GZ_1_TL_Grayscale

April 14, 2022

[ ]:
```
%matplotlib inline
import os
import matplotlib.pyplot as plt
import pandas as pd
import numpy as np
import random
from importlib import reload
from tensorflow import keras
from keras.preprocessing.image import ImageDataGenerator
from keras.applications.resnet import ResNet50
from keras.layers import Flatten
from keras.layers import Dense
from keras.layers import Input
from keras.models import Model
from keras import backend as K
import tensorflow as tf
import glob
from shutil import copyfile
from keras.models import load_model
from keras import optimizers
```

[ ]:
```
img_shape = (224, 224, 3)
resnet_model = ResNet50(include_top=False, input_shape=img_shape) #Exclude the␣
 ↪top Layer by adding include_top=False
```

[ ]:
```
classes = [
    'Class1.1', 'Class1.2', 'Class1.3', 'Class2.1', 'Class2.2', 'Class3.1',
    'Class3.2', 'Class4.1', 'Class4.2', 'Class5.1', 'Class5.2', 'Class5.3',
    'Class5.4', 'Class6.1', 'Class6.2', 'Class7.1', 'Class7.2', 'Class7.3',
    'Class8.1', 'Class8.2', 'Class8.3', 'Class8.4', 'Class8.5', 'Class8.6',
    'Class8.7', 'Class9.1', 'Class9.2', 'Class9.3', 'Class10.1', 'Class10.2',
    'Class10.3', 'Class11.1', 'Class11.2', 'Class11.3', 'Class11.4',
    'Class11.5', 'Class11.6'
] #37 vectors of Galaxy Zoo divided into 11 classes based on the 11 different␣
 ↪questions and their responses
```

```
def append_ext(fn):
    '''
    This function is used to take the GalaxyID from the CSV and append .jpg to␣
 ↪it in order to denote the image names.
    '''
    return fn + ".jpg"

traindf = pd.read_csv(os.path.join(r"D:\OneDrive\Major␣
 ↪Project\Code\Galaxy_Morphology\Data\GalaxyZoo1\train",␣
 ↪'training_solutions_rev1.csv')) #Read the Data Frame using pandas

traindf["id"] = traindf['GalaxyID'].astype(str).apply(append_ext) #Create a new␣
 ↪column in the Data Frame called 'id' which has the image names.
traindf
```

[ ]:

	GalaxyID	Class1.1	Class1.2	Class1.3	Class2.1	Class2.2	Class3.1	\
0	100008	0.383147	0.616853	0.000000	0.000000	0.616853	0.038452	
1	100023	0.327001	0.663777	0.009222	0.031178	0.632599	0.467370	
2	100053	0.765717	0.177352	0.056931	0.000000	0.177352	0.000000	
3	100078	0.693377	0.238564	0.068059	0.000000	0.238564	0.109493	
4	100090	0.933839	0.000000	0.066161	0.000000	0.000000	0.000000	
…	…	…	…	…	…	…	…	
61573	999948	0.510379	0.489621	0.000000	0.059207	0.430414	0.000000	
61574	999950	0.901216	0.098784	0.000000	0.000000	0.098784	0.000000	
61575	999958	0.202841	0.777376	0.019783	0.116962	0.660414	0.067245	
61576	999964	0.091000	0.909000	0.000000	0.045450	0.863550	0.022452	
61577	999967	0.767000	0.140000	0.093000	0.000000	0.140000	0.000000	

	Class3.2	Class4.1	Class4.2	…	Class10.1	Class10.2	Class10.3	\
0	0.578401	0.418398	0.198455	…	0.279952	0.138445	0.000000	
1	0.165229	0.591328	0.041271	…	0.000000	0.131378	0.459950	
2	0.177352	0.000000	0.177352	…	0.000000	0.000000	0.000000	
3	0.129071	0.189098	0.049466	…	0.094549	0.000000	0.094549	
4	0.000000	0.000000	0.000000	…	0.000000	0.000000	0.000000	
…	…	…	…	…	…	…	…	
61573	0.430414	0.226257	0.204157	…	0.226257	0.000000	0.000000	
61574	0.098784	0.000000	0.098784	…	0.000000	0.000000	0.000000	
61575	0.593168	0.140022	0.520391	…	0.000000	0.090673	0.049349	
61576	0.841098	0.795330	0.068220	…	0.068398	0.318132	0.408799	
61577	0.140000	0.023380	0.116620	…	0.023380	0.000000	0.000000	

	Class11.1	Class11.2	Class11.3	Class11.4	Class11.5	Class11.6	\
0	0.000000	0.092886	0.000000	0.000000	0.0	0.325512	
1	0.000000	0.591328	0.000000	0.000000	0.0	0.000000	
2	0.000000	0.000000	0.000000	0.000000	0.0	0.000000	
3	0.189098	0.000000	0.000000	0.000000	0.0	0.000000	
4	0.000000	0.000000	0.000000	0.000000	0.0	0.000000	

```
…          …         …         …         …         …         …
61573   0.000000  0.000000  0.000000  0.000000       0.0  0.226257
61574   0.000000  0.000000  0.000000  0.000000       0.0  0.000000
61575   0.000000  0.067726  0.000000  0.000000       0.0  0.072296
61576   0.227464  0.408799  0.090668  0.023065       0.0  0.045334
61577   0.000000  0.000000  0.000000  0.000000       0.0  0.023380

                id
0       100008.jpg
1       100023.jpg
2       100053.jpg
3       100078.jpg
4       100090.jpg
…             …
61573   999948.jpg
61574   999950.jpg
61575   999958.jpg
61576   999964.jpg
61577   999967.jpg

[61578 rows x 39 columns]
```

