VGG_Combined_Model_Run1

March 25, 2020

```python
[1]: import numpy as np
     import time

     import keras

     from keras.preprocessing.image import ImageDataGenerator

     from keras.models import Sequential
     from keras.layers import Conv2D, MaxPooling2D
     from keras.layers import Activation, Dropout, Flatten, Dense
     from keras.layers import Dense, UpSampling2D, GlobalAveragePooling2D, Dropout,␣
     ↪BatchNormalization

     from keras.models import Model
     from keras.layers import Input
     from keras.layers import Dense
     from keras.layers import Flatten
     from keras.layers.merge import concatenate

     from keras.models import load_model

     from keras.optimizers import SGD, Adam, RMSprop

     from keras.applications.vgg16 import preprocess_input

     from keras.applications.vgg16 import VGG16
     from keras.applications.densenet import DenseNet201

     from keras.utils.vis_utils import plot_model

     from vgg16_places_365 import VGG16_Places365
```

Using TensorFlow backend.

```python
[2]: train_data_dir = r'Splits/split1/train'
     test_data_dir = r'Splits/split1/test'

     nb_train_samples = 19850
```

```
nb_test_samples = 19850
epochs = 10
batch_size = 32
img_width=224
img_height=224
num_classes = 397
```

[3]:
```
train_datagen = ImageDataGenerator(
    preprocessing_function=preprocess_input,
    shear_range=0.2,
    zoom_range=0.2,
    horizontal_flip=True)

test_datagen = ImageDataGenerator(preprocessing_function=preprocess_input)
```

[4]:
```
train_generator = train_datagen.flow_from_directory(
    train_data_dir,
    target_size=(224, 224),
    batch_size=batch_size,
    class_mode='categorical')

validation_generator = test_datagen.flow_from_directory(
    test_data_dir,
    target_size=(224, 224),
    batch_size=batch_size,
    class_mode='categorical')
```

```
Found 19850 images belonging to 397 classes.
Found 19850 images belonging to 397 classes.
```

[5]:
```
vgg_places = VGG16_Places365(weights='places', include_top=False,
→input_tensor=Input(shape=(224, 224, 3)))
```

```
WARNING:tensorflow:From /usr/local/lib/python3.5/dist-
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.
WARNING:tensorflow:From /usr/local/lib/python3.5/dist-
packages/keras/backend/tensorflow_backend.py:4070: The name tf.nn.max_pool is
deprecated. Please use tf.nn.max_pool2d instead.
```

[6]:
```
vgg_imagenet = VGG16(weights='imagenet', include_top=False,
→input_tensor=Input(shape=(224, 224, 3)))
```

```
[7]: for layer in vgg_places.layers:
         layer.trainable = False
```

```
[8]: for layer in vgg_imagenet.layers:
         layer.trainable = False
```

```
[9]: vgg_places.summary()
```

Model: "vgg16-places365"

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
    ================================================================
    Total params: 14,714,688
    Trainable params: 0
    Non-trainable params: 14,714,688
    ----------------------------------------------------------------
```

[10]: `vgg_imagenet.summary()`

```
Model: "vgg16"
----------------------------------------------------------------
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
=============================================================
Total params: 14,714,688
Trainable params: 0
Non-trainable params: 14,714,688

-------------------------------------------------------------
```

[11]:
```python
visible = Input(shape=(224,224,3))

model1 = vgg_places(visible)
model2 = vgg_imagenet(visible)
```

[12]:
```python
model1 = GlobalAveragePooling2D()(model1)
model2 = GlobalAveragePooling2D()(model2)

# model1 = Flatten(input_shape=vgg_places.output_shape[1:])(model1)
# model2 = Flatten(input_shape=vgg_imagenet.output_shape[1:])(model2)
```

[13]:
```python
merge = concatenate([model1,model2])
```

[14]:
```python
hidden1 = Dense(4096, activation='relu')(merge)
drop1 = Dropout(0.5)(hidden1)
hidden2 = Dense(4096, activation='relu')(drop1)
drop2 = Dropout(0.5)(hidden2)
hidden3 = Dense(4096, activation='relu')(drop2)
drop3 = Dropout(0.5)(hidden3)
output = Dense(num_classes, activation='softmax')(hidden2)
combined_model = Model(inputs=visible, outputs=output)
```

[15]:
```python
combined_model.summary()
```

