Model

May 6, 2020

0.0.1 This notebook is the implementation of a classification model on Celeba dataset from Kaggle.

The model is built using InceptionV3.

0.1 Import Libraries

[4]:
```
import pandas as pd
import os
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
import base64
import cv2
from sklearn.metrics import f1_score

from keras.applications.inception_v3 import InceptionV3, preprocess_input
from keras import optimizers
from keras.models import Sequential, Model
from keras.layers import Dropout, Flatten, Dense, GlobalAveragePooling2D
from keras.callbacks import ModelCheckpoint
from keras.preprocessing.image import ImageDataGenerator, array_to_img,␣
 ↪img_to_array, load_img
from keras.utils import np_utils
from keras.optimizers import SGD

from IPython.core.display import display, HTML
from PIL import Image
from io import BytesIO
```

```
Using TensorFlow backend.
C:\Users\admin\anaconda3\lib\site-
packages\tensorflow\python\framework\dtypes.py:516: FutureWarning: Passing
(type, 1) or '1type' as a synonym of type is deprecated; in a future version of
numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_qint8 = np.dtype([("qint8", np.int8, 1)])
C:\Users\admin\anaconda3\lib\site-
packages\tensorflow\python\framework\dtypes.py:517: FutureWarning: Passing
(type, 1) or '1type' as a synonym of type is deprecated; in a future version of
```

```
numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_quint8 = np.dtype([("quint8", np.uint8, 1)])
C:\Users\admin\anaconda3\lib\site-
packages\tensorflow\python\framework\dtypes.py:518: FutureWarning: Passing
(type, 1) or '1type' as a synonym of type is deprecated; in a future version of
numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_qint16 = np.dtype([("qint16", np.int16, 1)])
C:\Users\admin\anaconda3\lib\site-
packages\tensorflow\python\framework\dtypes.py:519: FutureWarning: Passing
(type, 1) or '1type' as a synonym of type is deprecated; in a future version of
numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_quint16 = np.dtype([("quint16", np.uint16, 1)])
C:\Users\admin\anaconda3\lib\site-
packages\tensorflow\python\framework\dtypes.py:520: FutureWarning: Passing
(type, 1) or '1type' as a synonym of type is deprecated; in a future version of
numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_qint32 = np.dtype([("qint32", np.int32, 1)])
C:\Users\admin\anaconda3\lib\site-
packages\tensorflow\python\framework\dtypes.py:525: FutureWarning: Passing
(type, 1) or '1type' as a synonym of type is deprecated; in a future version of
numpy, it will be understood as (type, (1,)) / '(1,)type'.
  np_resource = np.dtype([("resource", np.ubyte, 1)])
C:\Users\admin\anaconda3\lib\site-
packages\tensorboard\compat\tensorflow_stub\dtypes.py:541: FutureWarning:
Passing (type, 1) or '1type' as a synonym of type is deprecated; in a future
version of numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_qint8 = np.dtype([("qint8", np.int8, 1)])
C:\Users\admin\anaconda3\lib\site-
packages\tensorboard\compat\tensorflow_stub\dtypes.py:542: FutureWarning:
Passing (type, 1) or '1type' as a synonym of type is deprecated; in a future
version of numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_quint8 = np.dtype([("quint8", np.uint8, 1)])
C:\Users\admin\anaconda3\lib\site-
packages\tensorboard\compat\tensorflow_stub\dtypes.py:543: FutureWarning:
Passing (type, 1) or '1type' as a synonym of type is deprecated; in a future
version of numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_qint16 = np.dtype([("qint16", np.int16, 1)])
C:\Users\admin\anaconda3\lib\site-
packages\tensorboard\compat\tensorflow_stub\dtypes.py:544: FutureWarning:
Passing (type, 1) or '1type' as a synonym of type is deprecated; in a future
version of numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_quint16 = np.dtype([("quint16", np.uint16, 1)])
C:\Users\admin\anaconda3\lib\site-
packages\tensorboard\compat\tensorflow_stub\dtypes.py:545: FutureWarning:
Passing (type, 1) or '1type' as a synonym of type is deprecated; in a future
version of numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_qint32 = np.dtype([("qint32", np.int32, 1)])
C:\Users\admin\anaconda3\lib\site-
```

```
packages\tensorboard\compat\tensorflow_stub\dtypes.py:550: FutureWarning:
Passing (type, 1) or '1type' as a synonym of type is deprecated; in a future
version of numpy, it will be understood as (type, (1,)) / '(1,)type'.
  np_resource = np.dtype([("resource", np.ubyte, 1)])
```

[44]:
```
%matplotlib inline
```

[5]:
```
plt.style.use("ggplot")
print(os.getcwd())
```

```
C:\Users\admin
```

0.1.1 Setting main path

[6]:
```
# setting the main project folder path
mainPath = 'C:/Users/admin/Desktop/celeba-dataset'
print(mainPath)
```

```
C:/Users/admin/Desktop/celeba-dataset
```

0.1.2 Display one image from the folder

[7]:
```
# setting the images folder path
imagesPath = mainPath + '/img_align_celeba/img_align_celeba/'
# display an example pic from the dataset
pic = imagesPath + '000001.jpg'
image = load_img(pic)
plt.grid(False)
plt.imshow(image)
```

[7]:
```
<matplotlib.image.AxesImage at 0x236ff190488>
```

0.1.3 Processing Attributes file

[8]:
```
# setting folder path to attributes excel file
attributePath = mainPath + '/list_attr_celeba.csv'
```

[9]:
```
# read attribute csv file in a data frame
attributeDf = pd.read_csv(attributePath)
attributeDf.head()
```

[9]:

	image_id	5_o_Clock_Shadow	Arched_Eyebrows	Attractive	Bags_Under_Eyes	Bald	Bangs	Big_Lips	Big_Nose	Black_Hair	…	Sideburns	Smiling	Straight_Hair	Wavy_Hair	Wearing_Earrings	Wearing_Hat	Wearing_Lipstick
0	000001.jpg	-1	1	1	-1	-1	-1	-1	-1	-1	…	-1	1	1	-1	1	-1	1
1	000002.jpg	-1	-1	-1	1	-1	-1	-1	1	-1	…	-1	1					
2	000003.jpg	-1	-1	-1	-1	-1	-1	1	-1	-1	…	-1	-1					
3	000004.jpg	-1	-1	1	-1	-1	-1	-1	-1	-1	…	-1	-1					
4	000005.jpg	-1	1	1	-1	-1	-1	1	-1	-1	…	-1	-1					

```
1             -1         -1                -1          -1                -1
2             -1          1                -1          -1                -1
3              1         -1                 1          -1                 1
4             -1         -1                -1          -1                 1

   Wearing_Necklace  Wearing_Necktie  Young
0                -1               -1      1
1                -1               -1      1
2                -1               -1      1
3                 1               -1      1
4                -1               -1      1

[5 rows x 41 columns]
```

[10]:
```
# replace -1 values with 0
attributeDf.replace(to_replace = -1, value = 0, inplace = True)

# set image_id as index
attributeDf.set_index('image_id', inplace = True)

attributeDf.head()
```

[10]:
```
            5_o_Clock_Shadow  Arched_Eyebrows  Attractive  Bags_Under_Eyes  \
image_id
000001.jpg                 0                1           1                0
000002.jpg                 0                0           0                1
000003.jpg                 0                0           0                0
000004.jpg                 0                0           1                0
000005.jpg                 0                1           1                0

            Bald  Bangs  Big_Lips  Big_Nose  Black_Hair  Blond_Hair  …  \
image_id                                                               …
000001.jpg     0      0         0         0           0           0  …
000002.jpg     0      0         0         1           0           0  …
000003.jpg     0      0         1         0           0           0  …
000004.jpg     0      0         0         0           0           0  …
000005.jpg     0      0         1         0           0           0  …

            Sideburns  Smiling  Straight_Hair  Wavy_Hair  Wearing_Earrings  \
image_id
000001.jpg          0        1              1          0                 1
000002.jpg          0        1              0          0                 0
000003.jpg          0        0              0          1                 0
000004.jpg          0        0              1          0                 1
000005.jpg          0        0              0          0                 0

            Wearing_Hat  Wearing_Lipstick  Wearing_Necklace  Wearing_Necktie  \
```

```
image_id
000001.jpg            0                1                0                0
000002.jpg            0                0                0                0
000003.jpg            0                0                0                0
000004.jpg            0                1                1                0
000005.jpg            0                1                0                0

            Young
image_id
000001.jpg      1
000002.jpg      1
000003.jpg      1
000004.jpg      1
000005.jpg      1

[5 rows x 40 columns]
```

[11]:
```
# view attributeDf column names
attributeDf.columns
```

[11]:
```
Index(['5_o_Clock_Shadow', 'Arched_Eyebrows', 'Attractive', 'Bags_Under_Eyes',
       'Bald', 'Bangs', 'Big_Lips', 'Big_Nose', 'Black_Hair', 'Blond_Hair',
       'Blurry', 'Brown_Hair', 'Bushy_Eyebrows', 'Chubby', 'Double_Chin',
       'Eyeglasses', 'Goatee', 'Gray_Hair', 'Heavy_Makeup', 'High_Cheekbones',
       'Male', 'Mouth_Slightly_Open', 'Mustache', 'Narrow_Eyes', 'No_Beard',
       'Oval_Face', 'Pale_Skin', 'Pointy_Nose', 'Receding_Hairline',
       'Rosy_Cheeks', 'Sideburns', 'Smiling', 'Straight_Hair', 'Wavy_Hair',
       'Wearing_Earrings', 'Wearing_Hat', 'Wearing_Lipstick',
       'Wearing_Necklace', 'Wearing_Necktie', 'Young'],
      dtype='object')
```

0.1.4 Processing Partition File

[12]:
```
# loading partition dataframe, differentiating between training(0),␣
↪validation(1) and test(2) images
partitionPath = mainPath + '/list_eval_partition.csv'

partitionDf = pd.read_csv(partitionPath)
partitionDf.head()
```

[12]:
```
     image_id  partition
0  000001.jpg          0
1  000002.jpg          0
2  000003.jpg          0
3  000004.jpg          0
4  000005.jpg          0
```

[13]:
```
# display count of distinct partition values
partitionDf['partition'].value_counts().sort_index()
```

[13]:
```
0    162770
1     19867
2     19962
Name: partition, dtype: int64
```

[14]:
```
# join partitionDf and smiling column of attributeDf based on imageid
partitionDf.set_index('image_id', inplace=True)
newPartition = partitionDf.join(attributeDf['Smiling'], how='inner')
newPartition.head()
```

[14]:

image_id	partition	Smiling
000001.jpg	0	1
000002.jpg	0	1
000003.jpg	0	0
000004.jpg	0	0
000005.jpg	0	0

0.1.5 Pre- processing images

[15]:
```
# convert image into array
def load_reshape_img(fname):
    img = load_img(fname)
    x = img_to_array(img)/255.
    x = x.reshape((1,) + x.shape)

    return x

# get training, test and validation set
def getPartition(partition,df,number):
    name = pd.DataFrame()
    name = df[df['partition'] == partition].sample(n = number)
    return name
```

[16]:
```
# training set consists of 15000 images
# validation set consists of 7500 images
# test set consists of 9000
# there is no overlap between any of the sets
trainSet = getPartition(0,newPartition,15000)
validationSet = getPartition(1, newPartition, 7500)
testSet = getPartition(2, newPartition,9000)
```

Value counts to see class balancing in train, test and validation set

[20]:
```
trainSet['Smiling'].value_counts()
```

[20]:
```
0    7764
1    7236
Name: Smiling, dtype: int64
```

[21]:
```
validationSet['Smiling'].value_counts()
```

[21]:
```
0    3975
1    3525
Name: Smiling, dtype: int64
```

[22]:
```
testSet['Smiling'].value_counts()
```

[22]:
```
0    4680
1    4320
Name: Smiling, dtype: int64
```

Functions to extract feature label for images i.e. pixel value for each image

[17]:
```
def featureLabel(df,attr):
    x = []
    y = []
    x = np.array([load_reshape_img(imagesPath + fname) for fname in df.index])
    x = x.reshape(x.shape[0], 218, 178, 3)
    y = np_utils.to_categorical(df[attr],2)
    return x,y

def featureLabelTest(df,attr):
    x = []
    y = []
    for index, target in df.iterrows():
        im = cv2.imread(imagesPath + index)
        im = cv2.resize(cv2.cvtColor(im, cv2.COLOR_BGR2RGB), (178, 218)).
 ↪astype(np.float32) / 255.0
        im = np.expand_dims(im, axis =0)
        x.append(im)
        y.append(target[attr])
    return x, y
```

[18]:
```
x_validation,y_validation = featureLabel(validationSet,'Smiling')
```

[23]:
```
x_train,y_train = featureLabel(trainSet,'Smiling')
```

[19]:
```
x_test,y_test = featureLabelTest(testSet,'Smiling')
```

Data augmentation on training, validation set

Augmenting train data

[24]:
```
train_dataaugment = ImageDataGenerator(
    preprocessing_function = preprocess_input,
    rotation_range=45,
    width_shift_range=0.2,
    height_shift_range=0.2,
    shear_range=0.2,
    zoom_range=0.2,
    horizontal_flip=True)
```

[25]:
```
train_dataaugment.fit(x_train)
```

[26]:
```
train_generator = train_dataaugment.flow(x_train,y_train,batch_size=32)
```

Augmenting validation data

[27]:
```
validation_augment = ImageDataGenerator(
    preprocessing_function = preprocess_input)
```

[28]:
```
validation_augment.fit(x_validation)
```

[29]:
```
validation_generator = validation_augment.
↪flow(x_validation,y_validation,batch_size=32)
```

0.1.6 Training the model

Using pre- trained InceptionV3 model. This model has been trained on imagenet dataset

[32]:
```
model = InceptionV3(weights = 'C:/Users/admin/Desktop/celeba-dataset/
↪inception_v3_weights_tf_dim_ordering_tf_kernels_notop.h5',
                    include_top = False,
                    input_shape = (218,178,3))
```

```
WARNING:tensorflow:From C:\Users\admin\anaconda3\lib\site-
packages\keras\backend\tensorflow_backend.py:4070: The name tf.nn.max_pool is
deprecated. Please use tf.nn.max_pool2d instead.

WARNING:tensorflow:From C:\Users\admin\anaconda3\lib\site-
packages\keras\backend\tensorflow_backend.py:4074: The name tf.nn.avg_pool is
deprecated. Please use tf.nn.avg_pool2d instead.
```

