AMERICAN SIGN LANGUAGE RECOGNITION PROJECT

Setting up the environment and kaggle API

Importing tensorflow and checking tensorflow:

```
import tensorflow as tf

print(tf.__version__)
```

```
1.15.0-rc3
```

Installing kaggle so as to download the dataset using kaggle API:

```
!pip install -q kaggle
```

Setting up the kaggle.json authentication file enabling me to download the dataset:

```
!mkdir -p ~/.kaggle
!cp kaggle.json ~/.kaggle/
```

Downloading the grassknoted/asl-alphabet available h

Downloading the dataset using the API:

```
!kaggle datasets download -d grassknoted/asl-alphabet
```

```
Warning: Your Kaggle API key is readable by other users on this system! To fix this,
asl-alphabet.zip: Skipping, found more recently modified local copy (use --force to f
```

Extracting the contents:

```
!unzip asl-alphabet.zip
```

```
Archive:  asl-alphabet.zip
replace asl_alphabet_test/asl_alphabet_test/A_test.jpg? [y]es, [n]o, [A]ll, [N]one, [
```

Looking at the dataset

Specifying train and test directories:

```
# Specifying the training and test directories

TRAINING_DIR = './asl_alphabet_train/asl_alphabet_train/'
TEST_DIR = './asl_alphabet_test/asl_alphabet_test/'
```

Looking at some random images from the dataset:

```
# Printing 5 random images from any training category or from a specified category
%matplotlib inline

import cv2
import os
import random
import numpy as np
import matplotlib.image as mpimg
import matplotlib.pyplot as plt

number_of_rows = 1
number_of_columns = 5

categories = os.listdir(TRAINING_DIR)

random.seed(13)

category = categories[random.randint(1, 30)]
# category = 'A'

for i in range(number_of_columns):
  subplot = plt.subplot(number_of_rows, number_of_columns, i + 1)
  subplot.axis('Off')
  subplot.set_title(category)
  image_path = os.path.join(
      TRAINING_DIR,
      str(category),
      str(category) + str(random.randint(1, 1000)) + '.jpg'
  )
  image = mpimg.imread(image_path)
  plt.imshow(image)

plt.show()
```

Preparing the training set

Augmenting the data with brightness and zoom ranges:

```
# Preparing ImageDataGenerator object for training the model
from tensorflow.keras.preprocessing.image import ImageDataGenerator

IMAGE_SIZE = 200
BATCH_SIZE = 64

data_generator = ImageDataGenerator(
    samplewise_center=True,
    samplewise_std_normalization=True,
```

```
    brightness_range=[0.8, 1.0],
    zoom_range=[1.0, 1.2],
    validation_split=0.1
)

train_generator = data_generator.flow_from_directory(TRAINING_DIR, target_size=(IMAGE_SIZE, IMAG
                                                     class_mode='categorical', batch_size=BATCH_

validation_generator = data_generator.flow_from_directory(TRAINING_DIR, target_size=(IMAGE_SIZE,
                                                     class_mode='categorical', batch_size=BATCH_
```

```
Found 78300 images belonging to 29 classes.
Found 8700 images belonging to 29 classes.
```

Preparing the model for training

Downloading custom weight file if required:

```
!wget --no-check-certificate \
    https://storage.googleapis.com/mledu-datasets/inception_v3_weights_tf_dim_ordering_tf_kernel
    -O /content/inception_v3_weights_tf_dim_ordering_tf_kernels_notop.h5
```

```
--2019-10-09 00:38:03--  https://storage.googleapis.com/mledu-datasets/inception_v3_w
Resolving storage.googleapis.com (storage.googleapis.com)... 172.217.214.128, 2607:f8
Connecting to storage.googleapis.com (storage.googleapis.com)|172.217.214.128|:443...
HTTP request sent, awaiting response... 200 OK
Length: 87910968 (84M) [application/x-hdf]
Saving to: '/content/inception_v3_weights_tf_dim_ordering_tf_kernels_notop.h5'

/content/inception_ 100%[===================>]  83.84M   123MB/s    in 0.7s

2019-10-09 00:38:04 (123 MB/s) - '/content/inception_v3_weights_tf_dim_ordering_tf_ke
```

Preparing Inception V3 Network for transfer learning:

```
# Loading inception v3 network for transfer learning
from tensorflow.keras import layers
from tensorflow.keras import Model

from tensorflow.keras.applications.inception_v3 import InceptionV3

WEIGHTS_FILE = './inception_v3_weights_tf_dim_ordering_tf_kernels_notop.h5'

inception_v3_model = InceptionV3(
    input_shape = (IMAGE_SIZE, IMAGE_SIZE, 3),
    include_top = False,
    weights = 'imagenet'
)

# Not required --> inception_v3_model.load_weights(WEIGHTS_FILE)

# Enabling the top 2 inception blocks to train
for layer in model.layers[:249]:
    layer.trainable = False
for layer in model.layers[249:]:
    layer.trainable = True

# Checking model summary to pick a layer (if required)
inception_v3_model.summary()
```

```
Model: "inception_v3"
__________________________________________________________________________________________________
Layer (type)                    Output Shape         Param #     Connected to
==================================================================================================
input_14 (InputLayer)           [(None, 200, 200, 3) 0
__________________________________________________________________________________________________
conv2d_1222 (Conv2D)            (None, 99, 99, 32)   864         input_14[0][0]
__________________________________________________________________________________________________
batch_normalization_1222 (Batch (None, 99, 99, 32)   96          conv2d_1222[0][0]
__________________________________________________________________________________________________
activation_1222 (Activation)    (None, 99, 99, 32)   0           batch_normalization_
__________________________________________________________________________________________________
conv2d_1223 (Conv2D)            (None, 97, 97, 32)   9216        activation_1222[0][0
__________________________________________________________________________________________________
batch_normalization_1223 (Batch (None, 97, 97, 32)   96          conv2d_1223[0][0]
__________________________________________________________________________________________________
activation_1223 (Activation)    (None, 97, 97, 32)   0           batch_normalization_
__________________________________________________________________________________________________
conv2d_1224 (Conv2D)            (None, 97, 97, 64)   18432       activation_1223[0][0
__________________________________________________________________________________________________
batch_normalization_1224 (Batch (None, 97, 97, 64)   192         conv2d_1224[0][0]
__________________________________________________________________________________________________
activation_1224 (Activation)    (None, 97, 97, 64)   0           batch_normalization_
__________________________________________________________________________________________________
max_pooling2d_52 (MaxPooling2D) (None, 48, 48, 64)   0           activation_1224[0][0
__________________________________________________________________________________________________
conv2d_1225 (Conv2D)            (None, 48, 48, 80)   5120        max_pooling2d_52[0][
__________________________________________________________________________________________________
batch_normalization_1225 (Batch (None, 48, 48, 80)   240         conv2d_1225[0][0]
__________________________________________________________________________________________________
activation_1225 (Activation)    (None, 48, 48, 80)   0           batch_normalization_
__________________________________________________________________________________________________
conv2d_1226 (Conv2D)            (None, 46, 46, 192)  138240      activation_1225[0][0
__________________________________________________________________________________________________
batch_normalization_1226 (Batch (None, 46, 46, 192)  576         conv2d_1226[0][0]
__________________________________________________________________________________________________
activation_1226 (Activation)    (None, 46, 46, 192)  0           batch_normalization_
__________________________________________________________________________________________________
max_pooling2d_53 (MaxPooling2D) (None, 22, 22, 192)  0           activation_1226[0][0
__________________________________________________________________________________________________
conv2d_1230 (Conv2D)            (None, 22, 22, 64)   12288       max_pooling2d_53[0][
__________________________________________________________________________________________________
batch_normalization_1230 (Batch (None, 22, 22, 64)   192         conv2d_1230[0][0]
__________________________________________________________________________________________________
activation_1230 (Activation)    (None, 22, 22, 64)   0           batch_normalization_
__________________________________________________________________________________________________
conv2d_1228 (Conv2D)            (None, 22, 22, 48)   9216        max_pooling2d_53[0][
__________________________________________________________________________________________________
conv2d_1231 (Conv2D)            (None, 22, 22, 96)   55296       activation_1230[0][0
__________________________________________________________________________________________________
batch_normalization_1228 (Batch (None, 22, 22, 48)   144         conv2d_1228[0][0]
__________________________________________________________________________________________________
batch_normalization_1231 (Batch (None, 22, 22, 96)   288         conv2d_1231[0][0]
__________________________________________________________________________________________________
activation_1228 (Activation)    (None, 22, 22, 48)   0           batch_normalization_
__________________________________________________________________________________________________
activation_1231 (Activation)    (None, 22, 22, 96)   0           batch_normalization_
__________________________________________________________________________________________________
average_pooling2d_117 (AverageP (None, 22, 22, 192)  0           max_pooling2d_53[0][
__________________________________________________________________________________________________
conv2d_1227 (Conv2D)            (None, 22, 22, 64)   12288       max_pooling2d_53[0][
```