```
Model: "model_1"
---------------------------------------------------------------------------
------------------
Layer (type)                 Output Shape        Param #      Connected to
===========================================================================
==================
input_3 (InputLayer)         (None, 224, 224, 3) 0

---------------------------------------------------------------------------
------------------
vgg16-places365 (Model)      (None, 7, 7, 512)   14714688     input_3[0][0]

---------------------------------------------------------------------------
------------------
vgg16 (Model)                (None, 7, 7, 512)   14714688     input_3[0][0]

---------------------------------------------------------------------------
------------------
```

```
global_average_pooling2d_1 (Glo  (None, 512)          0
vgg16-places365[1][0]
--------------------------------------------------------------------------
------------------
global_average_pooling2d_2 (Glo  (None, 512)          0          vgg16[1][0]
--------------------------------------------------------------------------
------------------
concatenate_1 (Concatenate)     (None, 1024)         0
global_average_pooling2d_1[0][0]
global_average_pooling2d_2[0][0]
--------------------------------------------------------------------------
------------------
dense_1 (Dense)                 (None, 4096)         4198400
concatenate_1[0][0]
--------------------------------------------------------------------------
------------------
dropout_1 (Dropout)             (None, 4096)         0          dense_1[0][0]
--------------------------------------------------------------------------
------------------
dense_2 (Dense)                 (None, 4096)         16781312   dropout_1[0][0]
--------------------------------------------------------------------------
------------------
dense_4 (Dense)                 (None, 397)          1626509    dense_2[0][0]
==========================================================================
==================
Total params: 52,035,597
Trainable params: 22,606,221
Non-trainable params: 29,429,376

--------------------------------------------------------------------------
------------------
```
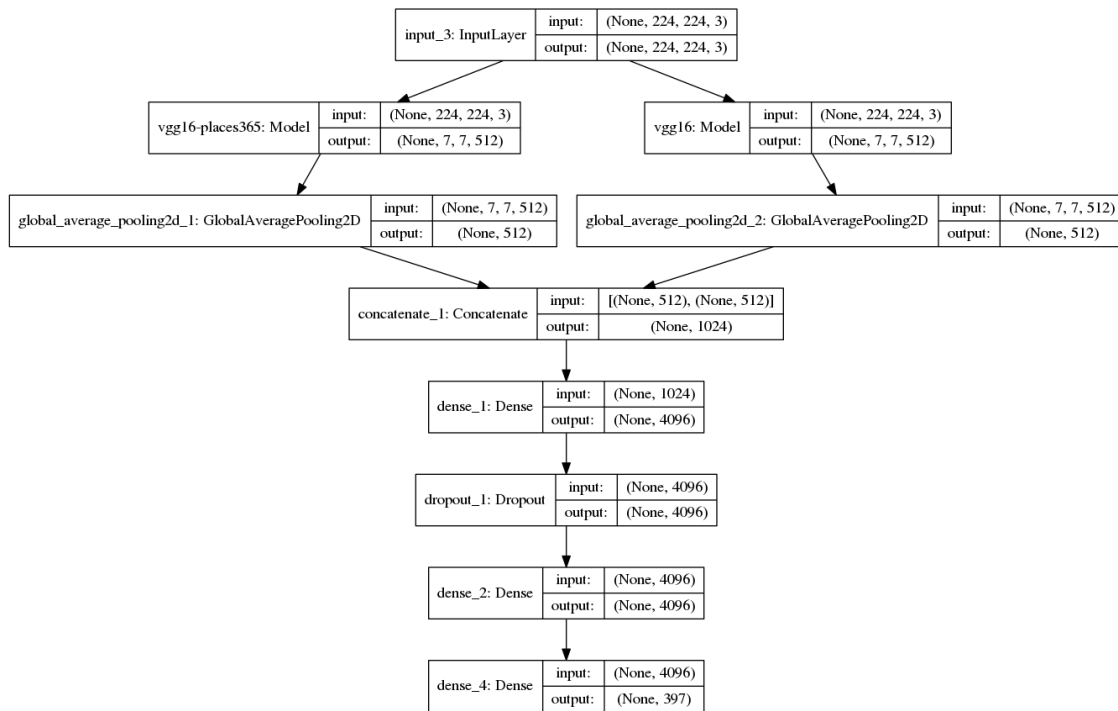
```python
[16]: plot_model(combined_model, to_file='combined_model_plot.png', show_shapes=True,
      ↪show_layer_names=True)
```

[16]:

input_3: InputLayer | input: (None, 224, 224, 3) | output: (None, 224, 224, 3)

vgg16-places365: Model | input: (None, 224, 224, 3) | output: (None, 7, 7, 512)

vgg16: Model | input: (None, 224, 224, 3) | output: (None, 7, 7, 512)

global_average_pooling2d_1: GlobalAveragePooling2D | input: (None, 7, 7, 512) | output: (None, 512)

global_average_pooling2d_2: GlobalAveragePooling2D | input: (None, 7, 7, 512) | output: (None, 512)

concatenate_1: Concatenate | input: [(None, 512), (None, 512)] | output: (None, 1024)

dense_1: Dense | input: (None, 1024) | output: (None, 4096)

dropout_1: Dropout | input: (None, 4096) | output: (None, 4096)

dense_2: Dense | input: (None, 4096) | output: (None, 4096)

dense_4: Dense | input: (None, 4096) | output: (None, 397)