[33]:
```
model.summary()
```

```
Model: "inception_v3"
__________________________________________________________________________________
_________________
```

```
Layer (type)                 Output Shape              Param #     Connected to
==================================================================================
==================
input_1 (InputLayer)         (None, 218, 178, 3)       0
----------------------------------------------------------------------------------
------------------
conv2d_1 (Conv2D)            (None, 108, 88, 32)       864         input_1[0][0]
----------------------------------------------------------------------------------
------------------
batch_normalization_1 (BatchNor (None, 108, 88, 32)    96          conv2d_1[0][0]
----------------------------------------------------------------------------------
------------------
activation_1 (Activation)    (None, 108, 88, 32)       0
batch_normalization_1[0][0]
----------------------------------------------------------------------------------
------------------
conv2d_2 (Conv2D)            (None, 106, 86, 32)       9216
activation_1[0][0]
----------------------------------------------------------------------------------
------------------
batch_normalization_2 (BatchNor (None, 106, 86, 32)    96          conv2d_2[0][0]
----------------------------------------------------------------------------------
------------------
activation_2 (Activation)    (None, 106, 86, 32)       0
batch_normalization_2[0][0]
----------------------------------------------------------------------------------
------------------
conv2d_3 (Conv2D)            (None, 106, 86, 64)       18432
activation_2[0][0]
----------------------------------------------------------------------------------
------------------
batch_normalization_3 (BatchNor (None, 106, 86, 64)    192         conv2d_3[0][0]
----------------------------------------------------------------------------------
------------------
activation_3 (Activation)    (None, 106, 86, 64)       0
batch_normalization_3[0][0]
----------------------------------------------------------------------------------
------------------
max_pooling2d_1 (MaxPooling2D)  (None, 52, 42, 64)     0
activation_3[0][0]
----------------------------------------------------------------------------------
------------------
conv2d_4 (Conv2D)            (None, 52, 42, 80)        5120
max_pooling2d_1[0][0]
----------------------------------------------------------------------------------
------------------
batch_normalization_4 (BatchNor (None, 52, 42, 80)     240         conv2d_4[0][0]
----------------------------------------------------------------------------------
```

```
__________________
activation_4 (Activation)       (None, 52, 42, 80)   0
batch_normalization_4[0][0]
__________________________________________________________________________________
__________________
conv2d_5 (Conv2D)               (None, 50, 40, 192)  138240
activation_4[0][0]
__________________________________________________________________________________
__________________
batch_normalization_5 (BatchNor (None, 50, 40, 192)  576         conv2d_5[0][0]
__________________________________________________________________________________
__________________
activation_5 (Activation)       (None, 50, 40, 192)  0
batch_normalization_5[0][0]
__________________________________________________________________________________
__________________
max_pooling2d_2 (MaxPooling2D)  (None, 24, 19, 192)  0
activation_5[0][0]
__________________________________________________________________________________
__________________
conv2d_9 (Conv2D)               (None, 24, 19, 64)   12288
max_pooling2d_2[0][0]
__________________________________________________________________________________
__________________
batch_normalization_9 (BatchNor (None, 24, 19, 64)   192         conv2d_9[0][0]
__________________________________________________________________________________
__________________
activation_9 (Activation)       (None, 24, 19, 64)   0
batch_normalization_9[0][0]
__________________________________________________________________________________
__________________
conv2d_7 (Conv2D)               (None, 24, 19, 48)   9216
max_pooling2d_2[0][0]
__________________________________________________________________________________
__________________
conv2d_10 (Conv2D)              (None, 24, 19, 96)   55296
activation_9[0][0]
__________________________________________________________________________________
__________________
batch_normalization_7 (BatchNor (None, 24, 19, 48)   144         conv2d_7[0][0]
__________________________________________________________________________________
__________________
batch_normalization_10 (BatchNo (None, 24, 19, 96)   288         conv2d_10[0][0]
__________________________________________________________________________________
__________________
activation_7 (Activation)       (None, 24, 19, 48)   0
batch_normalization_7[0][0]
__________________________________________________________________________________
```

```
__________________
activation_10 (Activation)      (None, 24, 19, 96)   0
batch_normalization_10[0][0]

____________________________________________________________________________
__________________
average_pooling2d_1 (AveragePoo (None, 24, 19, 192)  0
max_pooling2d_2[0][0]

____________________________________________________________________________
__________________
conv2d_6 (Conv2D)               (None, 24, 19, 64)   12288
max_pooling2d_2[0][0]

____________________________________________________________________________
__________________
conv2d_8 (Conv2D)               (None, 24, 19, 64)   76800
activation_7[0][0]

____________________________________________________________________________
__________________
conv2d_11 (Conv2D)              (None, 24, 19, 96)   82944
activation_10[0][0]

____________________________________________________________________________
__________________
conv2d_12 (Conv2D)              (None, 24, 19, 32)   6144
average_pooling2d_1[0][0]

____________________________________________________________________________
__________________
batch_normalization_6 (BatchNor (None, 24, 19, 64)   192         conv2d_6[0][0]

____________________________________________________________________________
__________________
batch_normalization_8 (BatchNor (None, 24, 19, 64)   192         conv2d_8[0][0]

____________________________________________________________________________
__________________
batch_normalization_11 (BatchNo (None, 24, 19, 96)   288         conv2d_11[0][0]

____________________________________________________________________________
__________________
batch_normalization_12 (BatchNo (None, 24, 19, 32)   96          conv2d_12[0][0]

____________________________________________________________________________
__________________
activation_6 (Activation)       (None, 24, 19, 64)   0
batch_normalization_6[0][0]

____________________________________________________________________________
__________________
activation_8 (Activation)       (None, 24, 19, 64)   0
batch_normalization_8[0][0]

____________________________________________________________________________
__________________
activation_11 (Activation)      (None, 24, 19, 96)   0
batch_normalization_11[0][0]

____________________________________________________________________________
```

```
__________________
activation_12 (Activation)      (None, 24, 19, 32)   0
batch_normalization_12[0][0]

__________________________________________________________________________________
__________________
mixed0 (Concatenate)            (None, 24, 19, 256)  0
activation_6[0][0]
activation_8[0][0]
activation_11[0][0]
activation_12[0][0]

__________________________________________________________________________________
__________________
conv2d_16 (Conv2D)              (None, 24, 19, 64)   16384       mixed0[0][0]

__________________________________________________________________________________
__________________
batch_normalization_16 (BatchNo (None, 24, 19, 64)   192         conv2d_16[0][0]

__________________________________________________________________________________
__________________
activation_16 (Activation)      (None, 24, 19, 64)   0
batch_normalization_16[0][0]

__________________________________________________________________________________
__________________
conv2d_14 (Conv2D)              (None, 24, 19, 48)   12288       mixed0[0][0]

__________________________________________________________________________________
__________________
conv2d_17 (Conv2D)              (None, 24, 19, 96)   55296
activation_16[0][0]

__________________________________________________________________________________
__________________
batch_normalization_14 (BatchNo (None, 24, 19, 48)   144         conv2d_14[0][0]

__________________________________________________________________________________
__________________
batch_normalization_17 (BatchNo (None, 24, 19, 96)   288         conv2d_17[0][0]

__________________________________________________________________________________
__________________
activation_14 (Activation)      (None, 24, 19, 48)   0
batch_normalization_14[0][0]

__________________________________________________________________________________
__________________
activation_17 (Activation)      (None, 24, 19, 96)   0
batch_normalization_17[0][0]

__________________________________________________________________________________
__________________
average_pooling2d_2 (AveragePoo (None, 24, 19, 256)  0           mixed0[0][0]

__________________________________________________________________________________
__________________
conv2d_13 (Conv2D)              (None, 24, 19, 64)   16384       mixed0[0][0]

__________________________________________________________________________________
```

```
__________________
conv2d_15 (Conv2D)              (None, 24, 19, 64)   76800
activation_14[0][0]
__________________________________________________________________________________
__________________
conv2d_18 (Conv2D)              (None, 24, 19, 96)   82944
activation_17[0][0]
__________________________________________________________________________________
__________________
conv2d_19 (Conv2D)              (None, 24, 19, 64)   16384
average_pooling2d_2[0][0]
__________________________________________________________________________________
__________________
batch_normalization_13 (BatchNo (None, 24, 19, 64)   192         conv2d_13[0][0]
__________________________________________________________________________________
__________________
batch_normalization_15 (BatchNo (None, 24, 19, 64)   192         conv2d_15[0][0]
__________________________________________________________________________________
__________________
batch_normalization_18 (BatchNo (None, 24, 19, 96)   288         conv2d_18[0][0]
__________________________________________________________________________________
__________________
batch_normalization_19 (BatchNo (None, 24, 19, 64)   192         conv2d_19[0][0]
__________________________________________________________________________________
__________________
activation_13 (Activation)      (None, 24, 19, 64)   0
batch_normalization_13[0][0]
__________________________________________________________________________________
__________________
activation_15 (Activation)      (None, 24, 19, 64)   0
batch_normalization_15[0][0]
__________________________________________________________________________________
__________________
activation_18 (Activation)      (None, 24, 19, 96)   0
batch_normalization_18[0][0]
__________________________________________________________________________________
__________________
activation_19 (Activation)      (None, 24, 19, 64)   0
batch_normalization_19[0][0]
__________________________________________________________________________________
__________________
mixed1 (Concatenate)            (None, 24, 19, 288)  0
activation_13[0][0]
activation_15[0][0]
activation_18[0][0]
activation_19[0][0]
__________________________________________________________________________________
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conv2d_23 (Conv2D)              (None, 24, 19, 64)   18432       mixed1[0][0]
__________________________________________________________________________________________________
batch_normalization_23 (BatchNo (None, 24, 19, 64)   192         conv2d_23[0][0]
__________________________________________________________________________________________________
activation_23 (Activation)      (None, 24, 19, 64)   0
batch_normalization_23[0][0]
__________________________________________________________________________________________________
conv2d_21 (Conv2D)              (None, 24, 19, 48)   13824       mixed1[0][0]
__________________________________________________________________________________________________
conv2d_24 (Conv2D)              (None, 24, 19, 96)   55296
activation_23[0][0]
__________________________________________________________________________________________________
batch_normalization_21 (BatchNo (None, 24, 19, 48)   144         conv2d_21[0][0]
__________________________________________________________________________________________________
batch_normalization_24 (BatchNo (None, 24, 19, 96)   288         conv2d_24[0][0]
__________________________________________________________________________________________________
activation_21 (Activation)      (None, 24, 19, 48)   0
batch_normalization_21[0][0]
__________________________________________________________________________________________________
activation_24 (Activation)      (None, 24, 19, 96)   0
batch_normalization_24[0][0]
__________________________________________________________________________________________________
average_pooling2d_3 (AveragePoo (None, 24, 19, 288)  0           mixed1[0][0]
__________________________________________________________________________________________________
conv2d_20 (Conv2D)              (None, 24, 19, 64)   18432       mixed1[0][0]
__________________________________________________________________________________________________
conv2d_22 (Conv2D)              (None, 24, 19, 64)   76800
activation_21[0][0]
__________________________________________________________________________________________________
conv2d_25 (Conv2D)              (None, 24, 19, 96)   82944
activation_24[0][0]
__________________________________________________________________________________________________
conv2d_26 (Conv2D)              (None, 24, 19, 64)   18432
average_pooling2d_3[0][0]
__________________________________________________________________________________________________
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__________________
batch_normalization_20 (BatchNo (None, 24, 19, 64)   192         conv2d_20[0][0]
_____________________________________________________________________________
__________________
batch_normalization_22 (BatchNo (None, 24, 19, 64)   192         conv2d_22[0][0]
_____________________________________________________________________________
__________________
batch_normalization_25 (BatchNo (None, 24, 19, 96)   288         conv2d_25[0][0]
_____________________________________________________________________________
__________________
batch_normalization_26 (BatchNo (None, 24, 19, 64)   192         conv2d_26[0][0]
_____________________________________________________________________________
__________________
activation_20 (Activation)      (None, 24, 19, 64)   0
batch_normalization_20[0][0]
_____________________________________________________________________________
__________________
activation_22 (Activation)      (None, 24, 19, 64)   0
batch_normalization_22[0][0]
_____________________________________________________________________________
__________________
activation_25 (Activation)      (None, 24, 19, 96)   0
batch_normalization_25[0][0]
_____________________________________________________________________________
__________________
activation_26 (Activation)      (None, 24, 19, 64)   0
batch_normalization_26[0][0]
_____________________________________________________________________________
__________________
mixed2 (Concatenate)            (None, 24, 19, 288)  0
activation_20[0][0]
activation_22[0][0]
activation_25[0][0]
activation_26[0][0]
_____________________________________________________________________________
__________________
conv2d_28 (Conv2D)              (None, 24, 19, 64)   18432       mixed2[0][0]
_____________________________________________________________________________
__________________
batch_normalization_28 (BatchNo (None, 24, 19, 64)   192         conv2d_28[0][0]
_____________________________________________________________________________
__________________
activation_28 (Activation)      (None, 24, 19, 64)   0
batch_normalization_28[0][0]
_____________________________________________________________________________
__________________
conv2d_29 (Conv2D)              (None, 24, 19, 96)   55296
activation_28[0][0]
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__________________________________________________________________________________
__________________
batch_normalization_29 (BatchNo (None, 24, 19, 96)   288         conv2d_29[0][0]
__________________________________________________________________________________
__________________
activation_29 (Activation)      (None, 24, 19, 96)   0
batch_normalization_29[0][0]
__________________________________________________________________________________
__________________
conv2d_27 (Conv2D)              (None, 11, 9, 384)   995328      mixed2[0][0]
__________________________________________________________________________________
__________________
conv2d_30 (Conv2D)              (None, 11, 9, 96)    82944
activation_29[0][0]
__________________________________________________________________________________
__________________
batch_normalization_27 (BatchNo (None, 11, 9, 384)   1152        conv2d_27[0][0]
__________________________________________________________________________________
__________________
batch_normalization_30 (BatchNo (None, 11, 9, 96)    288         conv2d_30[0][0]
__________________________________________________________________________________
__________________
activation_27 (Activation)      (None, 11, 9, 384)   0
batch_normalization_27[0][0]
__________________________________________________________________________________
__________________
activation_30 (Activation)      (None, 11, 9, 96)    0
batch_normalization_30[0][0]
__________________________________________________________________________________
__________________
max_pooling2d_3 (MaxPooling2D)  (None, 11, 9, 288)   0           mixed2[0][0]
__________________________________________________________________________________
__________________
mixed3 (Concatenate)            (None, 11, 9, 768)   0
activation_27[0][0]
activation_30[0][0]
max_pooling2d_3[0][0]
__________________________________________________________________________________
__________________
conv2d_35 (Conv2D)              (None, 11, 9, 128)   98304       mixed3[0][0]
__________________________________________________________________________________
__________________
batch_normalization_35 (BatchNo (None, 11, 9, 128)   384         conv2d_35[0][0]
__________________________________________________________________________________
__________________
activation_35 (Activation)      (None, 11, 9, 128)   0
batch_normalization_35[0][0]
__________________________________________________________________________________
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__________________
conv2d_36 (Conv2D)              (None, 11, 9, 128)   114688
activation_35[0][0]
__________________________________________________________________________________
__________________
batch_normalization_36 (BatchNo (None, 11, 9, 128)   384         conv2d_36[0][0]
__________________________________________________________________________________
__________________
activation_36 (Activation)      (None, 11, 9, 128)   0
batch_normalization_36[0][0]
__________________________________________________________________________________
__________________
conv2d_32 (Conv2D)              (None, 11, 9, 128)   98304       mixed3[0][0]
__________________________________________________________________________________
__________________
conv2d_37 (Conv2D)              (None, 11, 9, 128)   114688
activation_36[0][0]
__________________________________________________________________________________
__________________
batch_normalization_32 (BatchNo (None, 11, 9, 128)   384         conv2d_32[0][0]
__________________________________________________________________________________
__________________
batch_normalization_37 (BatchNo (None, 11, 9, 128)   384         conv2d_37[0][0]
__________________________________________________________________________________
__________________
activation_32 (Activation)      (None, 11, 9, 128)   0
batch_normalization_32[0][0]
__________________________________________________________________________________
__________________
activation_37 (Activation)      (None, 11, 9, 128)   0
batch_normalization_37[0][0]
__________________________________________________________________________________
__________________
conv2d_33 (Conv2D)              (None, 11, 9, 128)   114688
activation_32[0][0]
__________________________________________________________________________________
__________________
conv2d_38 (Conv2D)              (None, 11, 9, 128)   114688
activation_37[0][0]
__________________________________________________________________________________
__________________
batch_normalization_33 (BatchNo (None, 11, 9, 128)   384         conv2d_33[0][0]
__________________________________________________________________________________
__________________
batch_normalization_38 (BatchNo (None, 11, 9, 128)   384         conv2d_38[0][0]
__________________________________________________________________________________
__________________
activation_33 (Activation)      (None, 11, 9, 128)   0
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batch_normalization_33[0][0]
__________________________________________________________________________________________________
activation_38 (Activation)      (None, 11, 9, 128)   0
batch_normalization_38[0][0]
__________________________________________________________________________________________________
average_pooling2d_4 (AveragePoo (None, 11, 9, 768)   0           mixed3[0][0]
__________________________________________________________________________________________________
conv2d_31 (Conv2D)              (None, 11, 9, 192)   147456      mixed3[0][0]
__________________________________________________________________________________________________
conv2d_34 (Conv2D)              (None, 11, 9, 192)   172032
activation_33[0][0]
__________________________________________________________________________________________________
conv2d_39 (Conv2D)              (None, 11, 9, 192)   172032
activation_38[0][0]
__________________________________________________________________________________________________
conv2d_40 (Conv2D)              (None, 11, 9, 192)   147456
average_pooling2d_4[0][0]
__________________________________________________________________________________________________
batch_normalization_31 (BatchNo (None, 11, 9, 192)   576         conv2d_31[0][0]
__________________________________________________________________________________________________
batch_normalization_34 (BatchNo (None, 11, 9, 192)   576         conv2d_34[0][0]
__________________________________________________________________________________________________
batch_normalization_39 (BatchNo (None, 11, 9, 192)   576         conv2d_39[0][0]
__________________________________________________________________________________________________
batch_normalization_40 (BatchNo (None, 11, 9, 192)   576         conv2d_40[0][0]
__________________________________________________________________________________________________
activation_31 (Activation)      (None, 11, 9, 192)   0
batch_normalization_31[0][0]
__________________________________________________________________________________________________
activation_34 (Activation)      (None, 11, 9, 192)   0
batch_normalization_34[0][0]
__________________________________________________________________________________________________
activation_39 (Activation)      (None, 11, 9, 192)   0
batch_normalization_39[0][0]
__________________________________________________________________________________________________
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__________________
activation_40 (Activation)      (None, 11, 9, 192)   0
batch_normalization_40[0][0]

__________________________________________________________________________________
__________________
mixed4 (Concatenate)            (None, 11, 9, 768)   0
activation_31[0][0]
activation_34[0][0]
activation_39[0][0]
activation_40[0][0]

__________________________________________________________________________________
__________________
conv2d_45 (Conv2D)              (None, 11, 9, 160)   122880      mixed4[0][0]

__________________________________________________________________________________
__________________
batch_normalization_45 (BatchNo (None, 11, 9, 160)   480         conv2d_45[0][0]

__________________________________________________________________________________
__________________
activation_45 (Activation)      (None, 11, 9, 160)   0
batch_normalization_45[0][0]

__________________________________________________________________________________
__________________
conv2d_46 (Conv2D)              (None, 11, 9, 160)   179200
activation_45[0][0]

__________________________________________________________________________________
__________________
batch_normalization_46 (BatchNo (None, 11, 9, 160)   480         conv2d_46[0][0]

__________________________________________________________________________________
__________________
activation_46 (Activation)      (None, 11, 9, 160)   0
batch_normalization_46[0][0]

__________________________________________________________________________________
__________________
conv2d_42 (Conv2D)              (None, 11, 9, 160)   122880      mixed4[0][0]

__________________________________________________________________________________
__________________
conv2d_47 (Conv2D)              (None, 11, 9, 160)   179200
activation_46[0][0]

__________________________________________________________________________________
__________________
batch_normalization_42 (BatchNo (None, 11, 9, 160)   480         conv2d_42[0][0]

__________________________________________________________________________________
__________________
batch_normalization_47 (BatchNo (None, 11, 9, 160)   480         conv2d_47[0][0]

__________________________________________________________________________________
__________________
activation_42 (Activation)      (None, 11, 9, 160)   0
batch_normalization_42[0][0]
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__________________________________________________________________________________
__________________
activation_47 (Activation)      (None, 11, 9, 160)   0
batch_normalization_47[0][0]
__________________________________________________________________________________
__________________
conv2d_43 (Conv2D)              (None, 11, 9, 160)   179200
activation_42[0][0]
__________________________________________________________________________________
__________________
conv2d_48 (Conv2D)              (None, 11, 9, 160)   179200
activation_47[0][0]
__________________________________________________________________________________
__________________
batch_normalization_43 (BatchNo (None, 11, 9, 160)   480         conv2d_43[0][0]
__________________________________________________________________________________
__________________
batch_normalization_48 (BatchNo (None, 11, 9, 160)   480         conv2d_48[0][0]
__________________________________________________________________________________
__________________
activation_43 (Activation)      (None, 11, 9, 160)   0
batch_normalization_43[0][0]
__________________________________________________________________________________
__________________
activation_48 (Activation)      (None, 11, 9, 160)   0
batch_normalization_48[0][0]
__________________________________________________________________________________
__________________
average_pooling2d_5 (AveragePoo (None, 11, 9, 768)   0           mixed4[0][0]
__________________________________________________________________________________
__________________
conv2d_41 (Conv2D)              (None, 11, 9, 192)   147456      mixed4[0][0]
__________________________________________________________________________________
__________________
conv2d_44 (Conv2D)              (None, 11, 9, 192)   215040
activation_43[0][0]
__________________________________________________________________________________
__________________
conv2d_49 (Conv2D)              (None, 11, 9, 192)   215040
activation_48[0][0]
__________________________________________________________________________________
__________________
conv2d_50 (Conv2D)              (None, 11, 9, 192)   147456
average_pooling2d_5[0][0]
__________________________________________________________________________________
__________________
batch_normalization_41 (BatchNo (None, 11, 9, 192)   576         conv2d_41[0][0]
__________________________________________________________________________________
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batch_normalization_44 (BatchNo (None, 11, 9, 192)   576         conv2d_44[0][0]
------------------------------------------------------------------------------
------------------
batch_normalization_49 (BatchNo (None, 11, 9, 192)   576         conv2d_49[0][0]
------------------------------------------------------------------------------
------------------
batch_normalization_50 (BatchNo (None, 11, 9, 192)   576         conv2d_50[0][0]
------------------------------------------------------------------------------
------------------
activation_41 (Activation)      (None, 11, 9, 192)   0
batch_normalization_41[0][0]
------------------------------------------------------------------------------
------------------
activation_44 (Activation)      (None, 11, 9, 192)   0
batch_normalization_44[0][0]
------------------------------------------------------------------------------
------------------
activation_49 (Activation)      (None, 11, 9, 192)   0
batch_normalization_49[0][0]
------------------------------------------------------------------------------
------------------
activation_50 (Activation)      (None, 11, 9, 192)   0
batch_normalization_50[0][0]
------------------------------------------------------------------------------
------------------
mixed5 (Concatenate)            (None, 11, 9, 768)   0
activation_41[0][0]
activation_44[0][0]
activation_49[0][0]
activation_50[0][0]
------------------------------------------------------------------------------
------------------
conv2d_55 (Conv2D)              (None, 11, 9, 160)   122880      mixed5[0][0]
------------------------------------------------------------------------------
------------------
batch_normalization_55 (BatchNo (None, 11, 9, 160)   480         conv2d_55[0][0]
------------------------------------------------------------------------------
------------------
activation_55 (Activation)      (None, 11, 9, 160)   0
batch_normalization_55[0][0]
------------------------------------------------------------------------------
------------------
conv2d_56 (Conv2D)              (None, 11, 9, 160)   179200
activation_55[0][0]
------------------------------------------------------------------------------
------------------
batch_normalization_56 (BatchNo (None, 11, 9, 160)   480         conv2d_56[0][0]
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__________________________________________________________________________________
__________________
activation_56 (Activation)      (None, 11, 9, 160)   0
batch_normalization_56[0][0]
__________________________________________________________________________________
__________________
conv2d_52 (Conv2D)              (None, 11, 9, 160)   122880      mixed5[0][0]
__________________________________________________________________________________
__________________
conv2d_57 (Conv2D)              (None, 11, 9, 160)   179200
activation_56[0][0]
__________________________________________________________________________________
__________________
batch_normalization_52 (BatchNo (None, 11, 9, 160)   480         conv2d_52[0][0]
__________________________________________________________________________________
__________________
batch_normalization_57 (BatchNo (None, 11, 9, 160)   480         conv2d_57[0][0]
__________________________________________________________________________________
__________________
activation_52 (Activation)      (None, 11, 9, 160)   0
batch_normalization_52[0][0]
__________________________________________________________________________________
__________________
activation_57 (Activation)      (None, 11, 9, 160)   0
batch_normalization_57[0][0]
__________________________________________________________________________________
__________________
conv2d_53 (Conv2D)              (None, 11, 9, 160)   179200
activation_52[0][0]
__________________________________________________________________________________
__________________
conv2d_58 (Conv2D)              (None, 11, 9, 160)   179200
activation_57[0][0]
__________________________________________________________________________________
__________________
batch_normalization_53 (BatchNo (None, 11, 9, 160)   480         conv2d_53[0][0]
__________________________________________________________________________________
__________________
batch_normalization_58 (BatchNo (None, 11, 9, 160)   480         conv2d_58[0][0]
__________________________________________________________________________________
__________________
activation_53 (Activation)      (None, 11, 9, 160)   0
batch_normalization_53[0][0]
__________________________________________________________________________________
__________________
activation_58 (Activation)      (None, 11, 9, 160)   0
batch_normalization_58[0][0]
__________________________________________________________________________________
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__________________
average_pooling2d_6 (AveragePoo (None, 11, 9, 768)   0           mixed5[0][0]
__________________________________________________________________________________
__________________
conv2d_51 (Conv2D)              (None, 11, 9, 192)   147456      mixed5[0][0]
__________________________________________________________________________________
__________________
conv2d_54 (Conv2D)              (None, 11, 9, 192)   215040
activation_53[0][0]
__________________________________________________________________________________
__________________
conv2d_59 (Conv2D)              (None, 11, 9, 192)   215040
activation_58[0][0]
__________________________________________________________________________________
__________________
conv2d_60 (Conv2D)              (None, 11, 9, 192)   147456
average_pooling2d_6[0][0]
__________________________________________________________________________________
__________________
batch_normalization_51 (BatchNo (None, 11, 9, 192)   576         conv2d_51[0][0]
__________________________________________________________________________________
__________________
batch_normalization_54 (BatchNo (None, 11, 9, 192)   576         conv2d_54[0][0]
__________________________________________________________________________________
__________________
batch_normalization_59 (BatchNo (None, 11, 9, 192)   576         conv2d_59[0][0]
__________________________________________________________________________________
__________________
batch_normalization_60 (BatchNo (None, 11, 9, 192)   576         conv2d_60[0][0]
__________________________________________________________________________________
__________________
activation_51 (Activation)      (None, 11, 9, 192)   0
batch_normalization_51[0][0]
__________________________________________________________________________________
__________________
activation_54 (Activation)      (None, 11, 9, 192)   0
batch_normalization_54[0][0]
__________________________________________________________________________________
__________________
activation_59 (Activation)      (None, 11, 9, 192)   0
batch_normalization_59[0][0]
__________________________________________________________________________________
__________________
activation_60 (Activation)      (None, 11, 9, 192)   0
batch_normalization_60[0][0]
__________________________________________________________________________________
__________________
mixed6 (Concatenate)            (None, 11, 9, 768)   0
```