conv2d_1229 (Conv2D)	(None, 22, 22, 64)	76800	activation_1228[0][0
conv2d_1232 (Conv2D)	(None, 22, 22, 96)	82944	activation_1231[0][0
conv2d_1233 (Conv2D)	(None, 22, 22, 32)	6144	average_pooling2d_11
batch_normalization_1227 (Batch	(None, 22, 22, 64)	192	conv2d_1227[0][0]
batch_normalization_1229 (Batch	(None, 22, 22, 64)	192	conv2d_1229[0][0]
batch_normalization_1232 (Batch	(None, 22, 22, 96)	288	conv2d_1232[0][0]
batch_normalization_1233 (Batch	(None, 22, 22, 32)	96	conv2d_1233[0][0]
activation_1227 (Activation)	(None, 22, 22, 64)	0	batch_normalization_
activation_1229 (Activation)	(None, 22, 22, 64)	0	batch_normalization_
activation_1232 (Activation)	(None, 22, 22, 96)	0	batch_normalization_
activation_1233 (Activation)	(None, 22, 22, 32)	0	batch_normalization_
mixed0 (Concatenate)	(None, 22, 22, 256)	0	activation_1227[0][0 activation_1229[0][0 activation_1232[0][0 activation_1233[0][0
conv2d_1237 (Conv2D)	(None, 22, 22, 64)	16384	mixed0[0][0]
batch_normalization_1237 (Batch	(None, 22, 22, 64)	192	conv2d_1237[0][0]
activation_1237 (Activation)	(None, 22, 22, 64)	0	batch_normalization_
conv2d_1235 (Conv2D)	(None, 22, 22, 48)	12288	mixed0[0][0]
conv2d_1238 (Conv2D)	(None, 22, 22, 96)	55296	activation_1237[0][0
batch_normalization_1235 (Batch	(None, 22, 22, 48)	144	conv2d_1235[0][0]
batch_normalization_1238 (Batch	(None, 22, 22, 96)	288	conv2d_1238[0][0]
activation_1235 (Activation)	(None, 22, 22, 48)	0	batch_normalization_
activation_1238 (Activation)	(None, 22, 22, 96)	0	batch_normalization_
average_pooling2d_118 (AverageP	(None, 22, 22, 256)	0	mixed0[0][0]
conv2d_1234 (Conv2D)	(None, 22, 22, 64)	16384	mixed0[0][0]
conv2d_1236 (Conv2D)	(None, 22, 22, 64)	76800	activation_1235[0][0
conv2d_1239 (Conv2D)	(None, 22, 22, 96)	82944	activation_1238[0][0
conv2d_1240 (Conv2D)	(None, 22, 22, 64)	16384	average_pooling2d_11
batch_normalization_1234 (Batch	(None, 22, 22, 64)	192	conv2d_1234[0][0]
batch_normalization_1236 (Batch	(None, 22, 22, 64)	192	conv2d_1236[0][0]
batch_normalization_1239 (Batch	(None, 22, 22, 96)	288	conv2d_1239[0][0]

batch_normalization_1240 (Batch	(None, 22, 22, 64)	192	conv2d_1240[0][0]
activation_1234 (Activation)	(None, 22, 22, 64)	0	batch_normalization_
activation_1236 (Activation)	(None, 22, 22, 64)	0	batch_normalization_
activation_1239 (Activation)	(None, 22, 22, 96)	0	batch_normalization_
activation_1240 (Activation)	(None, 22, 22, 64)	0	batch_normalization_
mixed1 (Concatenate)	(None, 22, 22, 288)	0	activation_1234[0][0 activation_1236[0][0 activation_1239[0][0 activation_1240[0][0
conv2d_1244 (Conv2D)	(None, 22, 22, 64)	18432	mixed1[0][0]
batch_normalization_1244 (Batch	(None, 22, 22, 64)	192	conv2d_1244[0][0]
activation_1244 (Activation)	(None, 22, 22, 64)	0	batch_normalization_
conv2d_1242 (Conv2D)	(None, 22, 22, 48)	13824	mixed1[0][0]
conv2d_1245 (Conv2D)	(None, 22, 22, 96)	55296	activation_1244[0][0
batch_normalization_1242 (Batch	(None, 22, 22, 48)	144	conv2d_1242[0][0]
batch_normalization_1245 (Batch	(None, 22, 22, 96)	288	conv2d_1245[0][0]
activation_1242 (Activation)	(None, 22, 22, 48)	0	batch_normalization_
activation_1245 (Activation)	(None, 22, 22, 96)	0	batch_normalization_
average_pooling2d_119 (AverageP	(None, 22, 22, 288)	0	mixed1[0][0]
conv2d_1241 (Conv2D)	(None, 22, 22, 64)	18432	mixed1[0][0]
conv2d_1243 (Conv2D)	(None, 22, 22, 64)	76800	activation_1242[0][0
conv2d_1246 (Conv2D)	(None, 22, 22, 96)	82944	activation_1245[0][0
conv2d_1247 (Conv2D)	(None, 22, 22, 64)	18432	average_pooling2d_11
batch_normalization_1241 (Batch	(None, 22, 22, 64)	192	conv2d_1241[0][0]
batch_normalization_1243 (Batch	(None, 22, 22, 64)	192	conv2d_1243[0][0]
batch_normalization_1246 (Batch	(None, 22, 22, 96)	288	conv2d_1246[0][0]
batch_normalization_1247 (Batch	(None, 22, 22, 64)	192	conv2d_1247[0][0]
activation_1241 (Activation)	(None, 22, 22, 64)	0	batch_normalization_
activation_1243 (Activation)	(None, 22, 22, 64)	0	batch_normalization_
activation_1246 (Activation)	(None, 22, 22, 96)	0	batch_normalization_
activation_1247 (Activation)	(None, 22, 22, 64)	0	batch_normalization_
mixed2 (Concatenate)	(None, 22, 22, 288)	0	activation_1241[0][0 activation_1243[0][0

```
                                                                 activation_1246[0][0
                                                                 activation_1247[0][0
__________________________________________________________________________________________________
conv2d_1249 (Conv2D)            (None, 22, 22, 64)   18432       mixed2[0][0]
__________________________________________________________________________________________________
batch_normalization_1249 (Batch (None, 22, 22, 64)   192         conv2d_1249[0][0]
__________________________________________________________________________________________________
activation_1249 (Activation)    (None, 22, 22, 64)   0           batch_normalization_
__________________________________________________________________________________________________
conv2d_1250 (Conv2D)            (None, 22, 22, 96)   55296       activation_1249[0][0
__________________________________________________________________________________________________
batch_normalization_1250 (Batch (None, 22, 22, 96)   288         conv2d_1250[0][0]
__________________________________________________________________________________________________
activation_1250 (Activation)    (None, 22, 22, 96)   0           batch_normalization_
__________________________________________________________________________________________________
conv2d_1248 (Conv2D)            (None, 10, 10, 384)  995328      mixed2[0][0]
__________________________________________________________________________________________________
conv2d_1251 (Conv2D)            (None, 10, 10, 96)   82944       activation_1250[0][0
__________________________________________________________________________________________________
batch_normalization_1248 (Batch (None, 10, 10, 384)  1152        conv2d_1248[0][0]
__________________________________________________________________________________________________
batch_normalization_1251 (Batch (None, 10, 10, 96)   288         conv2d_1251[0][0]
__________________________________________________________________________________________________
activation_1248 (Activation)    (None, 10, 10, 384)  0           batch_normalization_
__________________________________________________________________________________________________
activation_1251 (Activation)    (None, 10, 10, 96)   0           batch_normalization_
__________________________________________________________________________________________________
max_pooling2d_54 (MaxPooling2D) (None, 10, 10, 288)  0           mixed2[0][0]
__________________________________________________________________________________________________
mixed3 (Concatenate)            (None, 10, 10, 768)  0           activation_1248[0][0
                                                                 activation_1251[0][0
                                                                 max_pooling2d_54[0][
__________________________________________________________________________________________________
conv2d_1256 (Conv2D)            (None, 10, 10, 128)  98304       mixed3[0][0]
__________________________________________________________________________________________________
batch_normalization_1256 (Batch (None, 10, 10, 128)  384         conv2d_1256[0][0]
__________________________________________________________________________________________________
activation_1256 (Activation)    (None, 10, 10, 128)  0           batch_normalization_
__________________________________________________________________________________________________
conv2d_1257 (Conv2D)            (None, 10, 10, 128)  114688      activation_1256[0][0
__________________________________________________________________________________________________
batch_normalization_1257 (Batch (None, 10, 10, 128)  384         conv2d_1257[0][0]
__________________________________________________________________________________________________
activation_1257 (Activation)    (None, 10, 10, 128)  0           batch_normalization_
__________________________________________________________________________________________________
conv2d_1253 (Conv2D)            (None, 10, 10, 128)  98304       mixed3[0][0]
__________________________________________________________________________________________________
conv2d_1258 (Conv2D)            (None, 10, 10, 128)  114688      activation_1257[0][0
__________________________________________________________________________________________________
batch_normalization_1253 (Batch (None, 10, 10, 128)  384         conv2d_1253[0][0]
__________________________________________________________________________________________________
batch_normalization_1258 (Batch (None, 10, 10, 128)  384         conv2d_1258[0][0]
__________________________________________________________________________________________________
activation_1253 (Activation)    (None, 10, 10, 128)  0           batch_normalization_
__________________________________________________________________________________________________
activation_1258 (Activation)    (None, 10, 10, 128)  0           batch_normalization_
__________________________________________________________________________________________________
conv2d_1254 (Conv2D)            (None, 10, 10, 128)  114688      activation_1253[0][0
__________________________________________________________________________________________________
conv2d_1259 (Conv2D)            (None, 10, 10, 128)  114688      activation_1258[0][0
__________________________________________________________________________________________________
batch_normalization_1254 (Batch (None, 10, 10, 128)  384         conv2d_1254[0][0]
```