```python
[17]: combined_model.compile(optimizer=RMSprop(lr=0.0002),
      ↪loss='categorical_crossentropy', metrics=['accuracy'] )
```

```python
[18]: import time

      class TimeHistory(keras.callbacks.Callback):
          def on_train_begin(self, logs={}):
              self.times = []

          def on_epoch_begin(self, batch, logs={}):
              self.epoch_time_start = time.time()

          def on_epoch_end(self, batch, logs={}):
              self.times.append(time.time() - self.epoch_time_start)
```

```python
[19]: from keras.callbacks import History , ModelCheckpoint

      history = History()
      checkpoint = ModelCheckpoint('Models/Run1/combined_vgg_best_model' ,
       ↪save_best_only=True)
      time_callback = TimeHistory()

      combined_model.fit_generator(
          train_generator,
```

```
    steps_per_epoch=nb_train_samples // batch_size,
    epochs=epochs,
    validation_data=validation_generator,
    validation_steps=nb_train_samples // batch_size,
    callbacks = [history , checkpoint, time_callback],
    shuffle=True)
```

WARNING:tensorflow:From /usr/local/lib/python3.5/dist-
packages/keras/backend/tensorflow_backend.py:422: The name tf.global_variables
is deprecated. Please use tf.compat.v1.global_variables instead.

Epoch 1/10
198/620 [========>…] - ETA: 6:58 - loss: 5.0078 - accuracy:
0.1905

/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data. Expecting to read 1385478 bytes but only got 23143.
Skipping tag 513
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data. Expecting to read 7276331008 bytes but only got 0.
Skipping tag 7
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data. Expecting to read 1879769088 bytes but only got 0.
Skipping tag 4
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data. Expecting to read 3014066176 bytes but only got 0.
Skipping tag 4
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data. Expecting to read 3568893952 bytes but only got
23144. Skipping tag 4
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data. Expecting to read 598221316 bytes but only got 0.
Skipping tag 0
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data. Expecting to read 4194304 bytes but only got 0.
Skipping tag 5
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data. Expecting to read 17249141424 bytes but only got 0.
Skipping tag 66
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
```