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activation_51[0][0]
activation_54[0][0]
activation_59[0][0]
activation_60[0][0]
__________________________________________________________________________________
__________________
conv2d_65 (Conv2D)              (None, 11, 9, 192)   147456      mixed6[0][0]
__________________________________________________________________________________
__________________
batch_normalization_65 (BatchNo (None, 11, 9, 192)   576         conv2d_65[0][0]
__________________________________________________________________________________
__________________
activation_65 (Activation)      (None, 11, 9, 192)   0
batch_normalization_65[0][0]
__________________________________________________________________________________
__________________
conv2d_66 (Conv2D)              (None, 11, 9, 192)   258048
activation_65[0][0]
__________________________________________________________________________________
__________________
batch_normalization_66 (BatchNo (None, 11, 9, 192)   576         conv2d_66[0][0]
__________________________________________________________________________________
__________________
activation_66 (Activation)      (None, 11, 9, 192)   0
batch_normalization_66[0][0]
__________________________________________________________________________________
__________________
conv2d_62 (Conv2D)              (None, 11, 9, 192)   147456      mixed6[0][0]
__________________________________________________________________________________
__________________
conv2d_67 (Conv2D)              (None, 11, 9, 192)   258048
activation_66[0][0]
__________________________________________________________________________________
__________________
batch_normalization_62 (BatchNo (None, 11, 9, 192)   576         conv2d_62[0][0]
__________________________________________________________________________________
__________________
batch_normalization_67 (BatchNo (None, 11, 9, 192)   576         conv2d_67[0][0]
__________________________________________________________________________________
__________________
activation_62 (Activation)      (None, 11, 9, 192)   0
batch_normalization_62[0][0]
__________________________________________________________________________________
__________________
activation_67 (Activation)      (None, 11, 9, 192)   0
batch_normalization_67[0][0]
__________________________________________________________________________________
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conv2d_63 (Conv2D)              (None, 11, 9, 192)   258048
activation_62[0][0]
__________________________________________________________________________________
__________________
conv2d_68 (Conv2D)              (None, 11, 9, 192)   258048
activation_67[0][0]
__________________________________________________________________________________
__________________
batch_normalization_63 (BatchNo (None, 11, 9, 192)   576         conv2d_63[0][0]
__________________________________________________________________________________
__________________
batch_normalization_68 (BatchNo (None, 11, 9, 192)   576         conv2d_68[0][0]
__________________________________________________________________________________
__________________
activation_63 (Activation)      (None, 11, 9, 192)   0
batch_normalization_63[0][0]
__________________________________________________________________________________
__________________
activation_68 (Activation)      (None, 11, 9, 192)   0
batch_normalization_68[0][0]
__________________________________________________________________________________
__________________
average_pooling2d_7 (AveragePoo (None, 11, 9, 768)   0           mixed6[0][0]
__________________________________________________________________________________
__________________
conv2d_61 (Conv2D)              (None, 11, 9, 192)   147456      mixed6[0][0]
__________________________________________________________________________________
__________________
conv2d_64 (Conv2D)              (None, 11, 9, 192)   258048
activation_63[0][0]
__________________________________________________________________________________
__________________
conv2d_69 (Conv2D)              (None, 11, 9, 192)   258048
activation_68[0][0]
__________________________________________________________________________________
__________________
conv2d_70 (Conv2D)              (None, 11, 9, 192)   147456
average_pooling2d_7[0][0]
__________________________________________________________________________________
__________________
batch_normalization_61 (BatchNo (None, 11, 9, 192)   576         conv2d_61[0][0]
__________________________________________________________________________________
__________________
batch_normalization_64 (BatchNo (None, 11, 9, 192)   576         conv2d_64[0][0]
__________________________________________________________________________________
__________________
batch_normalization_69 (BatchNo (None, 11, 9, 192)   576         conv2d_69[0][0]
__________________________________________________________________________________
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__________________
batch_normalization_70 (BatchNo (None, 11, 9, 192)   576         conv2d_70[0][0]
__________________________________________________________________________________
__________________
activation_61 (Activation)      (None, 11, 9, 192)   0
batch_normalization_61[0][0]
__________________________________________________________________________________
__________________
activation_64 (Activation)      (None, 11, 9, 192)   0
batch_normalization_64[0][0]
__________________________________________________________________________________
__________________
activation_69 (Activation)      (None, 11, 9, 192)   0
batch_normalization_69[0][0]
__________________________________________________________________________________
__________________
activation_70 (Activation)      (None, 11, 9, 192)   0
batch_normalization_70[0][0]
__________________________________________________________________________________
__________________
mixed7 (Concatenate)            (None, 11, 9, 768)   0
activation_61[0][0]
activation_64[0][0]
activation_69[0][0]
activation_70[0][0]
__________________________________________________________________________________
__________________
conv2d_73 (Conv2D)              (None, 11, 9, 192)   147456      mixed7[0][0]
__________________________________________________________________________________
__________________
batch_normalization_73 (BatchNo (None, 11, 9, 192)   576         conv2d_73[0][0]
__________________________________________________________________________________
__________________
activation_73 (Activation)      (None, 11, 9, 192)   0
batch_normalization_73[0][0]
__________________________________________________________________________________
__________________
conv2d_74 (Conv2D)              (None, 11, 9, 192)   258048
activation_73[0][0]
__________________________________________________________________________________
__________________
batch_normalization_74 (BatchNo (None, 11, 9, 192)   576         conv2d_74[0][0]
__________________________________________________________________________________
__________________
activation_74 (Activation)      (None, 11, 9, 192)   0
batch_normalization_74[0][0]
__________________________________________________________________________________
__________________
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conv2d_71 (Conv2D)              (None, 11, 9, 192)   147456      mixed7[0][0]
__________________________________________________________________________________________________
conv2d_75 (Conv2D)              (None, 11, 9, 192)   258048
activation_74[0][0]
__________________________________________________________________________________________________
batch_normalization_71 (BatchNo (None, 11, 9, 192)   576         conv2d_71[0][0]
__________________________________________________________________________________________________
batch_normalization_75 (BatchNo (None, 11, 9, 192)   576         conv2d_75[0][0]
__________________________________________________________________________________________________
activation_71 (Activation)      (None, 11, 9, 192)   0
batch_normalization_71[0][0]
__________________________________________________________________________________________________
activation_75 (Activation)      (None, 11, 9, 192)   0
batch_normalization_75[0][0]
__________________________________________________________________________________________________
conv2d_72 (Conv2D)              (None, 5, 4, 320)    552960
activation_71[0][0]
__________________________________________________________________________________________________
conv2d_76 (Conv2D)              (None, 5, 4, 192)    331776
activation_75[0][0]
__________________________________________________________________________________________________
batch_normalization_72 (BatchNo (None, 5, 4, 320)    960         conv2d_72[0][0]
__________________________________________________________________________________________________
batch_normalization_76 (BatchNo (None, 5, 4, 192)    576         conv2d_76[0][0]
__________________________________________________________________________________________________
activation_72 (Activation)      (None, 5, 4, 320)    0
batch_normalization_72[0][0]
__________________________________________________________________________________________________
activation_76 (Activation)      (None, 5, 4, 192)    0
batch_normalization_76[0][0]
__________________________________________________________________________________________________
max_pooling2d_4 (MaxPooling2D)  (None, 5, 4, 768)    0           mixed7[0][0]
__________________________________________________________________________________________________
mixed8 (Concatenate)            (None, 5, 4, 1280)   0
activation_72[0][0]
```

```
activation_76[0][0]
max_pooling2d_4[0][0]
__________________________________________________________________________________
__________________
conv2d_81 (Conv2D)              (None, 5, 4, 448)    573440      mixed8[0][0]
__________________________________________________________________________________
__________________
batch_normalization_81 (BatchNo (None, 5, 4, 448)    1344        conv2d_81[0][0]
__________________________________________________________________________________
__________________
activation_81 (Activation)      (None, 5, 4, 448)    0
batch_normalization_81[0][0]
__________________________________________________________________________________
__________________
conv2d_78 (Conv2D)              (None, 5, 4, 384)    491520      mixed8[0][0]
__________________________________________________________________________________
__________________
conv2d_82 (Conv2D)              (None, 5, 4, 384)    1548288
activation_81[0][0]
__________________________________________________________________________________
__________________
batch_normalization_78 (BatchNo (None, 5, 4, 384)    1152        conv2d_78[0][0]
__________________________________________________________________________________
__________________
batch_normalization_82 (BatchNo (None, 5, 4, 384)    1152        conv2d_82[0][0]
__________________________________________________________________________________
__________________
activation_78 (Activation)      (None, 5, 4, 384)    0
batch_normalization_78[0][0]
__________________________________________________________________________________
__________________
activation_82 (Activation)      (None, 5, 4, 384)    0
batch_normalization_82[0][0]
__________________________________________________________________________________
__________________
conv2d_79 (Conv2D)              (None, 5, 4, 384)    442368
activation_78[0][0]
__________________________________________________________________________________
__________________
conv2d_80 (Conv2D)              (None, 5, 4, 384)    442368
activation_78[0][0]
__________________________________________________________________________________
__________________
conv2d_83 (Conv2D)              (None, 5, 4, 384)    442368
activation_82[0][0]
__________________________________________________________________________________
__________________
conv2d_84 (Conv2D)              (None, 5, 4, 384)    442368
```

```
activation_82[0][0]
__________________________________________________________________________________________________
average_pooling2d_8 (AveragePoo (None, 5, 4, 1280)   0           mixed8[0][0]
__________________________________________________________________________________________________
conv2d_77 (Conv2D)              (None, 5, 4, 320)    409600      mixed8[0][0]
__________________________________________________________________________________________________
batch_normalization_79 (BatchNo (None, 5, 4, 384)    1152        conv2d_79[0][0]
__________________________________________________________________________________________________
batch_normalization_80 (BatchNo (None, 5, 4, 384)    1152        conv2d_80[0][0]
__________________________________________________________________________________________________
batch_normalization_83 (BatchNo (None, 5, 4, 384)    1152        conv2d_83[0][0]
__________________________________________________________________________________________________
batch_normalization_84 (BatchNo (None, 5, 4, 384)    1152        conv2d_84[0][0]
__________________________________________________________________________________________________
conv2d_85 (Conv2D)              (None, 5, 4, 192)    245760
average_pooling2d_8[0][0]
__________________________________________________________________________________________________
batch_normalization_77 (BatchNo (None, 5, 4, 320)    960         conv2d_77[0][0]
__________________________________________________________________________________________________
activation_79 (Activation)      (None, 5, 4, 384)    0
batch_normalization_79[0][0]
__________________________________________________________________________________________________
activation_80 (Activation)      (None, 5, 4, 384)    0
batch_normalization_80[0][0]
__________________________________________________________________________________________________
activation_83 (Activation)      (None, 5, 4, 384)    0
batch_normalization_83[0][0]
__________________________________________________________________________________________________
activation_84 (Activation)      (None, 5, 4, 384)    0
batch_normalization_84[0][0]
__________________________________________________________________________________________________
batch_normalization_85 (BatchNo (None, 5, 4, 192)    576         conv2d_85[0][0]
__________________________________________________________________________________________________
activation_77 (Activation)      (None, 5, 4, 320)    0
```

```
batch_normalization_77[0][0]
__________________________________________________________________________________
__________________
mixed9_0 (Concatenate)          (None, 5, 4, 768)    0
activation_79[0][0]
activation_80[0][0]
__________________________________________________________________________________
__________________
concatenate_1 (Concatenate)     (None, 5, 4, 768)    0
activation_83[0][0]
activation_84[0][0]
__________________________________________________________________________________
__________________
activation_85 (Activation)      (None, 5, 4, 192)    0
batch_normalization_85[0][0]
__________________________________________________________________________________
__________________
mixed9 (Concatenate)            (None, 5, 4, 2048)   0
activation_77[0][0]
                                                                   mixed9_0[0][0]
concatenate_1[0][0]
activation_85[0][0]
__________________________________________________________________________________
__________________
conv2d_90 (Conv2D)              (None, 5, 4, 448)    917504      mixed9[0][0]
__________________________________________________________________________________
__________________
batch_normalization_90 (BatchNo (None, 5, 4, 448)    1344        conv2d_90[0][0]
__________________________________________________________________________________
__________________
activation_90 (Activation)      (None, 5, 4, 448)    0
batch_normalization_90[0][0]
__________________________________________________________________________________
__________________
conv2d_87 (Conv2D)              (None, 5, 4, 384)    786432      mixed9[0][0]
__________________________________________________________________________________
__________________
conv2d_91 (Conv2D)              (None, 5, 4, 384)    1548288
activation_90[0][0]
__________________________________________________________________________________
__________________
batch_normalization_87 (BatchNo (None, 5, 4, 384)    1152        conv2d_87[0][0]
__________________________________________________________________________________
__________________
batch_normalization_91 (BatchNo (None, 5, 4, 384)    1152        conv2d_91[0][0]
__________________________________________________________________________________
__________________
activation_87 (Activation)      (None, 5, 4, 384)    0
```

```
batch_normalization_87[0][0]
__________________________________________________________________________________________________
activation_91 (Activation)      (None, 5, 4, 384)    0
batch_normalization_91[0][0]
__________________________________________________________________________________________________
conv2d_88 (Conv2D)              (None, 5, 4, 384)    442368
activation_87[0][0]
__________________________________________________________________________________________________
conv2d_89 (Conv2D)              (None, 5, 4, 384)    442368
activation_87[0][0]
__________________________________________________________________________________________________
conv2d_92 (Conv2D)              (None, 5, 4, 384)    442368
activation_91[0][0]
__________________________________________________________________________________________________
conv2d_93 (Conv2D)              (None, 5, 4, 384)    442368
activation_91[0][0]
__________________________________________________________________________________________________
average_pooling2d_9 (AveragePoo (None, 5, 4, 2048)   0           mixed9[0][0]
__________________________________________________________________________________________________
conv2d_86 (Conv2D)              (None, 5, 4, 320)    655360      mixed9[0][0]
__________________________________________________________________________________________________
batch_normalization_88 (BatchNo (None, 5, 4, 384)    1152        conv2d_88[0][0]
__________________________________________________________________________________________________
batch_normalization_89 (BatchNo (None, 5, 4, 384)    1152        conv2d_89[0][0]
__________________________________________________________________________________________________
batch_normalization_92 (BatchNo (None, 5, 4, 384)    1152        conv2d_92[0][0]
__________________________________________________________________________________________________
batch_normalization_93 (BatchNo (None, 5, 4, 384)    1152        conv2d_93[0][0]
__________________________________________________________________________________________________
conv2d_94 (Conv2D)              (None, 5, 4, 192)    393216
average_pooling2d_9[0][0]
__________________________________________________________________________________________________
batch_normalization_86 (BatchNo (None, 5, 4, 320)    960         conv2d_86[0][0]
__________________________________________________________________________________________________
```

```
activation_88 (Activation)      (None, 5, 4, 384)    0
batch_normalization_88[0][0]
__________________________________________________________________________________
__________________
activation_89 (Activation)      (None, 5, 4, 384)    0
batch_normalization_89[0][0]
__________________________________________________________________________________
__________________
activation_92 (Activation)      (None, 5, 4, 384)    0
batch_normalization_92[0][0]
__________________________________________________________________________________
__________________
activation_93 (Activation)      (None, 5, 4, 384)    0
batch_normalization_93[0][0]
__________________________________________________________________________________
__________________
batch_normalization_94 (BatchNo (None, 5, 4, 192)    576         conv2d_94[0][0]
__________________________________________________________________________________
__________________
activation_86 (Activation)      (None, 5, 4, 320)    0
batch_normalization_86[0][0]
__________________________________________________________________________________
__________________
mixed9_1 (Concatenate)          (None, 5, 4, 768)    0
activation_88[0][0]
activation_89[0][0]
__________________________________________________________________________________
__________________
concatenate_2 (Concatenate)     (None, 5, 4, 768)    0
activation_92[0][0]
activation_93[0][0]
__________________________________________________________________________________
__________________
activation_94 (Activation)      (None, 5, 4, 192)    0
batch_normalization_94[0][0]
__________________________________________________________________________________
__________________
mixed10 (Concatenate)           (None, 5, 4, 2048)   0
activation_86[0][0]
                                                                 mixed9_1[0][0]
concatenate_2[0][0]
activation_94[0][0]
==================================================================================
==================
Total params: 21,802,784
Trainable params: 21,768,352
Non-trainable params: 34,432
__________________________________________________________________________________
```

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

[35]:
```
len(model.layers)
```

[35]:
```
311
```

[36]:
```
# customizing the model
x = model.output
x = GlobalAveragePooling2D()(x)
x = Dense(1024,activation='relu')(x)
x = Dropout(0.4)(x)
x = Dense(512, activation='relu')(x)
predictions = Dense(2,activation='softmax')(x)
```

[37]:
```
# final model
image_model = Model(inputs=model.input, outputs=predictions)
```

[38]:
```
# excluding initial layers from being trained
for layer in image_model.layers[:60]:
    layer.trainable = False
```

[39]:
```
# compiling the final model
image_model.compile(optimizer = SGD(lr=0.0001, momentum = 0.9), loss =␣
↪'categorical_crossentropy', metrics = ['accuracy'])
```

[40]:
```
# creating a checkpoint to save epochs results
checkPoint = ModelCheckpoint(filepath = 'inception.smiling.hdf5', verbose = 1,␣
↪save_best_only=True)
```

[42]:
```
# run the model
epochs_num = 20
batch_size = 32

model_history = image_model.fit_generator(train_generator,
                                          validation_data =␣
↪(x_validation,y_validation),
                                          steps_per_epoch = 15000/32,
                                          epochs = epochs_num,
                                          callbacks = [checkPoint],
                                          verbose=1
                                          )
```

```
WARNING:tensorflow:From C:\Users\admin\anaconda3\lib\site-
packages\keras\backend\tensorflow_backend.py:422: The name tf.global_variables
is deprecated. Please use tf.compat.v1.global_variables instead.

Epoch 1/20
469/468 [==============================] - 6806s 15s/step - loss: 0.6848 -
```

```
accuracy: 0.5707 - val_loss: 0.6263 - val_accuracy: 0.6616

Epoch 00001: val_loss improved from inf to 0.62633, saving model to
inception.smiling.hdf5
Epoch 2/20
469/468 [==============================] - 5471s 12s/step - loss: 0.6019 -
accuracy: 0.6795 - val_loss: 0.5199 - val_accuracy: 0.7527

Epoch 00002: val_loss improved from 0.62633 to 0.51987, saving model to
inception.smiling.hdf5
Epoch 3/20
469/468 [==============================] - 5545s 12s/step - loss: 0.5139 -
accuracy: 0.7462 - val_loss: 0.4076 - val_accuracy: 0.8261

Epoch 00003: val_loss improved from 0.51987 to 0.40761, saving model to
inception.smiling.hdf5
Epoch 4/20
469/468 [==============================] - 5543s 12s/step - loss: 0.4337 -
accuracy: 0.8009 - val_loss: 0.3498 - val_accuracy: 0.8543

Epoch 00004: val_loss improved from 0.40761 to 0.34983, saving model to
inception.smiling.hdf5
Epoch 5/20
469/468 [==============================] - 5510s 12s/step - loss: 0.3894 -
accuracy: 0.8279 - val_loss: 0.3142 - val_accuracy: 0.8692

Epoch 00005: val_loss improved from 0.34983 to 0.31422, saving model to
inception.smiling.hdf5
Epoch 6/20
469/468 [==============================] - 5467s 12s/step - loss: 0.3596 -
accuracy: 0.8394 - val_loss: 0.2988 - val_accuracy: 0.8773

Epoch 00006: val_loss improved from 0.31422 to 0.29875, saving model to
inception.smiling.hdf5
Epoch 7/20
469/468 [==============================] - 5449s 12s/step - loss: 0.3447 -
accuracy: 0.8516 - val_loss: 0.2839 - val_accuracy: 0.8844

Epoch 00007: val_loss improved from 0.29875 to 0.28389, saving model to
inception.smiling.hdf5
Epoch 8/20
469/468 [==============================] - 5485s 12s/step - loss: 0.3262 -
accuracy: 0.8569 - val_loss: 0.2734 - val_accuracy: 0.8903

Epoch 00008: val_loss improved from 0.28389 to 0.27336, saving model to
inception.smiling.hdf5
Epoch 9/20
469/468 [==============================] - 5471s 12s/step - loss: 0.3113 -
```

```
accuracy: 0.8657 - val_loss: 0.2616 - val_accuracy: 0.8936

Epoch 00009: val_loss improved from 0.27336 to 0.26163, saving model to
inception.smiling.hdf5
Epoch 10/20
469/468 [==============================] - 5464s 12s/step - loss: 0.3018 -
accuracy: 0.8683 - val_loss: 0.2627 - val_accuracy: 0.8932

Epoch 00010: val_loss did not improve from 0.26163
Epoch 11/20
469/468 [==============================] - 5467s 12s/step - loss: 0.2953 -
accuracy: 0.8720 - val_loss: 0.2526 - val_accuracy: 0.8961

Epoch 00011: val_loss improved from 0.26163 to 0.25258, saving model to
inception.smiling.hdf5
Epoch 12/20
469/468 [==============================] - 5462s 12s/step - loss: 0.2938 -
accuracy: 0.8767 - val_loss: 0.2517 - val_accuracy: 0.8983

Epoch 00012: val_loss improved from 0.25258 to 0.25172, saving model to
inception.smiling.hdf5
Epoch 13/20
469/468 [==============================] - 5452s 12s/step - loss: 0.2839 -
accuracy: 0.8800 - val_loss: 0.2474 - val_accuracy: 0.8979

Epoch 00013: val_loss improved from 0.25172 to 0.24744, saving model to
inception.smiling.hdf5
Epoch 14/20
469/468 [==============================] - 5462s 12s/step - loss: 0.2778 -
accuracy: 0.8836 - val_loss: 0.2398 - val_accuracy: 0.9001

Epoch 00014: val_loss improved from 0.24744 to 0.23981, saving model to
inception.smiling.hdf5
Epoch 15/20
469/468 [==============================] - 5481s 12s/step - loss: 0.2726 -
accuracy: 0.8866 - val_loss: 0.2361 - val_accuracy: 0.9016

Epoch 00015: val_loss improved from 0.23981 to 0.23608, saving model to
inception.smiling.hdf5
Epoch 16/20
469/468 [==============================] - 5488s 12s/step - loss: 0.2669 -
accuracy: 0.8849 - val_loss: 0.2348 - val_accuracy: 0.9036

Epoch 00016: val_loss improved from 0.23608 to 0.23478, saving model to
inception.smiling.hdf5
Epoch 17/20
469/468 [==============================] - 5451s 12s/step - loss: 0.2609 -
accuracy: 0.8907 - val_loss: 0.2436 - val_accuracy: 0.8995
```

```
Epoch 00017: val_loss did not improve from 0.23478
Epoch 18/20
469/468 [==============================] - 5513s 12s/step - loss: 0.2539 -
accuracy: 0.8941 - val_loss: 0.2318 - val_accuracy: 0.9032

Epoch 00018: val_loss improved from 0.23478 to 0.23176, saving model to
inception.smiling.hdf5
Epoch 19/20
469/468 [==============================] - 5479s 12s/step - loss: 0.2536 -
accuracy: 0.8930 - val_loss: 0.2296 - val_accuracy: 0.9041

Epoch 00019: val_loss improved from 0.23176 to 0.22957, saving model to
inception.smiling.hdf5
Epoch 20/20
469/468 [==============================] - 5706s 12s/step - loss: 0.2481 -
accuracy: 0.8945 - val_loss: 0.2260 - val_accuracy: 0.9060

Epoch 00020: val_loss improved from 0.22957 to 0.22598, saving model to
inception.smiling.hdf5
```

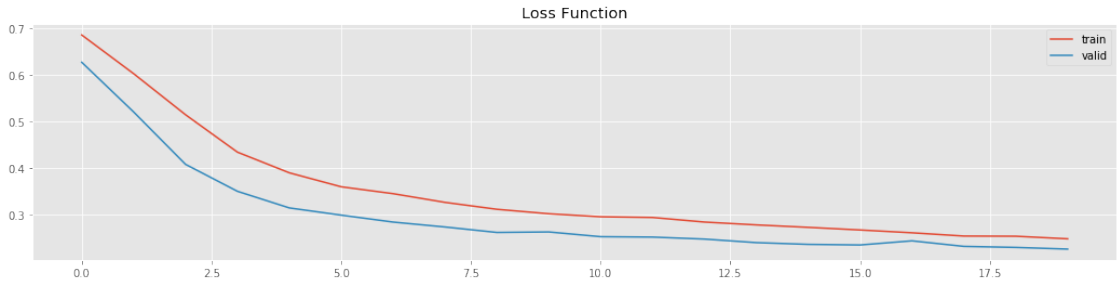
[48]:
```
# load the best model
image_model.load_weights('inception.smiling.hdf5')
```

[49]:
```
# generate predictions
predictions = [np.argmax(image_model.predict(feature)) for feature in x_test ]
```

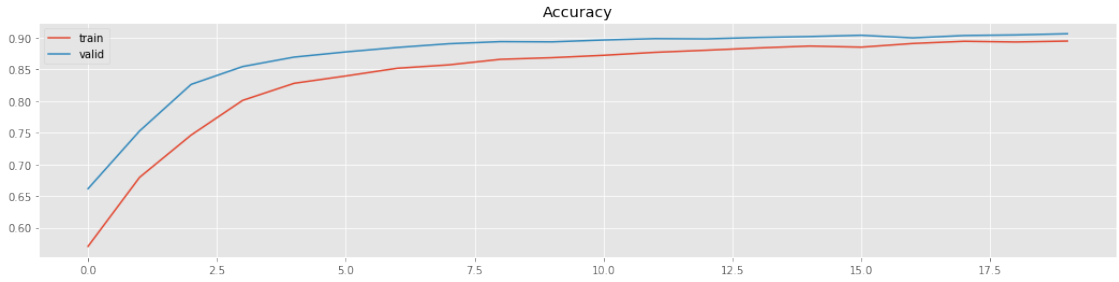
[51]:
```
# report test accuracy
test_accuracy = 100 * np.sum(np.array(predictions)==y_test) / len(predictions)
print('Model Evaluation')
print('Test accuracy: %.4f%%' % test_accuracy)
print('f1_score:', f1_score(y_test, predictions))
```

```
Model Evaluation
Test accuracy: 90.0556%
f1_score: 0.8978427120191759
```

[52]:
```
# Plot loss function value through epochs
plt.figure(figsize=(18, 4))
plt.plot(model_history.history['loss'], label = 'train')
plt.plot(model_history.history['val_loss'], label = 'valid')
plt.legend()
plt.title('Loss Function')
plt.show()
```



[54]:
```
# Plot accuracy through epochs
plt.figure(figsize=(18, 4))
plt.plot(model_history.history['accuracy'], label = 'train')
plt.plot(model_history.history['val_accuracy'], label = 'valid')
plt.legend()
plt.title('Accuracy')
plt.show()
```



0.1.7 Test and Display results for some images

[90]:
```
target_value = {0: 'Not Smiling'
                , 1: 'Smiling'}

def display_image(filename):
    pic = filename
    image = load_img(pic)
    plt.grid(False)
    plt.imshow(image)
    plt.show()
```

[91]:
```
def display_result(filename, prediction, target):
    expression = 'Smiling'

    if prediction[1] <= 0.5:
        expression = 'Not smiling'
```

```
    print("Predicted Image Expression : ",expression)
    print("Target Value : ",target_value[target])
    print("{0:.2f}%".format(round(max(prediction)*100,2)))
    print(filename.split('/')[-1])
```

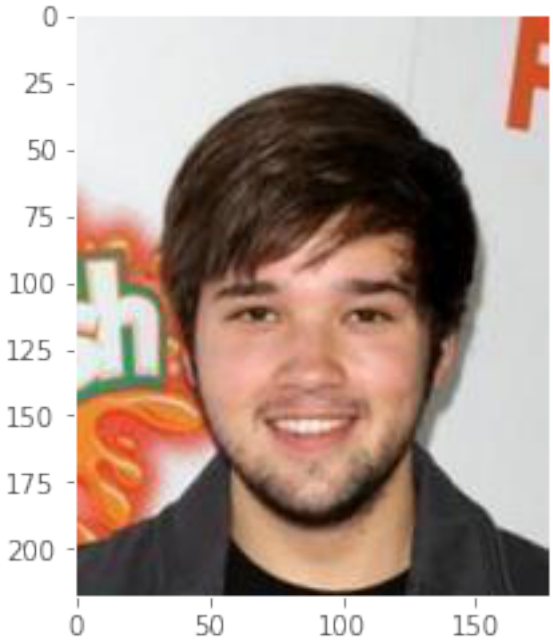
[92]:
```
def predict_expression(filename):
    image = cv2.imread(filename)
    image = cv2.resize(cv2.cvtColor(image, cv2.COLOR_BGR2RGB), (178, 218)).
 ↪astype(np.float32) / 255.0
    image = np.expand_dims(image, axis =0)

    # prediction
    result = image_model.predict(image)
    prediction = np.argmax(result)

    return result
```

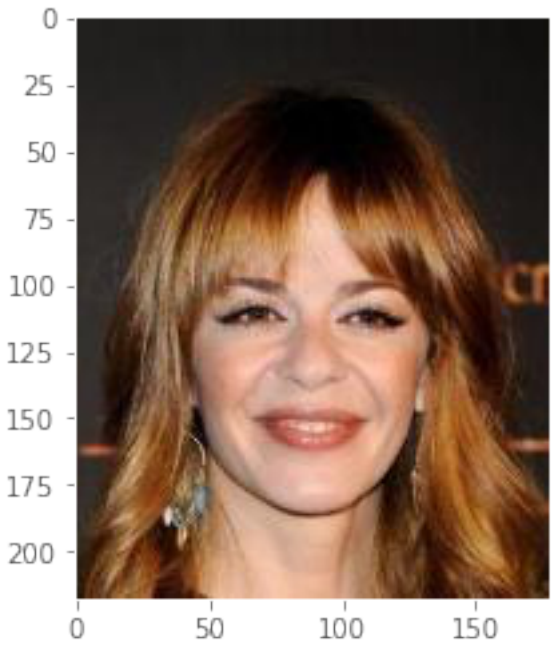
[93]:
```
#select random images of the test partition
testFew = newPartition[(newPartition['partition'] == 2)].sample(5)

for index, target in testFew.iterrows():
    display_image(imagesPath + index)
    result = predict_expression(imagesPath + index)
    display_result(imagesPath + index, result[0], target['Smiling'])
```

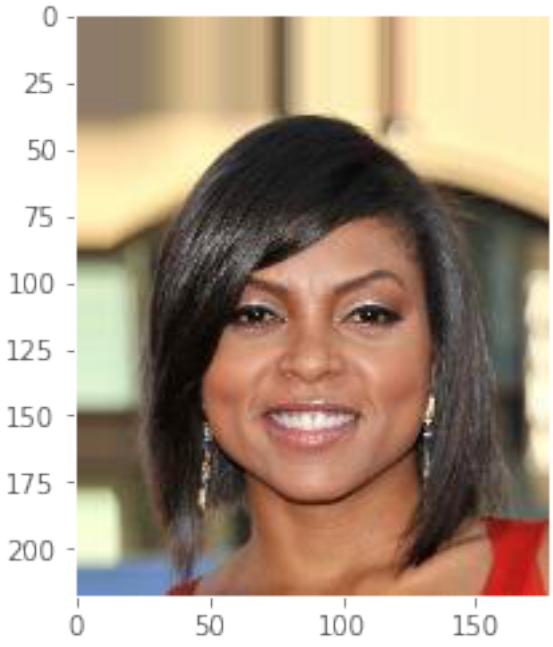


```
Predicted Image Expression :  Smiling
Target Value :  Smiling
99.59%
200917.jpg
```


```
Predicted Image Expression :  Not smiling
Target Value :  Not Smiling
58.66%
194990.jpg
```




```
Predicted Image Expression :  Smiling
Target Value :  Smiling
98.17%
189462.jpg
```



```
Predicted Image Expression :  Smiling
Target Value :  Smiling
99.89%
201966.jpg
```


```
Predicted Image Expression :  Smiling
Target Value :  Smiling
99.92%
192554.jpg
```

[ ]:

MobileNet

May 6, 2020

0.1 Import Libraries

[1]:
```
import keras
from keras import backend as K
from keras.layers.core import Dense, Activation
from keras.optimizers import Adam
from keras.metrics import sparse_categorical_crossentropy
from keras.preprocessing.image import ImageDataGenerator
from keras.preprocessing import image
from keras.models import Model
from keras.applications import imagenet_utils
from keras.layers import Dense, GlobalAveragePooling2D
from keras.applications import MobileNet
from keras.applications.mobilenet import preprocess_input
import numpy as np
from IPython.display import Image
import matplotlib.pyplot as plt
import os
import pandas as pd
import seaborn as sns
import base64
import cv2
from sklearn.metrics import f1_score
from keras.preprocessing.image import ImageDataGenerator, array_to_img,␣
 ↪img_to_array, load_img
from keras.applications.mobilenet_v2 import MobileNetV2
from keras.layers import Dropout,BatchNormalization
from keras.callbacks import ModelCheckpoint
```