batch_normalization_1259 (Batch	(None, 10, 10, 128)	384	conv2d_1259[0][0]
activation_1254 (Activation)	(None, 10, 10, 128)	0	batch_normalization_
activation_1259 (Activation)	(None, 10, 10, 128)	0	batch_normalization_
average_pooling2d_120 (AverageP	(None, 10, 10, 768)	0	mixed3[0][0]
conv2d_1252 (Conv2D)	(None, 10, 10, 192)	147456	mixed3[0][0]
conv2d_1255 (Conv2D)	(None, 10, 10, 192)	172032	activation_1254[0][0
conv2d_1260 (Conv2D)	(None, 10, 10, 192)	172032	activation_1259[0][0
conv2d_1261 (Conv2D)	(None, 10, 10, 192)	147456	average_pooling2d_12
batch_normalization_1252 (Batch	(None, 10, 10, 192)	576	conv2d_1252[0][0]
batch_normalization_1255 (Batch	(None, 10, 10, 192)	576	conv2d_1255[0][0]
batch_normalization_1260 (Batch	(None, 10, 10, 192)	576	conv2d_1260[0][0]
batch_normalization_1261 (Batch	(None, 10, 10, 192)	576	conv2d_1261[0][0]
activation_1252 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1255 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1260 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1261 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
mixed4 (Concatenate)	(None, 10, 10, 768)	0	activation_1252[0][0 activation_1255[0][0 activation_1260[0][0 activation_1261[0][0
conv2d_1266 (Conv2D)	(None, 10, 10, 160)	122880	mixed4[0][0]
batch_normalization_1266 (Batch	(None, 10, 10, 160)	480	conv2d_1266[0][0]
activation_1266 (Activation)	(None, 10, 10, 160)	0	batch_normalization_
conv2d_1267 (Conv2D)	(None, 10, 10, 160)	179200	activation_1266[0][0
batch_normalization_1267 (Batch	(None, 10, 10, 160)	480	conv2d_1267[0][0]
activation_1267 (Activation)	(None, 10, 10, 160)	0	batch_normalization_
conv2d_1263 (Conv2D)	(None, 10, 10, 160)	122880	mixed4[0][0]
conv2d_1268 (Conv2D)	(None, 10, 10, 160)	179200	activation_1267[0][0
batch_normalization_1263 (Batch	(None, 10, 10, 160)	480	conv2d_1263[0][0]
batch_normalization_1268 (Batch	(None, 10, 10, 160)	480	conv2d_1268[0][0]
activation_1263 (Activation)	(None, 10, 10, 160)	0	batch_normalization_
activation_1268 (Activation)	(None, 10, 10, 160)	0	batch_normalization_

conv2d_1264 (Conv2D)	(None, 10, 10, 160)	179200	activation_1263[0][0
conv2d_1269 (Conv2D)	(None, 10, 10, 160)	179200	activation_1268[0][0
batch_normalization_1264 (Batch	(None, 10, 10, 160)	480	conv2d_1264[0][0]
batch_normalization_1269 (Batch	(None, 10, 10, 160)	480	conv2d_1269[0][0]
activation_1264 (Activation)	(None, 10, 10, 160)	0	batch_normalization_
activation_1269 (Activation)	(None, 10, 10, 160)	0	batch_normalization_
average_pooling2d_121 (AverageP	(None, 10, 10, 768)	0	mixed4[0][0]
conv2d_1262 (Conv2D)	(None, 10, 10, 192)	147456	mixed4[0][0]
conv2d_1265 (Conv2D)	(None, 10, 10, 192)	215040	activation_1264[0][0
conv2d_1270 (Conv2D)	(None, 10, 10, 192)	215040	activation_1269[0][0
conv2d_1271 (Conv2D)	(None, 10, 10, 192)	147456	average_pooling2d_12
batch_normalization_1262 (Batch	(None, 10, 10, 192)	576	conv2d_1262[0][0]
batch_normalization_1265 (Batch	(None, 10, 10, 192)	576	conv2d_1265[0][0]
batch_normalization_1270 (Batch	(None, 10, 10, 192)	576	conv2d_1270[0][0]
batch_normalization_1271 (Batch	(None, 10, 10, 192)	576	conv2d_1271[0][0]
activation_1262 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1265 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1270 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1271 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
mixed5 (Concatenate)	(None, 10, 10, 768)	0	activation_1262[0][0 activation_1265[0][0 activation_1270[0][0 activation_1271[0][0
conv2d_1276 (Conv2D)	(None, 10, 10, 160)	122880	mixed5[0][0]
batch_normalization_1276 (Batch	(None, 10, 10, 160)	480	conv2d_1276[0][0]
activation_1276 (Activation)	(None, 10, 10, 160)	0	batch_normalization_
conv2d_1277 (Conv2D)	(None, 10, 10, 160)	179200	activation_1276[0][0
batch_normalization_1277 (Batch	(None, 10, 10, 160)	480	conv2d_1277[0][0]
activation_1277 (Activation)	(None, 10, 10, 160)	0	batch_normalization_
conv2d_1273 (Conv2D)	(None, 10, 10, 160)	122880	mixed5[0][0]
conv2d_1278 (Conv2D)	(None, 10, 10, 160)	179200	activation_1277[0][0
batch_normalization_1273 (Batch	(None, 10, 10, 160)	480	conv2d_1273[0][0]