Possibly corrupt EXIF data.  Expecting to read 33554580 bytes but only got 0.
Skipping tag 11
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data.  Expecting to read 10878986 bytes but only got 0.
Skipping tag 712
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data.  Expecting to read 4383056960 bytes but only got
22044. Skipping tag 18
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data.  Expecting to read 541786190 bytes but only got 0.
Skipping tag 16576
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data.  Expecting to read 2256669952 bytes but only got 0.
Skipping tag 17
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data.  Expecting to read 67518482 bytes but only got 0.
Skipping tag 7
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data.  Expecting to read 4454482224 bytes but only got 0.
Skipping tag 237
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data.  Expecting to read 2359296 bytes but only got 0.
Skipping tag 4096
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data.  Expecting to read 671088900 bytes but only got 0.
Skipping tag 20
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data.  Expecting to read 65537 bytes but only got 0.
Skipping tag 65535
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data.  Expecting to read 262146 bytes but only got 0.
Skipping tag 2
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data.  Expecting to read 262151 bytes but only got 0.
Skipping tag 56
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:

```
Possibly corrupt EXIF data.  Expecting to read 8834460608 bytes but only got 0.
Skipping tag 35831
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:788: UserWarning:
Corrupt EXIF data.  Expecting to read 12 bytes but only got 6.
  warnings.warn(str(msg))

619/620 [=============================>.] - ETA: 0s - loss: 3.5330 - accuracy:
0.3302

/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data.  Expecting to read 150 bytes but only got 128.
Skipping tag 37510
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:788: UserWarning:
Corrupt EXIF data.  Expecting to read 4 bytes but only got 0.
  warnings.warn(str(msg))

620/620 [==============================] - 1012s 2s/step - loss: 3.5309 -
accuracy: 0.3305 - val_loss: 1.8052 - val_accuracy: 0.5174
Epoch 2/10
620/620 [==============================] - 1072s 2s/step - loss: 1.9904 -
accuracy: 0.5517 - val_loss: 2.3669 - val_accuracy: 0.5520
Epoch 3/10
620/620 [==============================] - 1008s 2s/step - loss: 1.6340 -
accuracy: 0.6317 - val_loss: 2.2866 - val_accuracy: 0.5572
Epoch 4/10
620/620 [==============================] - 1054s 2s/step - loss: 1.4032 -
accuracy: 0.6832 - val_loss: 2.4002 - val_accuracy: 0.5763
Epoch 5/10
620/620 [==============================] - 1043s 2s/step - loss: 1.2409 -
accuracy: 0.7243 - val_loss: 1.7923 - val_accuracy: 0.5842
Epoch 6/10
620/620 [==============================] - 1008s 2s/step - loss: 1.1296 -
accuracy: 0.7524 - val_loss: 2.9658 - val_accuracy: 0.5787
Epoch 7/10
620/620 [==============================] - 1012s 2s/step - loss: 1.0414 -
accuracy: 0.7756 - val_loss: 2.6363 - val_accuracy: 0.5859
Epoch 8/10
620/620 [==============================] - 1018s 2s/step - loss: 0.9594 -
accuracy: 0.7948 - val_loss: 3.4890 - val_accuracy: 0.5793
Epoch 9/10
620/620 [==============================] - 1004s 2s/step - loss: 0.9097 -
accuracy: 0.8123 - val_loss: 2.2764 - val_accuracy: 0.5881
Epoch 10/10
620/620 [==============================] - 1004s 2s/step - loss: 0.8695 -
accuracy: 0.8247 - val_loss: 4.1855 - val_accuracy: 0.5895
```