[ ]:
```
def convert_rgb_to_grayscale(image):
    return tf.image.rgb_to_grayscale(image)

datagenerator = ImageDataGenerator(
    fill_mode='nearest',
    cval=0,
    rescale=1/255,
    preprocessing_function=convert_rgb_to_grayscale,
    rotation_range=90,
    width_shift_range=0.1,
    height_shift_range=0.1,
    horizontal_flip=True,
    vertical_flip=True,
    validation_split=0.02)

train_generator = datagenerator.flow_from_dataframe(
    dataframe=traindf,
    directory="D:/OneDrive/Major Project/Code/Galaxy_Morphology/Data/GalaxyZoo1/
 ↪train/images_training_rev1",
    x_col="id",
    y_col=classes,
    subset="training",
    batch_size=16,
    seed=123,
    shuffle=True,
```

```
    class_mode="raw",
    target_size=(224, 224))

validation_generator = datagenerator.flow_from_dataframe(
    dataframe=traindf,
    directory="D:/OneDrive/Major Project/Code/Galaxy_Morphology/Data/GalaxyZoo1/
 ↪train/images_training_rev1",
    x_col="id",
    y_col=classes,
    subset="validation",
    batch_size=16,
    seed=123,
    shuffle=True,
    class_mode="raw",
    target_size=(224, 224))

STEP_SIZE_TRAIN = train_generator.n // train_generator.batch_size
STEP_SIZE_VALID = validation_generator.n // validation_generator.batch_size
```

```
Found 60347 validated image filenames.
Found 1231 validated image filenames.
```

[ ]:
```
# Flatten output of last layer before adding output layer (Dense layer)
x = Flatten()(resnet_model.output)

# Add output layer (number of outputs = 37)
x = Dense(len(classes), activation='sigmoid')(x)

# Load the modified model
model = Model(inputs=resnet_model.input, outputs=x)
```

[ ]:
```
print(model.summary())
```

```
Model: "model"
__________________________________________________________________________________
__________________
 Layer (type)                   Output Shape         Param #     Connected to
==================================================================================
==================
 input_1 (InputLayer)           [(None, 224, 224, 3  0           []
                                )]

 conv1_pad (ZeroPadding2D)      (None, 230, 230, 3)  0
['input_1[0][0]']

 conv1_conv (Conv2D)            (None, 112, 112, 64  9472
['conv1_pad[0][0]']
```

```
                                )

 conv1_bn (BatchNormalization)  (None, 112, 112, 64  256
['conv1_conv[0][0]']
                                )

 conv1_relu (Activation)        (None, 112, 112, 64  0
['conv1_bn[0][0]']
                                )

 pool1_pad (ZeroPadding2D)      (None, 114, 114, 64  0
['conv1_relu[0][0]']
                                )

 pool1_pool (MaxPooling2D)      (None, 56, 56, 64)   0
['pool1_pad[0][0]']

 conv2_block1_1_conv (Conv2D)   (None, 56, 56, 64)   4160
['pool1_pool[0][0]']

 conv2_block1_1_bn (BatchNormal  (None, 56, 56, 64)  256
['conv2_block1_1_conv[0][0]']
 ization)

 conv2_block1_1_relu (Activatio  (None, 56, 56, 64)  0
['conv2_block1_1_bn[0][0]']
 n)

 conv2_block1_2_conv (Conv2D)   (None, 56, 56, 64)   36928
['conv2_block1_1_relu[0][0]']

 conv2_block1_2_bn (BatchNormal  (None, 56, 56, 64)  256
['conv2_block1_2_conv[0][0]']
 ization)

 conv2_block1_2_relu (Activatio  (None, 56, 56, 64)  0
['conv2_block1_2_bn[0][0]']
 n)

 conv2_block1_0_conv (Conv2D)   (None, 56, 56, 256)  16640
['pool1_pool[0][0]']

 conv2_block1_3_conv (Conv2D)   (None, 56, 56, 256)  16640
['conv2_block1_2_relu[0][0]']

 conv2_block1_0_bn (BatchNormal  (None, 56, 56, 256)  1024
['conv2_block1_0_conv[0][0]']
 ization)
```

```
 conv2_block1_3_bn (BatchNormal  (None, 56, 56, 256)  1024
['conv2_block1_3_conv[0][0]']
 ization)

 conv2_block1_add (Add)         (None, 56, 56, 256)  0
['conv2_block1_0_bn[0][0]',
'conv2_block1_3_bn[0][0]']

 conv2_block1_out (Activation)  (None, 56, 56, 256)  0
['conv2_block1_add[0][0]']

 conv2_block2_1_conv (Conv2D)   (None, 56, 56, 64)   16448
['conv2_block1_out[0][0]']

 conv2_block2_1_bn (BatchNormal  (None, 56, 56, 64)  256
['conv2_block2_1_conv[0][0]']
 ization)

 conv2_block2_1_relu (Activatio  (None, 56, 56, 64)  0
['conv2_block2_1_bn[0][0]']
 n)

 conv2_block2_2_conv (Conv2D)   (None, 56, 56, 64)   36928
['conv2_block2_1_relu[0][0]']

 conv2_block2_2_bn (BatchNormal  (None, 56, 56, 64)  256
['conv2_block2_2_conv[0][0]']
 ization)

 conv2_block2_2_relu (Activatio  (None, 56, 56, 64)  0
['conv2_block2_2_bn[0][0]']
 n)

 conv2_block2_3_conv (Conv2D)   (None, 56, 56, 256)  16640
['conv2_block2_2_relu[0][0]']

 conv2_block2_3_bn (BatchNormal  (None, 56, 56, 256)  1024
['conv2_block2_3_conv[0][0]']
 ization)

 conv2_block2_add (Add)         (None, 56, 56, 256)  0
['conv2_block1_out[0][0]',
'conv2_block2_3_bn[0][0]']

 conv2_block2_out (Activation)  (None, 56, 56, 256)  0
['conv2_block2_add[0][0]']
```

```
 conv2_block3_1_conv (Conv2D)   (None, 56, 56, 64)   16448
['conv2_block2_out[0][0]']

 conv2_block3_1_bn (BatchNormal  (None, 56, 56, 64)  256
['conv2_block3_1_conv[0][0]']
 ization)

 conv2_block3_1_relu (Activatio  (None, 56, 56, 64)  0
['conv2_block3_1_bn[0][0]']
 n)

 conv2_block3_2_conv (Conv2D)   (None, 56, 56, 64)   36928
['conv2_block3_1_relu[0][0]']

 conv2_block3_2_bn (BatchNormal  (None, 56, 56, 64)  256
['conv2_block3_2_conv[0][0]']
 ization)

 conv2_block3_2_relu (Activatio  (None, 56, 56, 64)  0
['conv2_block3_2_bn[0][0]']
 n)

 conv2_block3_3_conv (Conv2D)   (None, 56, 56, 256)  16640
['conv2_block3_2_relu[0][0]']

 conv2_block3_3_bn (BatchNormal  (None, 56, 56, 256)  1024
['conv2_block3_3_conv[0][0]']
 ization)

 conv2_block3_add (Add)         (None, 56, 56, 256)  0
['conv2_block2_out[0][0]',
'conv2_block3_3_bn[0][0]']

 conv2_block3_out (Activation)  (None, 56, 56, 256)  0
['conv2_block3_add[0][0]']

 conv3_block1_1_conv (Conv2D)   (None, 28, 28, 128)  32896
['conv2_block3_out[0][0]']

 conv3_block1_1_bn (BatchNormal  (None, 28, 28, 128)  512
['conv3_block1_1_conv[0][0]']
 ization)

 conv3_block1_1_relu (Activatio  (None, 28, 28, 128)  0
['conv3_block1_1_bn[0][0]']
 n)

 conv3_block1_2_conv (Conv2D)   (None, 28, 28, 128)  147584
```

```
['conv3_block1_1_relu[0][0]']

 conv3_block1_2_bn (BatchNormal  (None, 28, 28, 128)  512
['conv3_block1_2_conv[0][0]']
 ization)

 conv3_block1_2_relu (Activatio  (None, 28, 28, 128)  0
['conv3_block1_2_bn[0][0]']
 n)

 conv3_block1_0_conv (Conv2D)   (None, 28, 28, 512)  131584
['conv2_block3_out[0][0]']

 conv3_block1_3_conv (Conv2D)   (None, 28, 28, 512)  66048
['conv3_block1_2_relu[0][0]']

 conv3_block1_0_bn (BatchNormal  (None, 28, 28, 512)  2048
['conv3_block1_0_conv[0][0]']
 ization)

 conv3_block1_3_bn (BatchNormal  (None, 28, 28, 512)  2048
['conv3_block1_3_conv[0][0]']
 ization)

 conv3_block1_add (Add)         (None, 28, 28, 512)  0
['conv3_block1_0_bn[0][0]',
'conv3_block1_3_bn[0][0]']

 conv3_block1_out (Activation)  (None, 28, 28, 512)  0
['conv3_block1_add[0][0]']

 conv3_block2_1_conv (Conv2D)   (None, 28, 28, 128)  65664
['conv3_block1_out[0][0]']

 conv3_block2_1_bn (BatchNormal  (None, 28, 28, 128)  512
['conv3_block2_1_conv[0][0]']
 ization)

 conv3_block2_1_relu (Activatio  (None, 28, 28, 128)  0
['conv3_block2_1_bn[0][0]']
 n)

 conv3_block2_2_conv (Conv2D)   (None, 28, 28, 128)  147584
['conv3_block2_1_relu[0][0]']

 conv3_block2_2_bn (BatchNormal  (None, 28, 28, 128)  512
['conv3_block2_2_conv[0][0]']
 ization)
```

```
 conv3_block2_2_relu (Activatio  (None, 28, 28, 128)  0
['conv3_block2_2_bn[0][0]']
 n)

 conv3_block2_3_conv (Conv2D)   (None, 28, 28, 512)  66048
['conv3_block2_2_relu[0][0]']

 conv3_block2_3_bn (BatchNormal  (None, 28, 28, 512)  2048
['conv3_block2_3_conv[0][0]']
 ization)

 conv3_block2_add (Add)         (None, 28, 28, 512)  0
['conv3_block1_out[0][0]',
'conv3_block2_3_bn[0][0]']

 conv3_block2_out (Activation)  (None, 28, 28, 512)  0
['conv3_block2_add[0][0]']

 conv3_block3_1_conv (Conv2D)   (None, 28, 28, 128)  65664
['conv3_block2_out[0][0]']

 conv3_block3_1_bn (BatchNormal  (None, 28, 28, 128)  512
['conv3_block3_1_conv[0][0]']
 ization)

 conv3_block3_1_relu (Activatio  (None, 28, 28, 128)  0
['conv3_block3_1_bn[0][0]']
 n)

 conv3_block3_2_conv (Conv2D)   (None, 28, 28, 128)  147584
['conv3_block3_1_relu[0][0]']

 conv3_block3_2_bn (BatchNormal  (None, 28, 28, 128)  512
['conv3_block3_2_conv[0][0]']
 ization)

 conv3_block3_2_relu (Activatio  (None, 28, 28, 128)  0
['conv3_block3_2_bn[0][0]']
 n)

 conv3_block3_3_conv (Conv2D)   (None, 28, 28, 512)  66048
['conv3_block3_2_relu[0][0]']

 conv3_block3_3_bn (BatchNormal  (None, 28, 28, 512)  2048
['conv3_block3_3_conv[0][0]']
 ization)
```

```
 conv3_block3_add (Add)         (None, 28, 28, 512)  0
['conv3_block2_out[0][0]',
'conv3_block3_3_bn[0][0]']

 conv3_block3_out (Activation)  (None, 28, 28, 512)  0
['conv3_block3_add[0][0]']

 conv3_block4_1_conv (Conv2D)   (None, 28, 28, 128)  65664
['conv3_block3_out[0][0]']

 conv3_block4_1_bn (BatchNormal  (None, 28, 28, 128)  512
['conv3_block4_1_conv[0][0]']
 ization)

 conv3_block4_1_relu (Activatio  (None, 28, 28, 128)  0
['conv3_block4_1_bn[0][0]']
 n)

 conv3_block4_2_conv (Conv2D)   (None, 28, 28, 128)  147584
['conv3_block4_1_relu[0][0]']

 conv3_block4_2_bn (BatchNormal  (None, 28, 28, 128)  512
['conv3_block4_2_conv[0][0]']
 ization)

 conv3_block4_2_relu (Activatio  (None, 28, 28, 128)  0
['conv3_block4_2_bn[0][0]']
 n)

 conv3_block4_3_conv (Conv2D)   (None, 28, 28, 512)  66048
['conv3_block4_2_relu[0][0]']

 conv3_block4_3_bn (BatchNormal  (None, 28, 28, 512)  2048
['conv3_block4_3_conv[0][0]']
 ization)

 conv3_block4_add (Add)         (None, 28, 28, 512)  0
['conv3_block3_out[0][0]',
'conv3_block4_3_bn[0][0]']

 conv3_block4_out (Activation)  (None, 28, 28, 512)  0
['conv3_block4_add[0][0]']

 conv4_block1_1_conv (Conv2D)   (None, 14, 14, 256)  131328
['conv3_block4_out[0][0]']

 conv4_block1_1_bn (BatchNormal  (None, 14, 14, 256)  1024
['conv4_block1_1_conv[0][0]']
```

```
 ization)

 conv4_block1_1_relu (Activatio  (None, 14, 14, 256)  0
['conv4_block1_1_bn[0][0]']
 n)

 conv4_block1_2_conv (Conv2D)   (None, 14, 14, 256)  590080
['conv4_block1_1_relu[0][0]']

 conv4_block1_2_bn (BatchNormal  (None, 14, 14, 256)  1024
['conv4_block1_2_conv[0][0]']
 ization)

 conv4_block1_2_relu (Activatio  (None, 14, 14, 256)  0
['conv4_block1_2_bn[0][0]']
 n)

 conv4_block1_0_conv (Conv2D)   (None, 14, 14, 1024  525312
['conv3_block4_out[0][0]']
                                )

 conv4_block1_3_conv (Conv2D)   (None, 14, 14, 1024  263168
['conv4_block1_2_relu[0][0]']
                                )

 conv4_block1_0_bn (BatchNormal  (None, 14, 14, 1024  4096
['conv4_block1_0_conv[0][0]']
 ization)                       )

 conv4_block1_3_bn (BatchNormal  (None, 14, 14, 1024  4096
['conv4_block1_3_conv[0][0]']
 ization)                       )

 conv4_block1_add (Add)         (None, 14, 14, 1024  0
['conv4_block1_0_bn[0][0]',
                                )
'conv4_block1_3_bn[0][0]']

 conv4_block1_out (Activation)  (None, 14, 14, 1024  0
['conv4_block1_add[0][0]']
                                )

 conv4_block2_1_conv (Conv2D)   (None, 14, 14, 256)  262400
['conv4_block1_out[0][0]']

 conv4_block2_1_bn (BatchNormal  (None, 14, 14, 256)  1024
['conv4_block2_1_conv[0][0]']
 ization)
```

```
 conv4_block2_1_relu (Activatio  (None, 14, 14, 256)  0
['conv4_block2_1_bn[0][0]']
 n)

 conv4_block2_2_conv (Conv2D)   (None, 14, 14, 256)  590080
['conv4_block2_1_relu[0][0]']

 conv4_block2_2_bn (BatchNormal  (None, 14, 14, 256)  1024
['conv4_block2_2_conv[0][0]']
 ization)

 conv4_block2_2_relu (Activatio  (None, 14, 14, 256)  0
['conv4_block2_2_bn[0][0]']
 n)

 conv4_block2_3_conv (Conv2D)   (None, 14, 14, 1024  263168
['conv4_block2_2_relu[0][0]']
                                )

 conv4_block2_3_bn (BatchNormal  (None, 14, 14, 1024  4096
['conv4_block2_3_conv[0][0]']
 ization)                       )

 conv4_block2_add (Add)         (None, 14, 14, 1024  0
['conv4_block1_out[0][0]',
                                )
'conv4_block2_3_bn[0][0]']

 conv4_block2_out (Activation)  (None, 14, 14, 1024  0
['conv4_block2_add[0][0]']
                                )

 conv4_block3_1_conv (Conv2D)   (None, 14, 14, 256)  262400
['conv4_block2_out[0][0]']

 conv4_block3_1_bn (BatchNormal  (None, 14, 14, 256)  1024
['conv4_block3_1_conv[0][0]']
 ization)

 conv4_block3_1_relu (Activatio  (None, 14, 14, 256)  0
['conv4_block3_1_bn[0][0]']
 n)

 conv4_block3_2_conv (Conv2D)   (None, 14, 14, 256)  590080
['conv4_block3_1_relu[0][0]']

 conv4_block3_2_bn (BatchNormal  (None, 14, 14, 256)  1024
```

```
['conv4_block3_2_conv[0][0]']
 ization)

 conv4_block3_2_relu (Activatio  (None, 14, 14, 256)  0
['conv4_block3_2_bn[0][0]']
 n)

 conv4_block3_3_conv (Conv2D)   (None, 14, 14, 1024  263168
['conv4_block3_2_relu[0][0]']
                                )

 conv4_block3_3_bn (BatchNormal  (None, 14, 14, 1024  4096
['conv4_block3_3_conv[0][0]']
 ization)                       )

 conv4_block3_add (Add)         (None, 14, 14, 1024  0
['conv4_block2_out[0][0]',
                                )
'conv4_block3_3_bn[0][0]']

 conv4_block3_out (Activation)  (None, 14, 14, 1024  0
['conv4_block3_add[0][0]']
                                )

 conv4_block4_1_conv (Conv2D)   (None, 14, 14, 256)  262400
['conv4_block3_out[0][0]']

 conv4_block4_1_bn (BatchNormal  (None, 14, 14, 256)  1024
['conv4_block4_1_conv[0][0]']
 ization)

 conv4_block4_1_relu (Activatio  (None, 14, 14, 256)  0
['conv4_block4_1_bn[0][0]']
 n)

 conv4_block4_2_conv (Conv2D)   (None, 14, 14, 256)  590080
['conv4_block4_1_relu[0][0]']

 conv4_block4_2_bn (BatchNormal  (None, 14, 14, 256)  1024
['conv4_block4_2_conv[0][0]']
 ization)

 conv4_block4_2_relu (Activatio  (None, 14, 14, 256)  0
['conv4_block4_2_bn[0][0]']
 n)

 conv4_block4_3_conv (Conv2D)   (None, 14, 14, 1024  263168
['conv4_block4_2_relu[0][0]']
```

```
                                )

 conv4_block4_3_bn (BatchNormal  (None, 14, 14, 1024  4096
['conv4_block4_3_conv[0][0]']
 ization)                       )

 conv4_block4_add (Add)         (None, 14, 14, 1024  0
['conv4_block3_out[0][0]',
                                )
'conv4_block4_3_bn[0][0]']

 conv4_block4_out (Activation)  (None, 14, 14, 1024  0
['conv4_block4_add[0][0]']
                                )

 conv4_block5_1_conv (Conv2D)   (None, 14, 14, 256)  262400
['conv4_block4_out[0][0]']

 conv4_block5_1_bn (BatchNormal  (None, 14, 14, 256)  1024
['conv4_block5_1_conv[0][0]']
 ization)

 conv4_block5_1_relu (Activatio  (None, 14, 14, 256)  0
['conv4_block5_1_bn[0][0]']
 n)

 conv4_block5_2_conv (Conv2D)   (None, 14, 14, 256)  590080
['conv4_block5_1_relu[0][0]']

 conv4_block5_2_bn (BatchNormal  (None, 14, 14, 256)  1024
['conv4_block5_2_conv[0][0]']
 ization)

 conv4_block5_2_relu (Activatio  (None, 14, 14, 256)  0
['conv4_block5_2_bn[0][0]']
 n)

 conv4_block5_3_conv (Conv2D)   (None, 14, 14, 1024  263168
['conv4_block5_2_relu[0][0]']
                                )

 conv4_block5_3_bn (BatchNormal  (None, 14, 14, 1024  4096
['conv4_block5_3_conv[0][0]']
 ization)                       )

 conv4_block5_add (Add)         (None, 14, 14, 1024  0
['conv4_block4_out[0][0]',
                                )
```

```
'conv4_block5_3_bn[0][0]']

 conv4_block5_out (Activation)  (None, 14, 14, 1024  0
['conv4_block5_add[0][0]']
                                )

 conv4_block6_1_conv (Conv2D)   (None, 14, 14, 256)  262400
['conv4_block5_out[0][0]']

 conv4_block6_1_bn (BatchNormal  (None, 14, 14, 256)  1024
['conv4_block6_1_conv[0][0]']
 ization)

 conv4_block6_1_relu (Activatio  (None, 14, 14, 256)  0
['conv4_block6_1_bn[0][0]']
 n)

 conv4_block6_2_conv (Conv2D)   (None, 14, 14, 256)  590080
['conv4_block6_1_relu[0][0]']

 conv4_block6_2_bn (BatchNormal  (None, 14, 14, 256)  1024
['conv4_block6_2_conv[0][0]']
 ization)

 conv4_block6_2_relu (Activatio  (None, 14, 14, 256)  0
['conv4_block6_2_bn[0][0]']
 n)

 conv4_block6_3_conv (Conv2D)   (None, 14, 14, 1024  263168
['conv4_block6_2_relu[0][0]']
                                )

 conv4_block6_3_bn (BatchNormal  (None, 14, 14, 1024  4096
['conv4_block6_3_conv[0][0]']
 ization)                       )

 conv4_block6_add (Add)         (None, 14, 14, 1024  0
['conv4_block5_out[0][0]',
                                )
'conv4_block6_3_bn[0][0]']

 conv4_block6_out (Activation)  (None, 14, 14, 1024  0
['conv4_block6_add[0][0]']
                                )

 conv5_block1_1_conv (Conv2D)   (None, 7, 7, 512)    524800
['conv4_block6_out[0][0]']
```

```
 conv5_block1_1_bn (BatchNormal  (None, 7, 7, 512)   2048
['conv5_block1_1_conv[0][0]']
 ization)

 conv5_block1_1_relu (Activatio  (None, 7, 7, 512)   0
['conv5_block1_1_bn[0][0]']
 n)

 conv5_block1_2_conv (Conv2D)   (None, 7, 7, 512)    2359808
['conv5_block1_1_relu[0][0]']

 conv5_block1_2_bn (BatchNormal  (None, 7, 7, 512)   2048
['conv5_block1_2_conv[0][0]']
 ization)

 conv5_block1_2_relu (Activatio  (None, 7, 7, 512)   0
['conv5_block1_2_bn[0][0]']
 n)

 conv5_block1_0_conv (Conv2D)   (None, 7, 7, 2048)   2099200
['conv4_block6_out[0][0]']

 conv5_block1_3_conv (Conv2D)   (None, 7, 7, 2048)   1050624
['conv5_block1_2_relu[0][0]']

 conv5_block1_0_bn (BatchNormal  (None, 7, 7, 2048)  8192
['conv5_block1_0_conv[0][0]']
 ization)

 conv5_block1_3_bn (BatchNormal  (None, 7, 7, 2048)  8192
['conv5_block1_3_conv[0][0]']
 ization)

 conv5_block1_add (Add)         (None, 7, 7, 2048)   0
['conv5_block1_0_bn[0][0]',
'conv5_block1_3_bn[0][0]']

 conv5_block1_out (Activation)  (None, 7, 7, 2048)   0
['conv5_block1_add[0][0]']

 conv5_block2_1_conv (Conv2D)   (None, 7, 7, 512)    1049088
['conv5_block1_out[0][0]']

 conv5_block2_1_bn (BatchNormal  (None, 7, 7, 512)   2048
['conv5_block2_1_conv[0][0]']
 ization)

 conv5_block2_1_relu (Activatio  (None, 7, 7, 512)   0
```

```
['conv5_block2_1_bn[0][0]']
 n)

 conv5_block2_2_conv (Conv2D)   (None, 7, 7, 512)    2359808
['conv5_block2_1_relu[0][0]']

 conv5_block2_2_bn (BatchNormal  (None, 7, 7, 512)   2048
['conv5_block2_2_conv[0][0]']
 ization)

 conv5_block2_2_relu (Activatio  (None, 7, 7, 512)   0
['conv5_block2_2_bn[0][0]']
 n)

 conv5_block2_3_conv (Conv2D)   (None, 7, 7, 2048)   1050624
['conv5_block2_2_relu[0][0]']

 conv5_block2_3_bn (BatchNormal  (None, 7, 7, 2048)  8192
['conv5_block2_3_conv[0][0]']
 ization)

 conv5_block2_add (Add)         (None, 7, 7, 2048)   0
['conv5_block1_out[0][0]',
'conv5_block2_3_bn[0][0]']

 conv5_block2_out (Activation)  (None, 7, 7, 2048)   0
['conv5_block2_add[0][0]']

 conv5_block3_1_conv (Conv2D)   (None, 7, 7, 512)    1049088
['conv5_block2_out[0][0]']

 conv5_block3_1_bn (BatchNormal  (None, 7, 7, 512)   2048
['conv5_block3_1_conv[0][0]']
 ization)

 conv5_block3_1_relu (Activatio  (None, 7, 7, 512)   0
['conv5_block3_1_bn[0][0]']
 n)

 conv5_block3_2_conv (Conv2D)   (None, 7, 7, 512)    2359808
['conv5_block3_1_relu[0][0]']

 conv5_block3_2_bn (BatchNormal  (None, 7, 7, 512)   2048
['conv5_block3_2_conv[0][0]']
 ization)

 conv5_block3_2_relu (Activatio  (None, 7, 7, 512)   0
['conv5_block3_2_bn[0][0]']
```

```
 n)

 conv5_block3_3_conv (Conv2D)   (None, 7, 7, 2048)   1050624
['conv5_block3_2_relu[0][0]']

 conv5_block3_3_bn (BatchNormal  (None, 7, 7, 2048)  8192
['conv5_block3_3_conv[0][0]']
 ization)

 conv5_block3_add (Add)         (None, 7, 7, 2048)   0
['conv5_block2_out[0][0]',
'conv5_block3_3_bn[0][0]']

 conv5_block3_out (Activation)  (None, 7, 7, 2048)   0
['conv5_block3_add[0][0]']

 flatten (Flatten)              (None, 100352)       0
['conv5_block3_out[0][0]']

 dense (Dense)                  (None, 37)           3713061
['flatten[0][0]']

==================================================================================
==================
Total params: 27,300,773
Trainable params: 27,247,653
Non-trainable params: 53,120
----------------------------------------------------------------------------------
------------------
None
```

[ ]:
```python
for layer in model.layers:
    layer.trainable = True

optimizer = keras.optimizers.Adam(learning_rate=0.001, decay=5e-4)

model.compile(optimizer, loss='mse', metrics=["accuracy"])
```

[ ]:
```python
from keras.callbacks import Callback
from keras.callbacks import ModelCheckpoint, Callback, EarlyStopping


class LossHistory(Callback):
    def on_train_begin(self, logs={}):
        self.losses = []
        self.val_losses = []
```

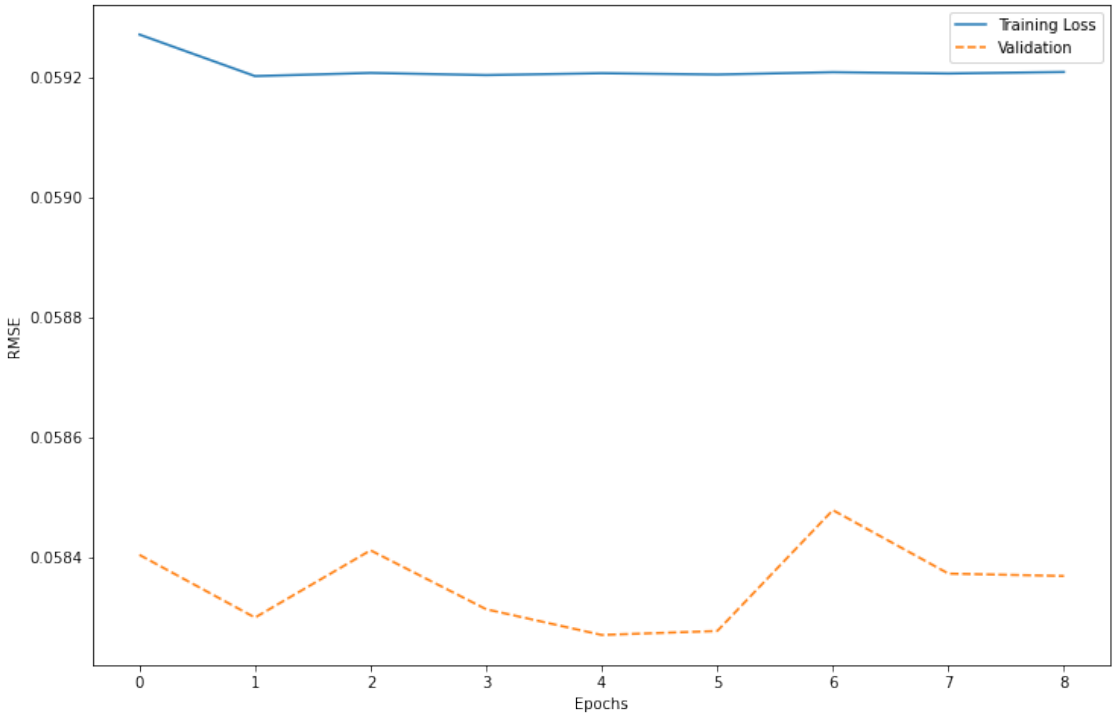
```
    def on_batch_end(self, batch, logs={}):
        self.losses.append(logs.get('loss'))
        self.val_losses.append(logs.get('val_loss'))


early_stopping = EarlyStopping(
    monitor='val_loss', patience=4, verbose=1, mode='auto')

history = LossHistory()

from keras.callbacks import ModelCheckpoint
checkpointer = ModelCheckpoint(
    filepath='../../../Data/GalaxyZoo1/weights/graynofreezeweights.hdf5',␣
 ↪verbose=2, save_best_only=True)
```

[ ]:
```
hist = model.fit(
    train_generator,
    steps_per_epoch=STEP_SIZE_TRAIN,
    validation_data=validation_generator,
    validation_steps=STEP_SIZE_VALID,
    epochs=30,
    callbacks=[history, checkpointer, early_stopping])
```

```
Epoch 1/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0593 - accuracy:
0.5953
Epoch 1: val_loss improved from inf to 0.05840, saving model to
../../../Data/GalaxyZoo1/weights\graynofreezeweights.hdf5
3771/3771 [==============================] - 3217s 848ms/step - loss: 0.0593 -
accuracy: 0.5953 - val_loss: 0.0584 - val_accuracy: 0.6308
Epoch 2/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0592 - accuracy:
0.5954
Epoch 2: val_loss improved from 0.05840 to 0.05830, saving model to
../../../Data/GalaxyZoo1/weights\graynofreezeweights.hdf5
3771/3771 [==============================] - 1753s 465ms/step - loss: 0.0592 -
accuracy: 0.5954 - val_loss: 0.0583 - val_accuracy: 0.6308
Epoch 3/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0592 - accuracy:
0.5954
Epoch 3: val_loss did not improve from 0.05830
3771/3771 [==============================] - 2291s 607ms/step - loss: 0.0592 -
accuracy: 0.5954 - val_loss: 0.0584 - val_accuracy: 0.6291
Epoch 4/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0592 - accuracy:
0.5955
Epoch 4: val_loss did not improve from 0.05830
```

```
3771/3771 [==============================] - 9070s 2s/step - loss: 0.0592 -
accuracy: 0.5955 - val_loss: 0.0583 - val_accuracy: 0.6316
Epoch 5/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0592 - accuracy:
0.5954
Epoch 5: val_loss improved from 0.05830 to 0.05827, saving model to
../../../Data/GalaxyZoo1/weights\graynofreezeweights.hdf5
3771/3771 [==============================] - 1938s 514ms/step - loss: 0.0592 -
accuracy: 0.5954 - val_loss: 0.0583 - val_accuracy: 0.6299
Epoch 6/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0592 - accuracy:
0.5954
Epoch 6: val_loss did not improve from 0.05827
3771/3771 [==============================] - 1756s 466ms/step - loss: 0.0592 -
accuracy: 0.5954 - val_loss: 0.0583 - val_accuracy: 0.6291
Epoch 7/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0592 - accuracy:
0.5954
Epoch 7: val_loss did not improve from 0.05827
3771/3771 [==============================] - 1736s 460ms/step - loss: 0.0592 -
accuracy: 0.5954 - val_loss: 0.0585 - val_accuracy: 0.6291
Epoch 8/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0592 - accuracy:
0.5954
Epoch 8: val_loss did not improve from 0.05827
3771/3771 [==============================] - 1738s 461ms/step - loss: 0.0592 -
accuracy: 0.5954 - val_loss: 0.0584 - val_accuracy: 0.6291
Epoch 9/30
3771/3771 [==============================] - ETA: 0s - loss: 0.0592 - accuracy:
0.5954
Epoch 9: val_loss did not improve from 0.05827
3771/3771 [==============================] - 1741s 462ms/step - loss: 0.0592 -
accuracy: 0.5954 - val_loss: 0.0584 - val_accuracy: 0.6291
Epoch 9: early stopping
```

[ ]:
```
plt.figure(figsize=(12, 8))
plt.plot(hist.epoch, hist.history['loss'], label='Training Loss')
plt.plot(
    hist.epoch, hist.history['val_loss'], label='Validation', linestyle='--')
plt.xlabel("Epochs")
plt.ylabel("RMSE")
plt.legend()
plt.show()
```


Training Loss
Validation
0.0592
0.0590
0.0588
0.0586
0.0584
RMSE
0
1
2
3
4
5
6
7
8
Epochs