batch_normalization_1278 (Batch	(None, 10, 10, 160)	480	conv2d_1278[0][0]
activation_1273 (Activation)	(None, 10, 10, 160)	0	batch_normalization_
activation_1278 (Activation)	(None, 10, 10, 160)	0	batch_normalization_
conv2d_1274 (Conv2D)	(None, 10, 10, 160)	179200	activation_1273[0][0
conv2d_1279 (Conv2D)	(None, 10, 10, 160)	179200	activation_1278[0][0
batch_normalization_1274 (Batch	(None, 10, 10, 160)	480	conv2d_1274[0][0]
batch_normalization_1279 (Batch	(None, 10, 10, 160)	480	conv2d_1279[0][0]
activation_1274 (Activation)	(None, 10, 10, 160)	0	batch_normalization_
activation_1279 (Activation)	(None, 10, 10, 160)	0	batch_normalization_
average_pooling2d_122 (AverageP	(None, 10, 10, 768)	0	mixed5[0][0]
conv2d_1272 (Conv2D)	(None, 10, 10, 192)	147456	mixed5[0][0]
conv2d_1275 (Conv2D)	(None, 10, 10, 192)	215040	activation_1274[0][0
conv2d_1280 (Conv2D)	(None, 10, 10, 192)	215040	activation_1279[0][0
conv2d_1281 (Conv2D)	(None, 10, 10, 192)	147456	average_pooling2d_12
batch_normalization_1272 (Batch	(None, 10, 10, 192)	576	conv2d_1272[0][0]
batch_normalization_1275 (Batch	(None, 10, 10, 192)	576	conv2d_1275[0][0]
batch_normalization_1280 (Batch	(None, 10, 10, 192)	576	conv2d_1280[0][0]
batch_normalization_1281 (Batch	(None, 10, 10, 192)	576	conv2d_1281[0][0]
activation_1272 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1275 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1280 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1281 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
mixed6 (Concatenate)	(None, 10, 10, 768)	0	activation_1272[0][0 activation_1275[0][0 activation_1280[0][0 activation_1281[0][0
conv2d_1286 (Conv2D)	(None, 10, 10, 192)	147456	mixed6[0][0]
batch_normalization_1286 (Batch	(None, 10, 10, 192)	576	conv2d_1286[0][0]
activation_1286 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
conv2d_1287 (Conv2D)	(None, 10, 10, 192)	258048	activation_1286[0][0
batch_normalization_1287 (Batch	(None, 10, 10, 192)	576	conv2d_1287[0][0]
activation_1287 (Activation)	(None, 10, 10, 192)	0	batch_normalization_

conv2d_1283 (Conv2D)	(None, 10, 10, 192)	147456	mixed6[0][0]
conv2d_1288 (Conv2D)	(None, 10, 10, 192)	258048	activation_1287[0][0
batch_normalization_1283 (Batch	(None, 10, 10, 192)	576	conv2d_1283[0][0]
batch_normalization_1288 (Batch	(None, 10, 10, 192)	576	conv2d_1288[0][0]
activation_1283 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1288 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
conv2d_1284 (Conv2D)	(None, 10, 10, 192)	258048	activation_1283[0][0
conv2d_1289 (Conv2D)	(None, 10, 10, 192)	258048	activation_1288[0][0
batch_normalization_1284 (Batch	(None, 10, 10, 192)	576	conv2d_1284[0][0]
batch_normalization_1289 (Batch	(None, 10, 10, 192)	576	conv2d_1289[0][0]
activation_1284 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1289 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
average_pooling2d_123 (AverageP	(None, 10, 10, 768)	0	mixed6[0][0]
conv2d_1282 (Conv2D)	(None, 10, 10, 192)	147456	mixed6[0][0]
conv2d_1285 (Conv2D)	(None, 10, 10, 192)	258048	activation_1284[0][0
conv2d_1290 (Conv2D)	(None, 10, 10, 192)	258048	activation_1289[0][0
conv2d_1291 (Conv2D)	(None, 10, 10, 192)	147456	average_pooling2d_12
batch_normalization_1282 (Batch	(None, 10, 10, 192)	576	conv2d_1282[0][0]
batch_normalization_1285 (Batch	(None, 10, 10, 192)	576	conv2d_1285[0][0]
batch_normalization_1290 (Batch	(None, 10, 10, 192)	576	conv2d_1290[0][0]
batch_normalization_1291 (Batch	(None, 10, 10, 192)	576	conv2d_1291[0][0]
activation_1282 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1285 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1290 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1291 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
mixed7 (Concatenate)	(None, 10, 10, 768)	0	activation_1282[0][0 activation_1285[0][0 activation_1290[0][0 activation_1291[0][0
conv2d_1294 (Conv2D)	(None, 10, 10, 192)	147456	mixed7[0][0]
batch_normalization_1294 (Batch	(None, 10, 10, 192)	576	conv2d_1294[0][0]
activation_1294 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
conv2d_1295 (Conv2D)	(None, 10, 10, 192)	258048	activation_1294[0][0

batch_normalization_1295 (Batch	(None, 10, 10, 192)	576	conv2d_1295[0][0]
activation_1295 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
conv2d_1292 (Conv2D)	(None, 10, 10, 192)	147456	mixed7[0][0]
conv2d_1296 (Conv2D)	(None, 10, 10, 192)	258048	activation_1295[0][0
batch_normalization_1292 (Batch	(None, 10, 10, 192)	576	conv2d_1292[0][0]
batch_normalization_1296 (Batch	(None, 10, 10, 192)	576	conv2d_1296[0][0]
activation_1292 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1296 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
conv2d_1293 (Conv2D)	(None, 4, 4, 320)	552960	activation_1292[0][0
conv2d_1297 (Conv2D)	(None, 4, 4, 192)	331776	activation_1296[0][0
batch_normalization_1293 (Batch	(None, 4, 4, 320)	960	conv2d_1293[0][0]
batch_normalization_1297 (Batch	(None, 4, 4, 192)	576	conv2d_1297[0][0]
activation_1293 (Activation)	(None, 4, 4, 320)	0	batch_normalization_
activation_1297 (Activation)	(None, 4, 4, 192)	0	batch_normalization_
max_pooling2d_55 (MaxPooling2D)	(None, 4, 4, 768)	0	mixed7[0][0]
mixed8 (Concatenate)	(None, 4, 4, 1280)	0	activation_1293[0][0 activation_1297[0][0 max_pooling2d_55[0][
conv2d_1302 (Conv2D)	(None, 4, 4, 448)	573440	mixed8[0][0]
batch_normalization_1302 (Batch	(None, 4, 4, 448)	1344	conv2d_1302[0][0]
activation_1302 (Activation)	(None, 4, 4, 448)	0	batch_normalization_
conv2d_1299 (Conv2D)	(None, 4, 4, 384)	491520	mixed8[0][0]
conv2d_1303 (Conv2D)	(None, 4, 4, 384)	1548288	activation_1302[0][0
batch_normalization_1299 (Batch	(None, 4, 4, 384)	1152	conv2d_1299[0][0]
batch_normalization_1303 (Batch	(None, 4, 4, 384)	1152	conv2d_1303[0][0]
activation_1299 (Activation)	(None, 4, 4, 384)	0	batch_normalization_
activation_1303 (Activation)	(None, 4, 4, 384)	0	batch_normalization_
conv2d_1300 (Conv2D)	(None, 4, 4, 384)	442368	activation_1299[0][0
conv2d_1301 (Conv2D)	(None, 4, 4, 384)	442368	activation_1299[0][0
conv2d_1304 (Conv2D)	(None, 4, 4, 384)	442368	activation_1303[0][0
conv2d_1305 (Conv2D)	(None, 4, 4, 384)	442368	activation_1303[0][0