[19]: <keras.callbacks.callbacks.History at 0x7f424dd1a358>

```python
[20]: combined_model.save('Models/Run1/combined_vgg_full_model')
```

```python
[21]: model_history = np.array(history.history)
      np.save('History/Run1/model_history', model_history)
```

```python
[22]: model_time = np.array(time_callback.times)
      np.save('History/Run1/model_time', model_time)
```

```python
[23]: combined_model = load_model('Models/Run1/combined_vgg_best_model')
```

```python
[24]: train_generator.reset()
      validation_generator.reset()
```

```python
[25]: combined_model.summary()
```

```
Model: "model_1"
----------------------------------------------------------------------------
------------------
Layer (type)                    Output Shape          Param #     Connected to
============================================================================
==================
input_3 (InputLayer)            (None, 224, 224, 3)   0
----------------------------------------------------------------------------
------------------
vgg16-places365 (Model)         (None, 7, 7, 512)     14714688    input_3[0][0]
----------------------------------------------------------------------------
------------------
vgg16 (Model)                   (None, 7, 7, 512)     14714688    input_3[0][0]
----------------------------------------------------------------------------
------------------
global_average_pooling2d_1 (Glo (None, 512)           0
vgg16-places365[1][0]
----------------------------------------------------------------------------
------------------
global_average_pooling2d_2 (Glo (None, 512)           0           vgg16[1][0]
----------------------------------------------------------------------------
------------------
concatenate_1 (Concatenate)     (None, 1024)          0
global_average_pooling2d_1[0][0]
global_average_pooling2d_2[0][0]
----------------------------------------------------------------------------
------------------
dense_1 (Dense)                 (None, 4096)          4198400
concatenate_1[0][0]
----------------------------------------------------------------------------
------------------
dropout_1 (Dropout)             (None, 4096)          0           dense_1[0][0]
```

```
--------------------------------------------------------------------------------
------------------
dense_2 (Dense)                 (None, 4096)         16781312    dropout_1[0][0]
--------------------------------------------------------------------------------
------------------
dense_4 (Dense)                 (None, 397)          1626509     dense_2[0][0]
================================================================================
==================
Total params: 52,035,597
Trainable params: 22,606,221
Non-trainable params: 29,429,376
--------------------------------------------------------------------------------
------------------
```

[26]:
```python
for layer in combined_model.layers[1].layers[15:]:
    layer.trainable = True
```

[27]:
```python
for layer in combined_model.layers[2].layers[15:]:
    layer.trainable = True
```

[28]:
```python
combined_model.summary()
```

```
Model: "model_1"
--------------------------------------------------------------------------------
------------------
Layer (type)                    Output Shape         Param #     Connected to
================================================================================
==================
input_3 (InputLayer)            (None, 224, 224, 3)  0
--------------------------------------------------------------------------------
------------------
vgg16-places365 (Model)         (None, 7, 7, 512)    14714688    input_3[0][0]
--------------------------------------------------------------------------------
------------------
vgg16 (Model)                   (None, 7, 7, 512)    14714688    input_3[0][0]
--------------------------------------------------------------------------------
------------------
global_average_pooling2d_1 (Glo (None, 512)          0
vgg16-places365[1][0]
--------------------------------------------------------------------------------
------------------
global_average_pooling2d_2 (Glo (None, 512)          0           vgg16[1][0]
--------------------------------------------------------------------------------
------------------
concatenate_1 (Concatenate)     (None, 1024)         0
global_average_pooling2d_1[0][0]
global_average_pooling2d_2[0][0]
--------------------------------------------------------------------------------
```

```
        -------------------
dense_1 (Dense)                 (None, 4096)          4198400
concatenate_1[0][0]

        ----------------------------------------------------------------------
        -------------------
dropout_1 (Dropout)             (None, 4096)          0            dense_1[0][0]

        ----------------------------------------------------------------------
        -------------------
dense_2 (Dense)                 (None, 4096)          16781312     dropout_1[0][0]

        ----------------------------------------------------------------------
        -------------------
dense_4 (Dense)                 (None, 397)           1626509      dense_2[0][0]
        ======================================================================
        ================
Total params: 37,876,749
Trainable params: 22,606,221
Non-trainable params: 15,270,528

        ----------------------------------------------------------------------
        -------------------
/usr/local/lib/python3.5/dist-packages/keras/engine/training.py:297:
UserWarning: Discrepancy between trainable weights and collected trainable
weights, did you set `model.trainable` without calling `model.compile` after ?
  'Discrepancy between trainable weights and collected trainable'
```

[29]:
```python
combined_model.compile(optimizer=RMSprop(lr=0.00002),
 →loss='categorical_crossentropy', metrics=['accuracy'])
```

[30]:
```python
from keras.callbacks import History , ModelCheckpoint

history = History()
checkpoint = ModelCheckpoint('Models/Run1/ft_combined_vgg_best_model' ,
 →save_best_only=True)
time_callback = TimeHistory()

combined_model.fit_generator(
    train_generator,
    steps_per_epoch=nb_train_samples // batch_size,
    epochs=5,
    validation_data=validation_generator,
    validation_steps=nb_train_samples // batch_size,
    callbacks = [history , checkpoint, time_callback],
    shuffle=True)
```

```
Epoch 1/5
305/620 [=============>…] - ETA: 5:13 - loss: 0.8927 - accuracy:
0.8081

/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
```