```
Using TensorFlow backend.
C:\Users\admin\anaconda3\lib\site-
packages\tensorflow\python\framework\dtypes.py:516: FutureWarning: Passing
(type, 1) or '1type' as a synonym of type is deprecated; in a future version of
numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_qint8 = np.dtype([("qint8", np.int8, 1)])
C:\Users\admin\anaconda3\lib\site-
packages\tensorflow\python\framework\dtypes.py:517: FutureWarning: Passing
(type, 1) or '1type' as a synonym of type is deprecated; in a future version of
```

```
numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_quint8 = np.dtype([("quint8", np.uint8, 1)])
C:\Users\admin\anaconda3\lib\site-
packages\tensorflow\python\framework\dtypes.py:518: FutureWarning: Passing
(type, 1) or '1type' as a synonym of type is deprecated; in a future version of
numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_qint16 = np.dtype([("qint16", np.int16, 1)])
C:\Users\admin\anaconda3\lib\site-
packages\tensorflow\python\framework\dtypes.py:519: FutureWarning: Passing
(type, 1) or '1type' as a synonym of type is deprecated; in a future version of
numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_quint16 = np.dtype([("quint16", np.uint16, 1)])
C:\Users\admin\anaconda3\lib\site-
packages\tensorflow\python\framework\dtypes.py:520: FutureWarning: Passing
(type, 1) or '1type' as a synonym of type is deprecated; in a future version of
numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_qint32 = np.dtype([("qint32", np.int32, 1)])
C:\Users\admin\anaconda3\lib\site-
packages\tensorflow\python\framework\dtypes.py:525: FutureWarning: Passing
(type, 1) or '1type' as a synonym of type is deprecated; in a future version of
numpy, it will be understood as (type, (1,)) / '(1,)type'.
  np_resource = np.dtype([("resource", np.ubyte, 1)])
C:\Users\admin\anaconda3\lib\site-
packages\tensorboard\compat\tensorflow_stub\dtypes.py:541: FutureWarning:
Passing (type, 1) or '1type' as a synonym of type is deprecated; in a future
version of numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_qint8 = np.dtype([("qint8", np.int8, 1)])
C:\Users\admin\anaconda3\lib\site-
packages\tensorboard\compat\tensorflow_stub\dtypes.py:542: FutureWarning:
Passing (type, 1) or '1type' as a synonym of type is deprecated; in a future
version of numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_quint8 = np.dtype([("quint8", np.uint8, 1)])
C:\Users\admin\anaconda3\lib\site-
packages\tensorboard\compat\tensorflow_stub\dtypes.py:543: FutureWarning:
Passing (type, 1) or '1type' as a synonym of type is deprecated; in a future
version of numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_qint16 = np.dtype([("qint16", np.int16, 1)])
C:\Users\admin\anaconda3\lib\site-
packages\tensorboard\compat\tensorflow_stub\dtypes.py:544: FutureWarning:
Passing (type, 1) or '1type' as a synonym of type is deprecated; in a future
version of numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_quint16 = np.dtype([("quint16", np.uint16, 1)])
C:\Users\admin\anaconda3\lib\site-
packages\tensorboard\compat\tensorflow_stub\dtypes.py:545: FutureWarning:
Passing (type, 1) or '1type' as a synonym of type is deprecated; in a future
version of numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_qint32 = np.dtype([("qint32", np.int32, 1)])
C:\Users\admin\anaconda3\lib\site-
```

```
packages\tensorboard\compat\tensorflow_stub\dtypes.py:550: FutureWarning:
Passing (type, 1) or '1type' as a synonym of type is deprecated; in a future
version of numpy, it will be understood as (type, (1,)) / '(1,)type'.
  np_resource = np.dtype([("resource", np.ubyte, 1)])
```

[2]:
```
%matplotlib inline
```

[3]:
```
plt.style.use("ggplot")
print(os.getcwd())
```

```
C:\Users\admin\Desktop\celeba-dataset
```

0.1.1 Set main folder path

[4]:
```
# setting the main project folder path
mainPath = 'C:/Users/admin/Desktop/celeba-dataset'
print(mainPath)
```

```
C:/Users/admin/Desktop/celeba-dataset
```

0.1.2 Display image

[5]:
```
# setting the images folder path
imagesPath = mainPath + '/img_align_celeba/img_align_celeba/'
# display an example pic from the dataset
pic = imagesPath + '000005.jpg'
image = load_img(pic)
plt.grid(False)
plt.imshow(image)
```

[5]:
```
<matplotlib.image.AxesImage at 0x25851cbfcc8>
```

0.1.3 Pre - process Attribute dataframe

[6]:
```
# setting folder path to attributes excel file
attributePath = mainPath + '/list_attr_celeba.csv'
```

[7]:
```
# read attribute csv file in a data frame
attributeDf = pd.read_csv(attributePath)
attributeDf.head()
```

[7]:

	image_id	5_o_Clock_Shadow	Arched_Eyebrows	Attractive	Bags_Under_Eyes	Bald	Bangs	Big_Lips	Big_Nose	Black_Hair	…	Sideburns	Smiling	Straight_Hair	Wavy_Hair	Wearing_Earrings	Wearing_Hat	Wearing_Lipstick
0	000001.jpg	-1	1	1	-1	-1	-1	-1	-1	-1	…	-1	1	1	-1	1	-1	1
1	000002.jpg	-1	-1	-1	1	-1	-1	-1	1	-1	…	-1	1					
2	000003.jpg	-1	-1	-1	-1	-1	-1	1	-1	-1	…	-1	-1					
3	000004.jpg	-1	-1	1	-1	-1	-1	-1	-1	-1	…	-1	-1					
4	000005.jpg	-1	1	1	-1	-1	-1	1	-1	-1	…	-1	-1					

```
1              -1         -1                -1           -1                -1
2              -1          1                -1           -1                -1
3               1         -1                 1           -1                 1
4              -1         -1                -1           -1                 1

   Wearing_Necklace  Wearing_Necktie  Young
0                -1               -1      1
1                -1               -1      1
2                -1               -1      1
3                 1               -1      1
4                -1               -1      1

[5 rows x 41 columns]
```

[8]:
```
# replace -1 values with 0
attributeDf.replace(to_replace = -1, value = 0, inplace = True)

# set image_id as index
attributeDf.set_index('image_id', inplace = True)

attributeDf.head()
```

[8]:
```
            5_o_Clock_Shadow  Arched_Eyebrows  Attractive  Bags_Under_Eyes  \
image_id
000001.jpg                 0                1           1                0
000002.jpg                 0                0           0                1
000003.jpg                 0                0           0                0
000004.jpg                 0                0           1                0
000005.jpg                 0                1           1                0

            Bald  Bangs  Big_Lips  Big_Nose  Black_Hair  Blond_Hair  …  \
image_id                                                               …
000001.jpg     0      0         0         0           0           0  …
000002.jpg     0      0         0         1           0           0  …
000003.jpg     0      0         1         0           0           0  …
000004.jpg     0      0         0         0           0           0  …
000005.jpg     0      0         1         0           0           0  …

            Sideburns  Smiling  Straight_Hair  Wavy_Hair  Wearing_Earrings  \
image_id
000001.jpg          0        1              1          0                 1
000002.jpg          0        1              0          0                 0
000003.jpg          0        0              0          1                 0
000004.jpg          0        0              1          0                 1
000005.jpg          0        0              0          0                 0

            Wearing_Hat  Wearing_Lipstick  Wearing_Necklace  Wearing_Necktie  \
```

```
image_id
000001.jpg            0                1                0                0
000002.jpg            0                0                0                0
000003.jpg            0                0                0                0
000004.jpg            0                1                1                0
000005.jpg            0                1                0                0

            Young
image_id
000001.jpg      1
000002.jpg      1
000003.jpg      1
000004.jpg      1
000005.jpg      1

[5 rows x 40 columns]
```

[9]:
```
# view attributeDf column names
attributeDf.columns
```

[9]:
```
Index(['5_o_Clock_Shadow', 'Arched_Eyebrows', 'Attractive', 'Bags_Under_Eyes',
       'Bald', 'Bangs', 'Big_Lips', 'Big_Nose', 'Black_Hair', 'Blond_Hair',
       'Blurry', 'Brown_Hair', 'Bushy_Eyebrows', 'Chubby', 'Double_Chin',
       'Eyeglasses', 'Goatee', 'Gray_Hair', 'Heavy_Makeup', 'High_Cheekbones',
       'Male', 'Mouth_Slightly_Open', 'Mustache', 'Narrow_Eyes', 'No_Beard',
       'Oval_Face', 'Pale_Skin', 'Pointy_Nose', 'Receding_Hairline',
       'Rosy_Cheeks', 'Sideburns', 'Smiling', 'Straight_Hair', 'Wavy_Hair',
       'Wearing_Earrings', 'Wearing_Hat', 'Wearing_Lipstick',
       'Wearing_Necklace', 'Wearing_Necktie', 'Young'],
      dtype='object')
```

0.1.4 Pre - process Partition file

[10]:
```
# loading partition dataframe, differentiating between training(0),␣
 ↪validation(1) and test(2) images
partitionPath = mainPath + '/list_eval_partition.csv'

partitionDf = pd.read_csv(partitionPath)
partitionDf.head()
```

[10]:
```
     image_id  partition
0  000001.jpg          0
1  000002.jpg          0
2  000003.jpg          0
3  000004.jpg          0
4  000005.jpg          0
```

[11]:
```
# display count of distinct partition values
partitionDf['partition'].value_counts().sort_index()
```

[11]:
```
0    162770
1     19867
2     19962
Name: partition, dtype: int64
```

[12]:
```
# join partitionDf and smiling column of attributeDf based on imageid
partitionDf.set_index('image_id', inplace=True)
newPartition = partitionDf.join(attributeDf['Smiling'], how='inner')
newPartition.head()
```

[12]:

image_id	partition	Smiling
000001.jpg	0	1
000002.jpg	0	1
000003.jpg	0	0
000004.jpg	0	0
000005.jpg	0	0

[13]:
```
newPartition.reset_index(inplace=True)
newPartition.head()
```

[13]:

	image_id	partition	Smiling
0	000001.jpg	0	1
1	000002.jpg	0	1
2	000003.jpg	0	0
3	000004.jpg	0	0
4	000005.jpg	0	0

[15]:
```
newPartition['Smiling'].replace(to_replace = 1, value = 'Smiling', inplace =␣
↪True)
newPartition['Smiling'].replace(to_replace = 0, value = 'Not Smiling', inplace␣
↪= True)
```

[16]:
```
newPartition.head()
```

[16]:

	image_id	partition	Smiling
0	000001.jpg	0	Smiling
1	000002.jpg	0	Smiling
2	000003.jpg	0	Not Smiling
3	000004.jpg	0	Not Smiling
4	000005.jpg	0	Not Smiling

0.1.5 Pre - process images

[17]:
```
# convert image into array
def load_reshape_img(fname):
    img = load_img(fname)
    x = img_to_array(img)/255.
    x = x.reshape((1,) + x.shape)

    return x

# get training, test and validation set
def getPartition(partition,df,number):
    name = pd.DataFrame()
    name = df[df['partition'] == partition].sample(n = number)
    return name
```

[18]:
```
# training set consists of 15000 images
# validation set consists of 7500 images
# test set consists of 9000
# there is no overlap between any of the sets
trainSet = getPartition(0,newPartition,15000)
validationSet = getPartition(1, newPartition, 7500)
testSet = getPartition(2, newPartition,9000)
```

[19]:
```
trainSet['Smiling'].value_counts()
```

[19]:
```
Not Smiling    7816
Smiling        7184
Name: Smiling, dtype: int64
```

[20]:
```
validationSet['Smiling'].value_counts()
```

[20]:
```
Not Smiling    3923
Smiling        3577
Name: Smiling, dtype: int64
```

[21]:
```
testSet['Smiling'].value_counts()
```

[21]:
```
Not Smiling    4640
Smiling        4360
Name: Smiling, dtype: int64
```

[22]:
```
image_size = 224
img_width = 224
img_height = 224
image_shape = (img_width,img_height,3)
target_size = (img_height,img_width)
```

0.1.6 Initialize and define the model

[23]:
```
base_model = MobileNetV2(input_shape = image_shape,
                         weights='imagenet',
                         include_top = False,
                         pooling = 'avg')
```

[24]:
```
base_model.summary()
```

```
Model: "mobilenetv2_1.00_224"
__________________________________________________________________________________________________
Layer (type)                    Output Shape         Param #     Connected to
==================================================================================================
input_1 (InputLayer)            (None, 224, 224, 3)  0
__________________________________________________________________________________________________
Conv1_pad (ZeroPadding2D)       (None, 225, 225, 3)  0           input_1[0][0]
__________________________________________________________________________________________________
Conv1 (Conv2D)                  (None, 112, 112, 32) 864         Conv1_pad[0][0]
__________________________________________________________________________________________________
bn_Conv1 (BatchNormalization)   (None, 112, 112, 32) 128         Conv1[0][0]
__________________________________________________________________________________________________
Conv1_relu (ReLU)               (None, 112, 112, 32) 0           bn_Conv1[0][0]
__________________________________________________________________________________________________
expanded_conv_depthwise (Depthw (None, 112, 112, 32) 288
Conv1_relu[0][0]
__________________________________________________________________________________________________
expanded_conv_depthwise_BN (Bat (None, 112, 112, 32) 128
expanded_conv_depthwise[0][0]
__________________________________________________________________________________________________
expanded_conv_depthwise_relu (R (None, 112, 112, 32) 0
expanded_conv_depthwise_BN[0][0]
__________________________________________________________________________________________________
expanded_conv_project (Conv2D)  (None, 112, 112, 16) 512
expanded_conv_depthwise_relu[0][0
__________________________________________________________________________________________________
expanded_conv_project_BN (Batch (None, 112, 112, 16) 64
expanded_conv_project[0][0]
```

```
----------------------------------------------------------------------------------------------------
block_1_expand (Conv2D)         (None, 112, 112, 96) 1536
expanded_conv_project_BN[0][0]
----------------------------------------------------------------------------------------------------
block_1_expand_BN (BatchNormali (None, 112, 112, 96) 384
block_1_expand[0][0]
----------------------------------------------------------------------------------------------------
block_1_expand_relu (ReLU)      (None, 112, 112, 96) 0
block_1_expand_BN[0][0]
----------------------------------------------------------------------------------------------------
block_1_pad (ZeroPadding2D)     (None, 113, 113, 96) 0
block_1_expand_relu[0][0]
----------------------------------------------------------------------------------------------------
block_1_depthwise (DepthwiseCon (None, 56, 56, 96)   864
block_1_pad[0][0]
----------------------------------------------------------------------------------------------------
block_1_depthwise_BN (BatchNorm (None, 56, 56, 96)   384
block_1_depthwise[0][0]
----------------------------------------------------------------------------------------------------
block_1_depthwise_relu (ReLU)   (None, 56, 56, 96)   0
block_1_depthwise_BN[0][0]
----------------------------------------------------------------------------------------------------
block_1_project (Conv2D)        (None, 56, 56, 24)   2304
block_1_depthwise_relu[0][0]
----------------------------------------------------------------------------------------------------
block_1_project_BN (BatchNormal (None, 56, 56, 24)   96
block_1_project[0][0]
----------------------------------------------------------------------------------------------------
block_2_expand (Conv2D)         (None, 56, 56, 144)  3456
block_1_project_BN[0][0]
----------------------------------------------------------------------------------------------------
block_2_expand_BN (BatchNormali (None, 56, 56, 144)  576
block_2_expand[0][0]
----------------------------------------------------------------------------------------------------
block_2_expand_relu (ReLU)      (None, 56, 56, 144)  0
block_2_expand_BN[0][0]
```

```
__________________________________________________________________________________
__________________
block_2_depthwise (DepthwiseCon (None, 56, 56, 144)  1296
block_2_expand_relu[0][0]
__________________________________________________________________________________
__________________
block_2_depthwise_BN (BatchNorm (None, 56, 56, 144)  576
block_2_depthwise[0][0]
__________________________________________________________________________________
__________________
block_2_depthwise_relu (ReLU)   (None, 56, 56, 144)  0
block_2_depthwise_BN[0][0]
__________________________________________________________________________________
__________________
block_2_project (Conv2D)        (None, 56, 56, 24)   3456
block_2_depthwise_relu[0][0]
__________________________________________________________________________________
__________________
block_2_project_BN (BatchNormal (None, 56, 56, 24)   96
block_2_project[0][0]
__________________________________________________________________________________
__________________
block_2_add (Add)               (None, 56, 56, 24)   0
block_1_project_BN[0][0]
block_2_project_BN[0][0]
__________________________________________________________________________________
__________________
block_3_expand (Conv2D)         (None, 56, 56, 144)  3456
block_2_add[0][0]
__________________________________________________________________________________
__________________
block_3_expand_BN (BatchNormali (None, 56, 56, 144)  576
block_3_expand[0][0]
__________________________________________________________________________________
__________________
block_3_expand_relu (ReLU)      (None, 56, 56, 144)  0
block_3_expand_BN[0][0]
__________________________________________________________________________________
__________________
block_3_pad (ZeroPadding2D)     (None, 57, 57, 144)  0
block_3_expand_relu[0][0]
__________________________________________________________________________________
__________________
block_3_depthwise (DepthwiseCon (None, 28, 28, 144)  1296
block_3_pad[0][0]
__________________________________________________________________________________
__________________
block_3_depthwise_BN (BatchNorm (None, 28, 28, 144)  576
```

```
block_3_depthwise[0][0]
__________________________________________________________________________________
__________________
block_3_depthwise_relu (ReLU)   (None, 28, 28, 144)  0
block_3_depthwise_BN[0][0]
__________________________________________________________________________________
__________________
block_3_project (Conv2D)        (None, 28, 28, 32)   4608
block_3_depthwise_relu[0][0]
__________________________________________________________________________________
__________________
block_3_project_BN (BatchNormal (None, 28, 28, 32)   128
block_3_project[0][0]
__________________________________________________________________________________
__________________
block_4_expand (Conv2D)         (None, 28, 28, 192)  6144
block_3_project_BN[0][0]
__________________________________________________________________________________
__________________
block_4_expand_BN (BatchNormali (None, 28, 28, 192)  768
block_4_expand[0][0]
__________________________________________________________________________________
__________________
block_4_expand_relu (ReLU)      (None, 28, 28, 192)  0
block_4_expand_BN[0][0]
__________________________________________________________________________________
__________________
block_4_depthwise (DepthwiseCon (None, 28, 28, 192)  1728
block_4_expand_relu[0][0]
__________________________________________________________________________________
__________________
block_4_depthwise_BN (BatchNorm (None, 28, 28, 192)  768
block_4_depthwise[0][0]
__________________________________________________________________________________
__________________
block_4_depthwise_relu (ReLU)   (None, 28, 28, 192)  0
block_4_depthwise_BN[0][0]
__________________________________________________________________________________
__________________
block_4_project (Conv2D)        (None, 28, 28, 32)   6144
block_4_depthwise_relu[0][0]
__________________________________________________________________________________
__________________
block_4_project_BN (BatchNormal (None, 28, 28, 32)   128
block_4_project[0][0]
__________________________________________________________________________________
__________________
block_4_add (Add)               (None, 28, 28, 32)   0
```

```
block_3_project_BN[0][0]
block_4_project_BN[0][0]
__________________________________________________________________________________
__________________
block_5_expand (Conv2D)         (None, 28, 28, 192)  6144
block_4_add[0][0]
__________________________________________________________________________________
__________________
block_5_expand_BN (BatchNormali (None, 28, 28, 192)  768
block_5_expand[0][0]
__________________________________________________________________________________
__________________
block_5_expand_relu (ReLU)      (None, 28, 28, 192)  0
block_5_expand_BN[0][0]
__________________________________________________________________________________
__________________
block_5_depthwise (DepthwiseCon (None, 28, 28, 192)  1728
block_5_expand_relu[0][0]
__________________________________________________________________________________
__________________
block_5_depthwise_BN (BatchNorm (None, 28, 28, 192)  768
block_5_depthwise[0][0]
__________________________________________________________________________________
__________________
block_5_depthwise_relu (ReLU)   (None, 28, 28, 192)  0
block_5_depthwise_BN[0][0]
__________________________________________________________________________________
__________________
block_5_project (Conv2D)        (None, 28, 28, 32)   6144
block_5_depthwise_relu[0][0]
__________________________________________________________________________________
__________________
block_5_project_BN (BatchNormal (None, 28, 28, 32)   128
block_5_project[0][0]
__________________________________________________________________________________
__________________
block_5_add (Add)               (None, 28, 28, 32)   0
block_4_add[0][0]
block_5_project_BN[0][0]
__________________________________________________________________________________
__________________
block_6_expand (Conv2D)         (None, 28, 28, 192)  6144
block_5_add[0][0]
__________________________________________________________________________________
__________________
block_6_expand_BN (BatchNormali (None, 28, 28, 192)  768
block_6_expand[0][0]
__________________________________________________________________________________
```

```
------------------
block_6_expand_relu (ReLU)      (None, 28, 28, 192)  0
block_6_expand_BN[0][0]
------------------------------------------------------------------------------------
------------------
block_6_pad (ZeroPadding2D)     (None, 29, 29, 192)  0
block_6_expand_relu[0][0]
------------------------------------------------------------------------------------
------------------
block_6_depthwise (DepthwiseCon (None, 14, 14, 192)  1728
block_6_pad[0][0]
------------------------------------------------------------------------------------
------------------
block_6_depthwise_BN (BatchNorm (None, 14, 14, 192)  768
block_6_depthwise[0][0]
------------------------------------------------------------------------------------
------------------
block_6_depthwise_relu (ReLU)   (None, 14, 14, 192)  0
block_6_depthwise_BN[0][0]
------------------------------------------------------------------------------------
------------------
block_6_project (Conv2D)        (None, 14, 14, 64)   12288
block_6_depthwise_relu[0][0]
------------------------------------------------------------------------------------
------------------
block_6_project_BN (BatchNormal (None, 14, 14, 64)   256
block_6_project[0][0]
------------------------------------------------------------------------------------
------------------
block_7_expand (Conv2D)         (None, 14, 14, 384)  24576
block_6_project_BN[0][0]
------------------------------------------------------------------------------------
------------------
block_7_expand_BN (BatchNormali (None, 14, 14, 384)  1536
block_7_expand[0][0]
------------------------------------------------------------------------------------
------------------
block_7_expand_relu (ReLU)      (None, 14, 14, 384)  0
block_7_expand_BN[0][0]
------------------------------------------------------------------------------------
------------------
block_7_depthwise (DepthwiseCon (None, 14, 14, 384)  3456
block_7_expand_relu[0][0]
------------------------------------------------------------------------------------
------------------
block_7_depthwise_BN (BatchNorm (None, 14, 14, 384)  1536
block_7_depthwise[0][0]
------------------------------------------------------------------------------------
```

```
------------------
block_7_depthwise_relu (ReLU)   (None, 14, 14, 384)  0
block_7_depthwise_BN[0][0]
------------------------------------------------------------------------------------
------------------
block_7_project (Conv2D)        (None, 14, 14, 64)   24576
block_7_depthwise_relu[0][0]
------------------------------------------------------------------------------------
------------------
block_7_project_BN (BatchNormal (None, 14, 14, 64)   256
block_7_project[0][0]
------------------------------------------------------------------------------------
------------------
block_7_add (Add)               (None, 14, 14, 64)   0
block_6_project_BN[0][0]
block_7_project_BN[0][0]
------------------------------------------------------------------------------------
------------------
block_8_expand (Conv2D)         (None, 14, 14, 384)  24576
block_7_add[0][0]
------------------------------------------------------------------------------------
------------------
block_8_expand_BN (BatchNormali (None, 14, 14, 384)  1536
block_8_expand[0][0]
------------------------------------------------------------------------------------
------------------
block_8_expand_relu (ReLU)      (None, 14, 14, 384)  0
block_8_expand_BN[0][0]
------------------------------------------------------------------------------------
------------------
block_8_depthwise (DepthwiseCon (None, 14, 14, 384)  3456
block_8_expand_relu[0][0]
------------------------------------------------------------------------------------
------------------
block_8_depthwise_BN (BatchNorm (None, 14, 14, 384)  1536
block_8_depthwise[0][0]
------------------------------------------------------------------------------------
------------------
block_8_depthwise_relu (ReLU)   (None, 14, 14, 384)  0
block_8_depthwise_BN[0][0]
------------------------------------------------------------------------------------
------------------
block_8_project (Conv2D)        (None, 14, 14, 64)   24576
block_8_depthwise_relu[0][0]
------------------------------------------------------------------------------------
------------------
block_8_project_BN (BatchNormal (None, 14, 14, 64)   256
block_8_project[0][0]
```

```
__________________________________________________________________________________
__________________
block_8_add (Add)               (None, 14, 14, 64)   0
block_7_add[0][0]
block_8_project_BN[0][0]
__________________________________________________________________________________
__________________
block_9_expand (Conv2D)         (None, 14, 14, 384)  24576
block_8_add[0][0]
__________________________________________________________________________________
__________________
block_9_expand_BN (BatchNormali (None, 14, 14, 384)  1536
block_9_expand[0][0]
__________________________________________________________________________________
__________________
block_9_expand_relu (ReLU)      (None, 14, 14, 384)  0
block_9_expand_BN[0][0]
__________________________________________________________________________________
__________________
block_9_depthwise (DepthwiseCon (None, 14, 14, 384)  3456
block_9_expand_relu[0][0]
__________________________________________________________________________________
__________________
block_9_depthwise_BN (BatchNorm (None, 14, 14, 384)  1536
block_9_depthwise[0][0]
__________________________________________________________________________________
__________________
block_9_depthwise_relu (ReLU)   (None, 14, 14, 384)  0
block_9_depthwise_BN[0][0]
__________________________________________________________________________________
__________________
block_9_project (Conv2D)        (None, 14, 14, 64)   24576
block_9_depthwise_relu[0][0]
__________________________________________________________________________________
__________________
block_9_project_BN (BatchNormal (None, 14, 14, 64)   256
block_9_project[0][0]
__________________________________________________________________________________
__________________
block_9_add (Add)               (None, 14, 14, 64)   0
block_8_add[0][0]
block_9_project_BN[0][0]
__________________________________________________________________________________
__________________
block_10_expand (Conv2D)        (None, 14, 14, 384)  24576
block_9_add[0][0]
__________________________________________________________________________________
__________________
```

```
block_10_expand_BN (BatchNormal (None, 14, 14, 384)  1536
block_10_expand[0][0]
------------------------------------------------------------------------------
------------------
block_10_expand_relu (ReLU)     (None, 14, 14, 384)  0
block_10_expand_BN[0][0]
------------------------------------------------------------------------------
------------------
block_10_depthwise (DepthwiseCo (None, 14, 14, 384)  3456
block_10_expand_relu[0][0]
------------------------------------------------------------------------------
------------------
block_10_depthwise_BN (BatchNor (None, 14, 14, 384)  1536
block_10_depthwise[0][0]
------------------------------------------------------------------------------
------------------
block_10_depthwise_relu (ReLU)  (None, 14, 14, 384)  0
block_10_depthwise_BN[0][0]
------------------------------------------------------------------------------
------------------
block_10_project (Conv2D)       (None, 14, 14, 96)   36864
block_10_depthwise_relu[0][0]
------------------------------------------------------------------------------
------------------
block_10_project_BN (BatchNorma (None, 14, 14, 96)   384
block_10_project[0][0]
------------------------------------------------------------------------------
------------------
block_11_expand (Conv2D)        (None, 14, 14, 576)  55296
block_10_project_BN[0][0]
------------------------------------------------------------------------------
------------------
block_11_expand_BN (BatchNormal (None, 14, 14, 576)  2304
block_11_expand[0][0]
------------------------------------------------------------------------------
------------------
block_11_expand_relu (ReLU)     (None, 14, 14, 576)  0
block_11_expand_BN[0][0]
------------------------------------------------------------------------------
------------------
block_11_depthwise (DepthwiseCo (None, 14, 14, 576)  5184
block_11_expand_relu[0][0]
------------------------------------------------------------------------------
------------------
block_11_depthwise_BN (BatchNor (None, 14, 14, 576)  2304
block_11_depthwise[0][0]
------------------------------------------------------------------------------
------------------
```

```
block_11_depthwise_relu (ReLU)  (None, 14, 14, 576)  0
block_11_depthwise_BN[0][0]
__________________________________________________________________________________
__________________
block_11_project (Conv2D)       (None, 14, 14, 96)   55296
block_11_depthwise_relu[0][0]
__________________________________________________________________________________
__________________
block_11_project_BN (BatchNorma (None, 14, 14, 96)   384
block_11_project[0][0]
__________________________________________________________________________________
__________________
block_11_add (Add)              (None, 14, 14, 96)   0
block_10_project_BN[0][0]
block_11_project_BN[0][0]
__________________________________________________________________________________
__________________
block_12_expand (Conv2D)        (None, 14, 14, 576)  55296
block_11_add[0][0]
__________________________________________________________________________________
__________________
block_12_expand_BN (BatchNormal (None, 14, 14, 576)  2304
block_12_expand[0][0]
__________________________________________________________________________________
__________________
block_12_expand_relu (ReLU)     (None, 14, 14, 576)  0
block_12_expand_BN[0][0]
__________________________________________________________________________________
__________________
block_12_depthwise (DepthwiseCo (None, 14, 14, 576)  5184
block_12_expand_relu[0][0]
__________________________________________________________________________________
__________________
block_12_depthwise_BN (BatchNor (None, 14, 14, 576)  2304
block_12_depthwise[0][0]
__________________________________________________________________________________
__________________
block_12_depthwise_relu (ReLU)  (None, 14, 14, 576)  0
block_12_depthwise_BN[0][0]
__________________________________________________________________________________
__________________
block_12_project (Conv2D)       (None, 14, 14, 96)   55296
block_12_depthwise_relu[0][0]
__________________________________________________________________________________
__________________
block_12_project_BN (BatchNorma (None, 14, 14, 96)   384
block_12_project[0][0]
__________________________________________________________________________________
```

```
__________________
block_12_add (Add)              (None, 14, 14, 96)   0
block_11_add[0][0]
block_12_project_BN[0][0]
__________________________________________________________________________________
__________________
block_13_expand (Conv2D)        (None, 14, 14, 576)  55296
block_12_add[0][0]
__________________________________________________________________________________
__________________
block_13_expand_BN (BatchNormal (None, 14, 14, 576)  2304
block_13_expand[0][0]
__________________________________________________________________________________
__________________
block_13_expand_relu (ReLU)     (None, 14, 14, 576)  0
block_13_expand_BN[0][0]
__________________________________________________________________________________
__________________
block_13_pad (ZeroPadding2D)    (None, 15, 15, 576)  0
block_13_expand_relu[0][0]
__________________________________________________________________________________
__________________
block_13_depthwise (DepthwiseCo (None, 7, 7, 576)    5184
block_13_pad[0][0]
__________________________________________________________________________________
__________________
block_13_depthwise_BN (BatchNor (None, 7, 7, 576)    2304
block_13_depthwise[0][0]
__________________________________________________________________________________
__________________
block_13_depthwise_relu (ReLU)  (None, 7, 7, 576)    0
block_13_depthwise_BN[0][0]
__________________________________________________________________________________
__________________
block_13_project (Conv2D)       (None, 7, 7, 160)    92160
block_13_depthwise_relu[0][0]
__________________________________________________________________________________
__________________
block_13_project_BN (BatchNorma (None, 7, 7, 160)    640
block_13_project[0][0]
__________________________________________________________________________________
__________________
block_14_expand (Conv2D)        (None, 7, 7, 960)    153600
block_13_project_BN[0][0]
__________________________________________________________________________________
__________________
block_14_expand_BN (BatchNormal (None, 7, 7, 960)    3840
block_14_expand[0][0]
```

```
__________________________________________________________________________________
__________________
block_14_expand_relu (ReLU)     (None, 7, 7, 960)    0
block_14_expand_BN[0][0]
__________________________________________________________________________________
__________________
block_14_depthwise (DepthwiseCo (None, 7, 7, 960)    8640
block_14_expand_relu[0][0]
__________________________________________________________________________________
__________________
block_14_depthwise_BN (BatchNor (None, 7, 7, 960)    3840
block_14_depthwise[0][0]
__________________________________________________________________________________
__________________
block_14_depthwise_relu (ReLU)  (None, 7, 7, 960)    0
block_14_depthwise_BN[0][0]
__________________________________________________________________________________
__________________
block_14_project (Conv2D)       (None, 7, 7, 160)    153600
block_14_depthwise_relu[0][0]
__________________________________________________________________________________
__________________
block_14_project_BN (BatchNorma (None, 7, 7, 160)    640
block_14_project[0][0]
__________________________________________________________________________________
__________________
block_14_add (Add)              (None, 7, 7, 160)    0
block_13_project_BN[0][0]
block_14_project_BN[0][0]
__________________________________________________________________________________
__________________
block_15_expand (Conv2D)        (None, 7, 7, 960)    153600
block_14_add[0][0]
__________________________________________________________________________________
__________________
block_15_expand_BN (BatchNormal (None, 7, 7, 960)    3840
block_15_expand[0][0]
__________________________________________________________________________________
__________________
block_15_expand_relu (ReLU)     (None, 7, 7, 960)    0
block_15_expand_BN[0][0]
__________________________________________________________________________________
__________________
block_15_depthwise (DepthwiseCo (None, 7, 7, 960)    8640
block_15_expand_relu[0][0]
__________________________________________________________________________________
__________________
block_15_depthwise_BN (BatchNor (None, 7, 7, 960)    3840
```

```
block_15_depthwise[0][0]
__________________________________________________________________________________
__________________
block_15_depthwise_relu (ReLU)  (None, 7, 7, 960)    0
block_15_depthwise_BN[0][0]
__________________________________________________________________________________
__________________
block_15_project (Conv2D)       (None, 7, 7, 160)    153600
block_15_depthwise_relu[0][0]
__________________________________________________________________________________
__________________
block_15_project_BN (BatchNorma (None, 7, 7, 160)    640
block_15_project[0][0]
__________________________________________________________________________________
__________________
block_15_add (Add)              (None, 7, 7, 160)    0
block_14_add[0][0]
block_15_project_BN[0][0]
__________________________________________________________________________________
__________________
block_16_expand (Conv2D)        (None, 7, 7, 960)    153600
block_15_add[0][0]
__________________________________________________________________________________
__________________
block_16_expand_BN (BatchNormal (None, 7, 7, 960)    3840
block_16_expand[0][0]
__________________________________________________________________________________
__________________
block_16_expand_relu (ReLU)     (None, 7, 7, 960)    0
block_16_expand_BN[0][0]
__________________________________________________________________________________
__________________
block_16_depthwise (DepthwiseCo (None, 7, 7, 960)    8640
block_16_expand_relu[0][0]
__________________________________________________________________________________
__________________
block_16_depthwise_BN (BatchNor (None, 7, 7, 960)    3840
block_16_depthwise[0][0]
__________________________________________________________________________________
__________________
block_16_depthwise_relu (ReLU)  (None, 7, 7, 960)    0
block_16_depthwise_BN[0][0]
__________________________________________________________________________________
__________________
block_16_project (Conv2D)       (None, 7, 7, 320)    307200
block_16_depthwise_relu[0][0]
__________________________________________________________________________________
__________________
```

```
block_16_project_BN (BatchNorma (None, 7, 7, 320)    1280
block_16_project[0][0]
__________________________________________________________________________________
__________________
Conv_1 (Conv2D)                 (None, 7, 7, 1280)   409600
block_16_project_BN[0][0]
__________________________________________________________________________________
__________________
Conv_1_bn (BatchNormalization)  (None, 7, 7, 1280)   5120        Conv_1[0][0]
__________________________________________________________________________________
__________________
out_relu (ReLU)                 (None, 7, 7, 1280)   0           Conv_1_bn[0][0]
__________________________________________________________________________________
__________________
global_average_pooling2d_1 (Glo (None, 1280)         0           out_relu[0][0]
==================================================================================
==================
Total params: 2,257,984
Trainable params: 2,223,872
Non-trainable params: 34,112
__________________________________________________________________________________
__________________
```

[25]:
```
len(base_model.layers)
```

[25]: 156

[26]:
```
# add custom layers to the model
x = base_model.output
x = Dense(1536, activation='relu')(x)
x = BatchNormalization()(x)
x = Dropout(0.3)(x)
predictions = Dense(2,activation='sigmoid')(x)
```

[27]:
```
image_model = Model(inputs=base_model.input, outputs = predictions)
```

[28]:
```
# excluding initial layers from being trained
for layer in image_model.layers[:40]:
    layer.trainable = False
```

0.1.7 Data Augmentation on Train and Validation set

[29]:
```
train_datagenerator = ImageDataGenerator(
    rotation_range=45,
    rescale = 1./255,
    width_shift_range=0.2,
    height_shift_range=0.2,
```

```
    shear_range=0.2,
    zoom_range=0.2,
    horizontal_flip=True,
    fill_mode = 'nearest')
```

[30]:
```
validation_datagenerator = ImageDataGenerator(rescale = 1./255)
```

[31]:
```
train_generator = train_datagenerator.flow_from_dataframe(
    dataframe = trainSet,
    directory = imagesPath,
    x_col = 'image_id',
    y_col = 'Smiling',
    target_size = target_size,
    batch_size = 32,
    class_mode = 'binary')
```

```
Found 15000 validated image filenames belonging to 2 classes.
```

[32]:
```
validation_generator = validation_datagenerator.flow_from_dataframe(dataframe =␣
↪validationSet,
                                                                    directory =␣
↪imagesPath,
                                                                    x_col =␣
↪'image_id',
                                                                    y_col =␣
↪'Smiling',
                                                                    target_size␣
↪= target_size,
                                                                    batch_size =␣
↪32,
                                                                    class_mode =␣
↪'binary')
```

```
Found 7500 validated image filenames belonging to 2 classes.
```

0.1.8 Train and Test model

[33]:
```
# compile the model
image_model.compile(loss = 'sparse_categorical_crossentropy',
                    optimizer = 'adam',
                    metrics = ['accuracy'])
```

[34]:
```
# create a checkpoint to save best models
checkpoint = ModelCheckpoint(filepath = 'mobilenet.smiling.hdf5',
                             verbose = 1,
                             save_best_only = True)
```

[35]:
```
# run the model
epochs_num = 10
batch_size = 75

model_history = image_model.fit_generator(train_generator,
                                          validation_data = validation_generator,
                                          steps_per_epoch = 15000/75,
                                          epochs = epochs_num,
                                          validation_steps = 7500/75,
                                          callbacks = [checkpoint],
                                          verbose=1
                                          )
```

```
WARNING:tensorflow:From C:\Users\admin\anaconda3\lib\site-
packages\tensorflow\python\ops\math_grad.py:1250:
add_dispatch_support.<locals>.wrapper (from tensorflow.python.ops.array_ops) is
deprecated and will be removed in a future version.
Instructions for updating:
Use tf.where in 2.0, which has the same broadcast rule as np.where
WARNING:tensorflow:From C:\Users\admin\anaconda3\lib\site-
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
200/200 [==============================] - 3439s 17s/step - loss: 0.5905 -
accuracy: 0.7623 - val_loss: 2.5316 - val_accuracy: 0.3259

Epoch 00001: val_loss improved from inf to 2.53157, saving model to
mobilenet.smiling.hdf5
Epoch 2/10
200/200 [==============================] - 3445s 17s/step - loss: 0.3162 -
accuracy: 0.8717 - val_loss: 6.4433 - val_accuracy: 0.4859

Epoch 00002: val_loss did not improve from 2.53157
Epoch 3/10
200/200 [==============================] - 3407s 17s/step - loss: 0.2665 -
accuracy: 0.8941 - val_loss: 6.7101 - val_accuracy: 0.4925

Epoch 00003: val_loss did not improve from 2.53157
Epoch 4/10
200/200 [==============================] - 3420s 17s/step - loss: 0.2702 -
accuracy: 0.8938 - val_loss: 3.8148 - val_accuracy: 0.6075

Epoch 00004: val_loss did not improve from 2.53157
Epoch 5/10
200/200 [==============================] - 3412s 17s/step - loss: 0.2548 -
accuracy: 0.8936 - val_loss: 1.4606 - val_accuracy: 0.7116
```

```
Epoch 00005: val_loss improved from 2.53157 to 1.46062, saving model to
mobilenet.smiling.hdf5
Epoch 6/10
200/200 [==============================] - 3414s 17s/step - loss: 0.2395 -
accuracy: 0.9038 - val_loss: 1.2720 - val_accuracy: 0.7212

Epoch 00006: val_loss improved from 1.46062 to 1.27205, saving model to
mobilenet.smiling.hdf5
Epoch 7/10
200/200 [==============================] - 3411s 17s/step - loss: 0.2360 -
accuracy: 0.9080 - val_loss: 3.8788 - val_accuracy: 0.5631

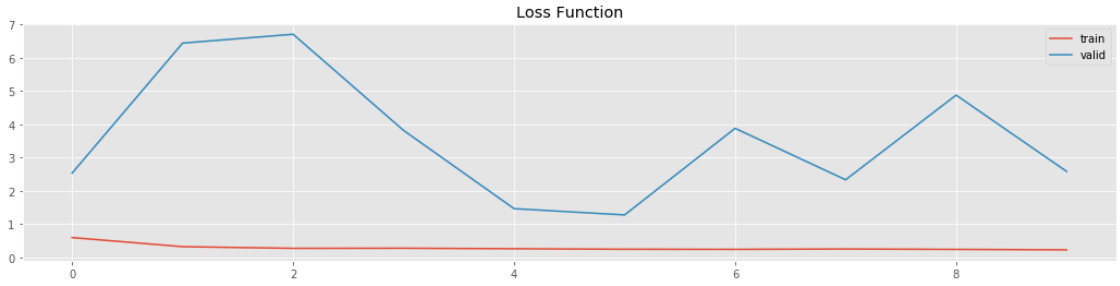
Epoch 00007: val_loss did not improve from 1.27205
Epoch 8/10
200/200 [==============================] - 3417s 17s/step - loss: 0.2472 -
accuracy: 0.9035 - val_loss: 2.3299 - val_accuracy: 0.6557

Epoch 00008: val_loss did not improve from 1.27205
Epoch 9/10
200/200 [==============================] - 3420s 17s/step - loss: 0.2350 -
accuracy: 0.9070 - val_loss: 4.8782 - val_accuracy: 0.6700

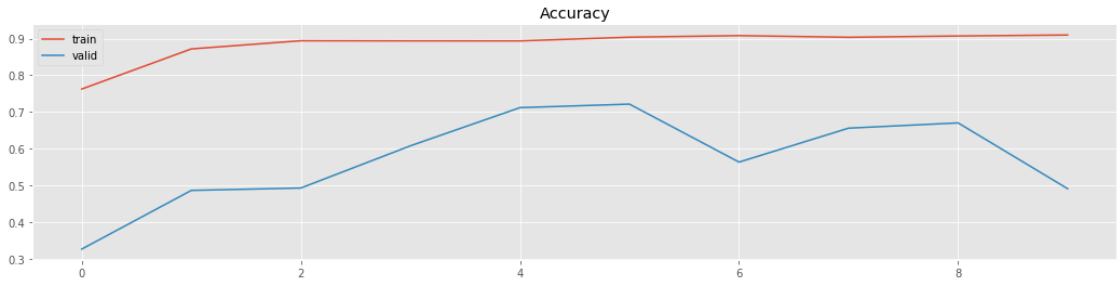
Epoch 00009: val_loss did not improve from 1.27205
Epoch 10/10
200/200 [==============================] - 3406s 17s/step - loss: 0.2216 -
accuracy: 0.9097 - val_loss: 2.5809 - val_accuracy: 0.4906

Epoch 00010: val_loss did not improve from 1.27205
```

[36]:
```
# Plot loss function value through epochs
plt.figure(figsize=(18, 4))
plt.plot(model_history.history['loss'], label = 'train')
plt.plot(model_history.history['val_loss'], label = 'valid')
plt.legend()
plt.title('Loss Function')
plt.show()
```



[37]:
```
# Plot accuracy through epochs
plt.figure(figsize=(18, 4))
plt.plot(model_history.history['accuracy'], label = 'train')
plt.plot(model_history.history['val_accuracy'], label = 'valid')
plt.legend()
plt.title('Accuracy')
plt.show()
```



[38]:
```
# get the best model
best_model = keras.models.load_model('mobilenet.smiling.hdf5')
```

[39]:
```
test_datagenerator = ImageDataGenerator(rescale=1./255)
```

[40]:
```
test_generator = test_datagenerator.flow_from_dataframe(
    dataframe = testSet,
    directory = imagesPath,
    x_col = 'image_id',
    y_col = 'Smiling',
    target_size = target_size,
    batch_size = 32,
    class_mode = 'binary')
```

```
Found 9000 validated image filenames belonging to 2 classes.
```

[41]:
```
test_score = best_model.evaluate_generator(test_generator,
                                           steps = len(test_generator),
                                           verbose = 1)
```

```
282/282 [==============================] - 2841s 10s/step
```

[43]:
```
print("Test score : ", test_score[0])
print("Test accuracy : ", test_score[1])
```

```
Test score :  1.5418912172317505
Test accuracy :  0.7210000157356262
```