average_pooling2d_124 (AverageP	(None, 4, 4, 1280)	0	mixed8[0][0]
conv2d_1298 (Conv2D)	(None, 4, 4, 320)	409600	mixed8[0][0]
batch_normalization_1300 (Batch	(None, 4, 4, 384)	1152	conv2d_1300[0][0]
batch_normalization_1301 (Batch	(None, 4, 4, 384)	1152	conv2d_1301[0][0]
batch_normalization_1304 (Batch	(None, 4, 4, 384)	1152	conv2d_1304[0][0]
batch_normalization_1305 (Batch	(None, 4, 4, 384)	1152	conv2d_1305[0][0]
conv2d_1306 (Conv2D)	(None, 4, 4, 192)	245760	average_pooling2d_12
batch_normalization_1298 (Batch	(None, 4, 4, 320)	960	conv2d_1298[0][0]
activation_1300 (Activation)	(None, 4, 4, 384)	0	batch_normalization_
activation_1301 (Activation)	(None, 4, 4, 384)	0	batch_normalization_
activation_1304 (Activation)	(None, 4, 4, 384)	0	batch_normalization_
activation_1305 (Activation)	(None, 4, 4, 384)	0	batch_normalization_
batch_normalization_1306 (Batch	(None, 4, 4, 192)	576	conv2d_1306[0][0]
activation_1298 (Activation)	(None, 4, 4, 320)	0	batch_normalization_
mixed9_0 (Concatenate)	(None, 4, 4, 768)	0	activation_1300[0][0] activation_1301[0][0]
concatenate_26 (Concatenate)	(None, 4, 4, 768)	0	activation_1304[0][0] activation_1305[0][0]
activation_1306 (Activation)	(None, 4, 4, 192)	0	batch_normalization_
mixed9 (Concatenate)	(None, 4, 4, 2048)	0	activation_1298[0][0] mixed9_0[0][0] concatenate_26[0][0] activation_1306[0][0]
conv2d_1311 (Conv2D)	(None, 4, 4, 448)	917504	mixed9[0][0]
batch_normalization_1311 (Batch	(None, 4, 4, 448)	1344	conv2d_1311[0][0]
activation_1311 (Activation)	(None, 4, 4, 448)	0	batch_normalization_
conv2d_1308 (Conv2D)	(None, 4, 4, 384)	786432	mixed9[0][0]
conv2d_1312 (Conv2D)	(None, 4, 4, 384)	1548288	activation_1311[0][0]
batch_normalization_1308 (Batch	(None, 4, 4, 384)	1152	conv2d_1308[0][0]
batch_normalization_1312 (Batch	(None, 4, 4, 384)	1152	conv2d_1312[0][0]
activation_1308 (Activation)	(None, 4, 4, 384)	0	batch_normalization_
activation_1312 (Activation)	(None, 4, 4, 384)	0	batch_normalization_
conv2d_1309 (Conv2D)	(None, 4, 4, 384)	442368	activation_1308[0][0]
conv2d_1310 (Conv2D)	(None, 4, 4, 384)	442368	activation_1308[0][0]

```
conv2d_1313 (Conv2D)            (None, 4, 4, 384)    442368      activation_1312[0][0
conv2d_1314 (Conv2D)            (None, 4, 4, 384)    442368      activation_1312[0][0
average_pooling2d_125 (AverageP (None, 4, 4, 2048)   0           mixed9[0][0]
conv2d_1307 (Conv2D)            (None, 4, 4, 320)    655360      mixed9[0][0]
batch_normalization_1309 (Batch (None, 4, 4, 384)    1152        conv2d_1309[0][0]
batch_normalization_1310 (Batch (None, 4, 4, 384)    1152        conv2d_1310[0][0]
batch_normalization_1313 (Batch (None, 4, 4, 384)    1152        conv2d_1313[0][0]
batch_normalization_1314 (Batch (None, 4, 4, 384)    1152        conv2d_1314[0][0]
conv2d_1315 (Conv2D)            (None, 4, 4, 192)    393216      average_pooling2d_12
batch_normalization_1307 (Batch (None, 4, 4, 320)    960         conv2d_1307[0][0]
activation_1309 (Activation)    (None, 4, 4, 384)    0           batch_normalization_
activation_1310 (Activation)    (None, 4, 4, 384)    0           batch_normalization_
activation_1313 (Activation)    (None, 4, 4, 384)    0           batch_normalization_
activation_1314 (Activation)    (None, 4, 4, 384)    0           batch_normalization_
batch_normalization_1315 (Batch (None, 4, 4, 192)    576         conv2d_1315[0][0]
activation_1307 (Activation)    (None, 4, 4, 320)    0           batch_normalization_
mixed9_1 (Concatenate)          (None, 4, 4, 768)    0           activation_1309[0][0
                                                                 activation_1310[0][0
concatenate_27 (Concatenate)    (None, 4, 4, 768)    0           activation_1313[0][0
                                                                 activation_1314[0][0
activation_1315 (Activation)    (None, 4, 4, 192)    0           batch_normalization_
mixed10 (Concatenate)           (None, 4, 4, 2048)   0           activation_1307[0][0
                                                                 mixed9_1[0][0]
                                                                 concatenate_27[0][0]
                                                                 activation_1315[0][0
==================================================================================================
Total params: 21,802,784
Trainable params: 21,768,352
Non-trainable params: 34,432
__________________________________________________________________________________________________
```

Choosing the inception output layer:

```
# Choosing the output layer to be merged with our FC layers (if required)
inception_output_layer = inception_v3_model.get_layer('mixed7')
print('Inception model output shape:', inception_output_layer.output_shape)

# Not required --> inception_output = inception_output_layer.output
inception_output = inception_v3_model.output
```

```
Inception model output shape: (None, 10, 10, 768)
```

Adding our own set of fully connected layers at the end of Inception v3 network:

```
from tensorflow.keras.optimizers import RMSprop, Adam, SGD

x = layers.GlobalAveragePooling2D()(inception_output)
x = layers.Dense(1024, activation='relu')(x)
# Not required --> x = layers.Dropout(0.2)(x)
x = layers.Dense(29, activation='softmax')(x)

model = Model(inception_v3_model.input, x)

model.compile(
    optimizer=SGD(lr=0.0001, momentum=0.9),
    loss='categorical_crossentropy',
    metrics=['acc']
)
```

Looking at the final model:

```
# Watch the new model summary
model.summary()
```

```
Model: "model_16"
__________________________________________________________________________________________________
Layer (type)                    Output Shape         Param #     Connected to
==================================================================================================
input_14 (InputLayer)           [(None, 200, 200, 3) 0
__________________________________________________________________________________________________
conv2d_1222 (Conv2D)            (None, 99, 99, 32)   864         input_14[0][0]
__________________________________________________________________________________________________
batch_normalization_1222 (Batch (None, 99, 99, 32)   96          conv2d_1222[0][0]
__________________________________________________________________________________________________
activation_1222 (Activation)    (None, 99, 99, 32)   0           batch_normalization_
__________________________________________________________________________________________________
conv2d_1223 (Conv2D)            (None, 97, 97, 32)   9216        activation_1222[0][0
__________________________________________________________________________________________________
batch_normalization_1223 (Batch (None, 97, 97, 32)   96          conv2d_1223[0][0]
__________________________________________________________________________________________________
activation_1223 (Activation)    (None, 97, 97, 32)   0           batch_normalization_
__________________________________________________________________________________________________
conv2d_1224 (Conv2D)            (None, 97, 97, 64)   18432       activation_1223[0][0
__________________________________________________________________________________________________
batch_normalization_1224 (Batch (None, 97, 97, 64)   192         conv2d_1224[0][0]
__________________________________________________________________________________________________
activation_1224 (Activation)    (None, 97, 97, 64)   0           batch_normalization_
__________________________________________________________________________________________________
max_pooling2d_52 (MaxPooling2D) (None, 48, 48, 64)   0           activation_1224[0][0
__________________________________________________________________________________________________
conv2d_1225 (Conv2D)            (None, 48, 48, 80)   5120        max_pooling2d_52[0][
__________________________________________________________________________________________________
batch_normalization_1225 (Batch (None, 48, 48, 80)   240         conv2d_1225[0][0]
__________________________________________________________________________________________________
activation_1225 (Activation)    (None, 48, 48, 80)   0           batch_normalization_
__________________________________________________________________________________________________
conv2d_1226 (Conv2D)            (None, 46, 46, 192)  138240      activation_1225[0][0
__________________________________________________________________________________________________
batch_normalization_1226 (Batch (None, 46, 46, 192)  576         conv2d_1226[0][0]
__________________________________________________________________________________________________
activation_1226 (Activation)    (None, 46, 46, 192)  0           batch_normalization_
__________________________________________________________________________________________________
max_pooling2d_53 (MaxPooling2D) (None, 22, 22, 192)  0           activation_1226[0][0
__________________________________________________________________________________________________
conv2d_1230 (Conv2D)            (None, 22, 22, 64)   12288       max_pooling2d_53[0][
__________________________________________________________________________________________________
batch_normalization_1230 (Batch (None, 22, 22, 64)   192         conv2d_1230[0][0]
__________________________________________________________________________________________________
activation_1230 (Activation)    (None, 22, 22, 64)   0           batch_normalization_
__________________________________________________________________________________________________
conv2d_1228 (Conv2D)            (None, 22, 22, 48)   9216        max_pooling2d_53[0][
__________________________________________________________________________________________________
conv2d_1231 (Conv2D)            (None, 22, 22, 96)   55296       activation_1230[0][0
__________________________________________________________________________________________________
batch_normalization_1228 (Batch (None, 22, 22, 48)   144         conv2d_1228[0][0]
__________________________________________________________________________________________________
batch_normalization_1231 (Batch (None, 22, 22, 96)   288         conv2d_1231[0][0]
__________________________________________________________________________________________________
activation_1228 (Activation)    (None, 22, 22, 48)   0           batch_normalization_
__________________________________________________________________________________________________
activation_1231 (Activation)    (None, 22, 22, 96)   0           batch_normalization_
__________________________________________________________________________________________________
average_pooling2d_117 (AverageP (None, 22, 22, 192)  0           max_pooling2d_53[0][
__________________________________________________________________________________________________
conv2d_1227 (Conv2D)            (None, 22, 22, 64)   12288       max_pooling2d_53[0][
```

conv2d_1229 (Conv2D)	(None, 22, 22, 64)	76800	activation_1228[0][0
conv2d_1232 (Conv2D)	(None, 22, 22, 96)	82944	activation_1231[0][0
conv2d_1233 (Conv2D)	(None, 22, 22, 32)	6144	average_pooling2d_11
batch_normalization_1227 (Batch	(None, 22, 22, 64)	192	conv2d_1227[0][0]
batch_normalization_1229 (Batch	(None, 22, 22, 64)	192	conv2d_1229[0][0]
batch_normalization_1232 (Batch	(None, 22, 22, 96)	288	conv2d_1232[0][0]
batch_normalization_1233 (Batch	(None, 22, 22, 32)	96	conv2d_1233[0][0]
activation_1227 (Activation)	(None, 22, 22, 64)	0	batch_normalization_
activation_1229 (Activation)	(None, 22, 22, 64)	0	batch_normalization_
activation_1232 (Activation)	(None, 22, 22, 96)	0	batch_normalization_
activation_1233 (Activation)	(None, 22, 22, 32)	0	batch_normalization_
mixed0 (Concatenate)	(None, 22, 22, 256)	0	activation_1227[0][0 activation_1229[0][0 activation_1232[0][0 activation_1233[0][0
conv2d_1237 (Conv2D)	(None, 22, 22, 64)	16384	mixed0[0][0]
batch_normalization_1237 (Batch	(None, 22, 22, 64)	192	conv2d_1237[0][0]
activation_1237 (Activation)	(None, 22, 22, 64)	0	batch_normalization_
conv2d_1235 (Conv2D)	(None, 22, 22, 48)	12288	mixed0[0][0]
conv2d_1238 (Conv2D)	(None, 22, 22, 96)	55296	activation_1237[0][0
batch_normalization_1235 (Batch	(None, 22, 22, 48)	144	conv2d_1235[0][0]
batch_normalization_1238 (Batch	(None, 22, 22, 96)	288	conv2d_1238[0][0]
activation_1235 (Activation)	(None, 22, 22, 48)	0	batch_normalization_
activation_1238 (Activation)	(None, 22, 22, 96)	0	batch_normalization_
average_pooling2d_118 (AverageP	(None, 22, 22, 256)	0	mixed0[0][0]
conv2d_1234 (Conv2D)	(None, 22, 22, 64)	16384	mixed0[0][0]
conv2d_1236 (Conv2D)	(None, 22, 22, 64)	76800	activation_1235[0][0
conv2d_1239 (Conv2D)	(None, 22, 22, 96)	82944	activation_1238[0][0
conv2d_1240 (Conv2D)	(None, 22, 22, 64)	16384	average_pooling2d_11
batch_normalization_1234 (Batch	(None, 22, 22, 64)	192	conv2d_1234[0][0]
batch_normalization_1236 (Batch	(None, 22, 22, 64)	192	conv2d_1236[0][0]
batch_normalization_1239 (Batch	(None, 22, 22, 96)	288	conv2d_1239[0][0]

batch_normalization_1240 (Batch	(None, 22, 22, 64)	192	conv2d_1240[0][0]
activation_1234 (Activation)	(None, 22, 22, 64)	0	batch_normalization_
activation_1236 (Activation)	(None, 22, 22, 64)	0	batch_normalization_
activation_1239 (Activation)	(None, 22, 22, 96)	0	batch_normalization_
activation_1240 (Activation)	(None, 22, 22, 64)	0	batch_normalization_
mixed1 (Concatenate)	(None, 22, 22, 288)	0	activation_1234[0][0 activation_1236[0][0 activation_1239[0][0 activation_1240[0][0
conv2d_1244 (Conv2D)	(None, 22, 22, 64)	18432	mixed1[0][0]
batch_normalization_1244 (Batch	(None, 22, 22, 64)	192	conv2d_1244[0][0]
activation_1244 (Activation)	(None, 22, 22, 64)	0	batch_normalization_
conv2d_1242 (Conv2D)	(None, 22, 22, 48)	13824	mixed1[0][0]
conv2d_1245 (Conv2D)	(None, 22, 22, 96)	55296	activation_1244[0][0
batch_normalization_1242 (Batch	(None, 22, 22, 48)	144	conv2d_1242[0][0]
batch_normalization_1245 (Batch	(None, 22, 22, 96)	288	conv2d_1245[0][0]
activation_1242 (Activation)	(None, 22, 22, 48)	0	batch_normalization_
activation_1245 (Activation)	(None, 22, 22, 96)	0	batch_normalization_
average_pooling2d_119 (AverageP	(None, 22, 22, 288)	0	mixed1[0][0]
conv2d_1241 (Conv2D)	(None, 22, 22, 64)	18432	mixed1[0][0]
conv2d_1243 (Conv2D)	(None, 22, 22, 64)	76800	activation_1242[0][0
conv2d_1246 (Conv2D)	(None, 22, 22, 96)	82944	activation_1245[0][0
conv2d_1247 (Conv2D)	(None, 22, 22, 64)	18432	average_pooling2d_11
batch_normalization_1241 (Batch	(None, 22, 22, 64)	192	conv2d_1241[0][0]
batch_normalization_1243 (Batch	(None, 22, 22, 64)	192	conv2d_1243[0][0]
batch_normalization_1246 (Batch	(None, 22, 22, 96)	288	conv2d_1246[0][0]
batch_normalization_1247 (Batch	(None, 22, 22, 64)	192	conv2d_1247[0][0]
activation_1241 (Activation)	(None, 22, 22, 64)	0	batch_normalization_
activation_1243 (Activation)	(None, 22, 22, 64)	0	batch_normalization_
activation_1246 (Activation)	(None, 22, 22, 96)	0	batch_normalization_
activation_1247 (Activation)	(None, 22, 22, 64)	0	batch_normalization_
mixed2 (Concatenate)	(None, 22, 22, 288)	0	activation_1241[0][0 activation_1243[0][0

```
                                                                 activation_1246[0][0
                                                                 activation_1247[0][0
__________________________________________________________________________________________________
conv2d_1249 (Conv2D)            (None, 22, 22, 64)   18432       mixed2[0][0]
__________________________________________________________________________________________________
batch_normalization_1249 (Batch (None, 22, 22, 64)   192         conv2d_1249[0][0]
__________________________________________________________________________________________________
activation_1249 (Activation)    (None, 22, 22, 64)   0           batch_normalization_
__________________________________________________________________________________________________
conv2d_1250 (Conv2D)            (None, 22, 22, 96)   55296       activation_1249[0][0
__________________________________________________________________________________________________
batch_normalization_1250 (Batch (None, 22, 22, 96)   288         conv2d_1250[0][0]
__________________________________________________________________________________________________
activation_1250 (Activation)    (None, 22, 22, 96)   0           batch_normalization_
__________________________________________________________________________________________________
conv2d_1248 (Conv2D)            (None, 10, 10, 384)  995328      mixed2[0][0]
__________________________________________________________________________________________________
conv2d_1251 (Conv2D)            (None, 10, 10, 96)   82944       activation_1250[0][0
__________________________________________________________________________________________________
batch_normalization_1248 (Batch (None, 10, 10, 384)  1152        conv2d_1248[0][0]
__________________________________________________________________________________________________
batch_normalization_1251 (Batch (None, 10, 10, 96)   288         conv2d_1251[0][0]
__________________________________________________________________________________________________
activation_1248 (Activation)    (None, 10, 10, 384)  0           batch_normalization_
__________________________________________________________________________________________________
activation_1251 (Activation)    (None, 10, 10, 96)   0           batch_normalization_
__________________________________________________________________________________________________
max_pooling2d_54 (MaxPooling2D) (None, 10, 10, 288)  0           mixed2[0][0]
__________________________________________________________________________________________________
mixed3 (Concatenate)            (None, 10, 10, 768)  0           activation_1248[0][0
                                                                 activation_1251[0][0
                                                                 max_pooling2d_54[0][
__________________________________________________________________________________________________
conv2d_1256 (Conv2D)            (None, 10, 10, 128)  98304       mixed3[0][0]
__________________________________________________________________________________________________
batch_normalization_1256 (Batch (None, 10, 10, 128)  384         conv2d_1256[0][0]
__________________________________________________________________________________________________
activation_1256 (Activation)    (None, 10, 10, 128)  0           batch_normalization_
__________________________________________________________________________________________________
conv2d_1257 (Conv2D)            (None, 10, 10, 128)  114688      activation_1256[0][0
__________________________________________________________________________________________________
batch_normalization_1257 (Batch (None, 10, 10, 128)  384         conv2d_1257[0][0]
__________________________________________________________________________________________________
activation_1257 (Activation)    (None, 10, 10, 128)  0           batch_normalization_
__________________________________________________________________________________________________
conv2d_1253 (Conv2D)            (None, 10, 10, 128)  98304       mixed3[0][0]
__________________________________________________________________________________________________
conv2d_1258 (Conv2D)            (None, 10, 10, 128)  114688      activation_1257[0][0
__________________________________________________________________________________________________
batch_normalization_1253 (Batch (None, 10, 10, 128)  384         conv2d_1253[0][0]
__________________________________________________________________________________________________
batch_normalization_1258 (Batch (None, 10, 10, 128)  384         conv2d_1258[0][0]
__________________________________________________________________________________________________
activation_1253 (Activation)    (None, 10, 10, 128)  0           batch_normalization_
__________________________________________________________________________________________________
activation_1258 (Activation)    (None, 10, 10, 128)  0           batch_normalization_
__________________________________________________________________________________________________
conv2d_1254 (Conv2D)            (None, 10, 10, 128)  114688      activation_1253[0][0
__________________________________________________________________________________________________
conv2d_1259 (Conv2D)            (None, 10, 10, 128)  114688      activation_1258[0][0
__________________________________________________________________________________________________
batch_normalization_1254 (Batch (None, 10, 10, 128)  384         conv2d_1254[0][0]
```

batch_normalization_1259 (Batch	(None, 10, 10, 128)	384	conv2d_1259[0][0]
activation_1254 (Activation)	(None, 10, 10, 128)	0	batch_normalization_
activation_1259 (Activation)	(None, 10, 10, 128)	0	batch_normalization_
average_pooling2d_120 (AverageP	(None, 10, 10, 768)	0	mixed3[0][0]
conv2d_1252 (Conv2D)	(None, 10, 10, 192)	147456	mixed3[0][0]
conv2d_1255 (Conv2D)	(None, 10, 10, 192)	172032	activation_1254[0][0
conv2d_1260 (Conv2D)	(None, 10, 10, 192)	172032	activation_1259[0][0
conv2d_1261 (Conv2D)	(None, 10, 10, 192)	147456	average_pooling2d_12
batch_normalization_1252 (Batch	(None, 10, 10, 192)	576	conv2d_1252[0][0]
batch_normalization_1255 (Batch	(None, 10, 10, 192)	576	conv2d_1255[0][0]
batch_normalization_1260 (Batch	(None, 10, 10, 192)	576	conv2d_1260[0][0]
batch_normalization_1261 (Batch	(None, 10, 10, 192)	576	conv2d_1261[0][0]
activation_1252 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1255 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1260 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1261 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
mixed4 (Concatenate)	(None, 10, 10, 768)	0	activation_1252[0][0 activation_1255[0][0 activation_1260[0][0 activation_1261[0][0
conv2d_1266 (Conv2D)	(None, 10, 10, 160)	122880	mixed4[0][0]
batch_normalization_1266 (Batch	(None, 10, 10, 160)	480	conv2d_1266[0][0]
activation_1266 (Activation)	(None, 10, 10, 160)	0	batch_normalization_
conv2d_1267 (Conv2D)	(None, 10, 10, 160)	179200	activation_1266[0][0
batch_normalization_1267 (Batch	(None, 10, 10, 160)	480	conv2d_1267[0][0]
activation_1267 (Activation)	(None, 10, 10, 160)	0	batch_normalization_
conv2d_1263 (Conv2D)	(None, 10, 10, 160)	122880	mixed4[0][0]
conv2d_1268 (Conv2D)	(None, 10, 10, 160)	179200	activation_1267[0][0
batch_normalization_1263 (Batch	(None, 10, 10, 160)	480	conv2d_1263[0][0]
batch_normalization_1268 (Batch	(None, 10, 10, 160)	480	conv2d_1268[0][0]
activation_1263 (Activation)	(None, 10, 10, 160)	0	batch_normalization_
activation_1268 (Activation)	(None, 10, 10, 160)	0	batch_normalization_