Possibly corrupt EXIF data. Expecting to read 1385478 bytes but only got 23143.
Skipping tag 513
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data. Expecting to read 7276331008 bytes but only got 0.
Skipping tag 7
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data. Expecting to read 1879769088 bytes but only got 0.
Skipping tag 4
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data. Expecting to read 3014066176 bytes but only got 0.
Skipping tag 4
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data. Expecting to read 3568893952 bytes but only got
23144. Skipping tag 4
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data. Expecting to read 598221316 bytes but only got 0.
Skipping tag 0
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data. Expecting to read 4194304 bytes but only got 0.
Skipping tag 5
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data. Expecting to read 17249141424 bytes but only got 0.
Skipping tag 66
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data. Expecting to read 33554580 bytes but only got 0.
Skipping tag 11
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data. Expecting to read 10878986 bytes but only got 0.
Skipping tag 712
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data. Expecting to read 4383056960 bytes but only got
22044. Skipping tag 18
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data. Expecting to read 541786190 bytes but only got 0.
Skipping tag 16576
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:

```
Possibly corrupt EXIF data.  Expecting to read 2256669952 bytes but only got 0.
Skipping tag 17
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data.  Expecting to read 67518482 bytes but only got 0.
Skipping tag 7
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data.  Expecting to read 4454482224 bytes but only got 0.
Skipping tag 237
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data.  Expecting to read 2359296 bytes but only got 0.
Skipping tag 4096
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data.  Expecting to read 671088900 bytes but only got 0.
Skipping tag 20
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data.  Expecting to read 65537 bytes but only got 0.
Skipping tag 65535
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data.  Expecting to read 262146 bytes but only got 0.
Skipping tag 2
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data.  Expecting to read 262151 bytes but only got 0.
Skipping tag 56
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data.  Expecting to read 8834460608 bytes but only got 0.
Skipping tag 35831
  " Skipping tag %s" % (size, len(data), tag)
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:788: UserWarning:
Corrupt EXIF data.  Expecting to read 12 bytes but only got 6.
  warnings.warn(str(msg))

619/620 [============================>.] - ETA: 0s - loss: 0.8593 - accuracy:
0.8196

/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:788: UserWarning:
Corrupt EXIF data.  Expecting to read 4 bytes but only got 0.
  warnings.warn(str(msg))
/usr/local/lib/python3.5/dist-packages/PIL/TiffImagePlugin.py:770: UserWarning:
Possibly corrupt EXIF data.  Expecting to read 150 bytes but only got 128.
Skipping tag 37510
  " Skipping tag %s" % (size, len(data), tag)
```

```
620/620 [==============================] - 1006s 2s/step - loss: 0.8592 -
accuracy: 0.8196 - val_loss: 1.9694 - val_accuracy: 0.6050
Epoch 2/5
620/620 [==============================] - 1009s 2s/step - loss: 0.6860 -
accuracy: 0.8631 - val_loss: 1.9882 - val_accuracy: 0.6149
Epoch 3/5
620/620 [==============================] - 1032s 2s/step - loss: 0.6105 -
accuracy: 0.8839 - val_loss: 2.9572 - val_accuracy: 0.6157
Epoch 4/5
620/620 [==============================] - 1033s 2s/step - loss: 0.5521 -
accuracy: 0.9027 - val_loss: 1.8621 - val_accuracy: 0.6122
Epoch 5/5
620/620 [==============================] - 1031s 2s/step - loss: 0.5116 -
accuracy: 0.9130 - val_loss: 2.4539 - val_accuracy: 0.6113
```

[30]: `<keras.callbacks.callbacks.History at 0x7f42c073cac8>`

[31]:
```python
combined_model.save('Models/Run1/ft_combined_vgg_full_model')
```

[32]:
```python
model_history = np.array(history.history)
np.save('History/Run1/ft_model_history', model_history)
```

[33]:
```python
model_time = np.array(time_callback.times)
np.save('History/Run1/ft_model_time', model_time)
```

[ ]: