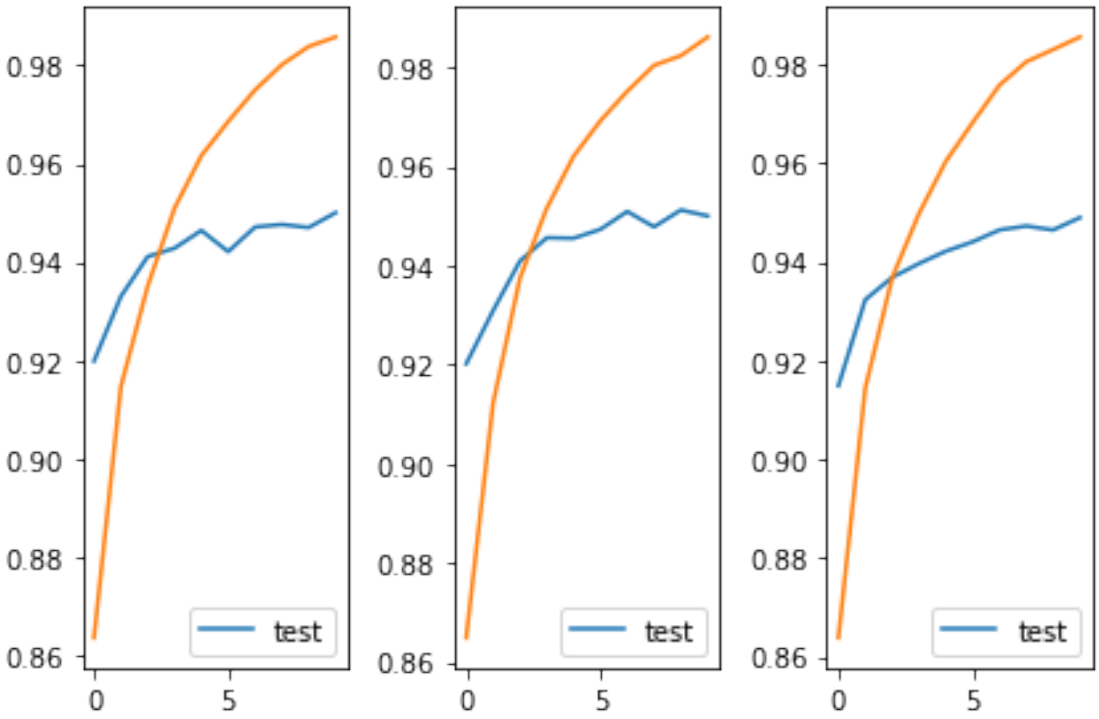
[18]:
```
plt.subplot(1, 3, 1)
plt.plot(history_full_list[0].history['val_acc'])
plt.legend(['test'], loc='lower right')

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

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

plt.show()

avg_train_acc = 0
avg_test_acc = 0
final_train_loss = []
final_test_loss = []

for his in history_full_list:
    final_train_loss.append(his.history['loss'][-1])
    final_test_loss.append(his.history['val_loss'][-1])
    avg_train_acc = avg_train_acc + his.history['acc'][-1]
    avg_test_acc = avg_test_acc + his.history['val_acc'][-1]

avg_train_acc = avg_train_acc/len(history_fc_list)
avg_test_acc = avg_test_acc/len(history_fc_list)


print("Average testing accuracy: {}".format(avg_test_acc))
```




```
Average testing accuracy: 0.9496527711550394
```

2.10 Train acc vs Test acc

[19]:
```
plt.subplot(1, 3, 1)
plt.plot(history_full_list[0].history['val_acc'])
plt.plot(history_full_list[0].history['acc'])
plt.legend(['test'], loc='lower right')

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

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

plt.show()
print("Average train accuracy: {}".format(avg_train_acc))
```




```
Average train accuracy: 0.9857969880104065
```

3 Final model accuracy is :

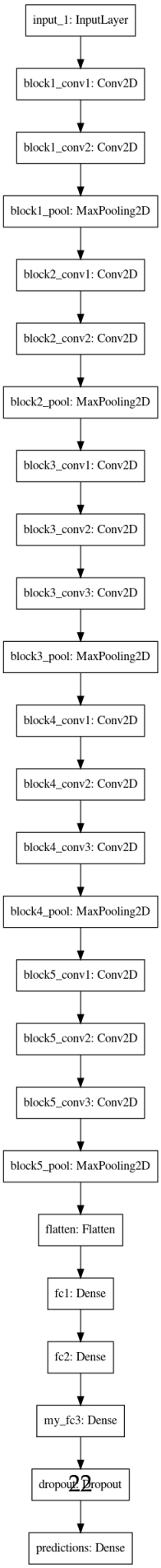
[20]:
```
print("Average Model Train accuracy is  : ",avg_test_acc*100,"%")
```

```
Average Model Train accuracy is  :  94.96527711550394 %
```

3.0.1 Model structure is saved to an image.

[21]:
```
from tensorflow.keras.utils import plot_model
plot_model(model_updated, to_file='model_CIFAR10_VGG16.png')
```

[21]:


input_1: InputLayer
block1_conv1: Conv2D
block1_conv2: Conv2D
block1_pool: MaxPooling2D
block2_conv1: Conv2D
block2_conv2: Conv2D
block2_pool: MaxPooling2D
block3_conv1: Conv2D
block3_conv2: Conv2D
block3_conv3: Conv2D
block3_pool: MaxPooling2D
block4_conv1: Conv2D
block4_conv2: Conv2D
block4_conv3: Conv2D
block4_pool: MaxPooling2D
block5_conv1: Conv2D
block5_conv2: Conv2D
block5_conv3: Conv2D
block5_pool: MaxPooling2D
flatten: Flatten
fc1: Dense
fc2: Dense
my_fc3: Dense
dropout_2: Dropout
predictions: Dense

Thank you