conv2d_1264 (Conv2D)	(None, 10, 10, 160)	179200	activation_1263[0][0
conv2d_1269 (Conv2D)	(None, 10, 10, 160)	179200	activation_1268[0][0
batch_normalization_1264 (Batch	(None, 10, 10, 160)	480	conv2d_1264[0][0]
batch_normalization_1269 (Batch	(None, 10, 10, 160)	480	conv2d_1269[0][0]
activation_1264 (Activation)	(None, 10, 10, 160)	0	batch_normalization_
activation_1269 (Activation)	(None, 10, 10, 160)	0	batch_normalization_
average_pooling2d_121 (AverageP	(None, 10, 10, 768)	0	mixed4[0][0]
conv2d_1262 (Conv2D)	(None, 10, 10, 192)	147456	mixed4[0][0]
conv2d_1265 (Conv2D)	(None, 10, 10, 192)	215040	activation_1264[0][0
conv2d_1270 (Conv2D)	(None, 10, 10, 192)	215040	activation_1269[0][0
conv2d_1271 (Conv2D)	(None, 10, 10, 192)	147456	average_pooling2d_12
batch_normalization_1262 (Batch	(None, 10, 10, 192)	576	conv2d_1262[0][0]
batch_normalization_1265 (Batch	(None, 10, 10, 192)	576	conv2d_1265[0][0]
batch_normalization_1270 (Batch	(None, 10, 10, 192)	576	conv2d_1270[0][0]
batch_normalization_1271 (Batch	(None, 10, 10, 192)	576	conv2d_1271[0][0]
activation_1262 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1265 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1270 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1271 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
mixed5 (Concatenate)	(None, 10, 10, 768)	0	activation_1262[0][0 activation_1265[0][0 activation_1270[0][0 activation_1271[0][0
conv2d_1276 (Conv2D)	(None, 10, 10, 160)	122880	mixed5[0][0]
batch_normalization_1276 (Batch	(None, 10, 10, 160)	480	conv2d_1276[0][0]
activation_1276 (Activation)	(None, 10, 10, 160)	0	batch_normalization_
conv2d_1277 (Conv2D)	(None, 10, 10, 160)	179200	activation_1276[0][0
batch_normalization_1277 (Batch	(None, 10, 10, 160)	480	conv2d_1277[0][0]
activation_1277 (Activation)	(None, 10, 10, 160)	0	batch_normalization_
conv2d_1273 (Conv2D)	(None, 10, 10, 160)	122880	mixed5[0][0]
conv2d_1278 (Conv2D)	(None, 10, 10, 160)	179200	activation_1277[0][0
batch_normalization_1273 (Batch	(None, 10, 10, 160)	480	conv2d_1273[0][0]

batch_normalization_1278 (Batch	(None, 10, 10, 160)	480	conv2d_1278[0][0]
activation_1273 (Activation)	(None, 10, 10, 160)	0	batch_normalization_
activation_1278 (Activation)	(None, 10, 10, 160)	0	batch_normalization_
conv2d_1274 (Conv2D)	(None, 10, 10, 160)	179200	activation_1273[0][0
conv2d_1279 (Conv2D)	(None, 10, 10, 160)	179200	activation_1278[0][0
batch_normalization_1274 (Batch	(None, 10, 10, 160)	480	conv2d_1274[0][0]
batch_normalization_1279 (Batch	(None, 10, 10, 160)	480	conv2d_1279[0][0]
activation_1274 (Activation)	(None, 10, 10, 160)	0	batch_normalization_
activation_1279 (Activation)	(None, 10, 10, 160)	0	batch_normalization_
average_pooling2d_122 (AverageP	(None, 10, 10, 768)	0	mixed5[0][0]
conv2d_1272 (Conv2D)	(None, 10, 10, 192)	147456	mixed5[0][0]
conv2d_1275 (Conv2D)	(None, 10, 10, 192)	215040	activation_1274[0][0
conv2d_1280 (Conv2D)	(None, 10, 10, 192)	215040	activation_1279[0][0
conv2d_1281 (Conv2D)	(None, 10, 10, 192)	147456	average_pooling2d_12
batch_normalization_1272 (Batch	(None, 10, 10, 192)	576	conv2d_1272[0][0]
batch_normalization_1275 (Batch	(None, 10, 10, 192)	576	conv2d_1275[0][0]
batch_normalization_1280 (Batch	(None, 10, 10, 192)	576	conv2d_1280[0][0]
batch_normalization_1281 (Batch	(None, 10, 10, 192)	576	conv2d_1281[0][0]
activation_1272 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1275 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1280 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1281 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
mixed6 (Concatenate)	(None, 10, 10, 768)	0	activation_1272[0][0 activation_1275[0][0 activation_1280[0][0 activation_1281[0][0
conv2d_1286 (Conv2D)	(None, 10, 10, 192)	147456	mixed6[0][0]
batch_normalization_1286 (Batch	(None, 10, 10, 192)	576	conv2d_1286[0][0]
activation_1286 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
conv2d_1287 (Conv2D)	(None, 10, 10, 192)	258048	activation_1286[0][0
batch_normalization_1287 (Batch	(None, 10, 10, 192)	576	conv2d_1287[0][0]
activation_1287 (Activation)	(None, 10, 10, 192)	0	batch_normalization_

conv2d_1283 (Conv2D)	(None, 10, 10, 192)	147456	mixed6[0][0]
conv2d_1288 (Conv2D)	(None, 10, 10, 192)	258048	activation_1287[0][0
batch_normalization_1283 (Batch	(None, 10, 10, 192)	576	conv2d_1283[0][0]
batch_normalization_1288 (Batch	(None, 10, 10, 192)	576	conv2d_1288[0][0]
activation_1283 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1288 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
conv2d_1284 (Conv2D)	(None, 10, 10, 192)	258048	activation_1283[0][0
conv2d_1289 (Conv2D)	(None, 10, 10, 192)	258048	activation_1288[0][0
batch_normalization_1284 (Batch	(None, 10, 10, 192)	576	conv2d_1284[0][0]
batch_normalization_1289 (Batch	(None, 10, 10, 192)	576	conv2d_1289[0][0]
activation_1284 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1289 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
average_pooling2d_123 (AverageP	(None, 10, 10, 768)	0	mixed6[0][0]
conv2d_1282 (Conv2D)	(None, 10, 10, 192)	147456	mixed6[0][0]
conv2d_1285 (Conv2D)	(None, 10, 10, 192)	258048	activation_1284[0][0
conv2d_1290 (Conv2D)	(None, 10, 10, 192)	258048	activation_1289[0][0
conv2d_1291 (Conv2D)	(None, 10, 10, 192)	147456	average_pooling2d_12
batch_normalization_1282 (Batch	(None, 10, 10, 192)	576	conv2d_1282[0][0]
batch_normalization_1285 (Batch	(None, 10, 10, 192)	576	conv2d_1285[0][0]
batch_normalization_1290 (Batch	(None, 10, 10, 192)	576	conv2d_1290[0][0]
batch_normalization_1291 (Batch	(None, 10, 10, 192)	576	conv2d_1291[0][0]
activation_1282 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1285 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1290 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1291 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
mixed7 (Concatenate)	(None, 10, 10, 768)	0	activation_1282[0][0 activation_1285[0][0 activation_1290[0][0 activation_1291[0][0
conv2d_1294 (Conv2D)	(None, 10, 10, 192)	147456	mixed7[0][0]
batch_normalization_1294 (Batch	(None, 10, 10, 192)	576	conv2d_1294[0][0]
activation_1294 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
conv2d_1295 (Conv2D)	(None, 10, 10, 192)	258048	activation_1294[0][0

batch_normalization_1295 (Batch	(None, 10, 10, 192)	576	conv2d_1295[0][0]
activation_1295 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
conv2d_1292 (Conv2D)	(None, 10, 10, 192)	147456	mixed7[0][0]
conv2d_1296 (Conv2D)	(None, 10, 10, 192)	258048	activation_1295[0][0
batch_normalization_1292 (Batch	(None, 10, 10, 192)	576	conv2d_1292[0][0]
batch_normalization_1296 (Batch	(None, 10, 10, 192)	576	conv2d_1296[0][0]
activation_1292 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
activation_1296 (Activation)	(None, 10, 10, 192)	0	batch_normalization_
conv2d_1293 (Conv2D)	(None, 4, 4, 320)	552960	activation_1292[0][0
conv2d_1297 (Conv2D)	(None, 4, 4, 192)	331776	activation_1296[0][0
batch_normalization_1293 (Batch	(None, 4, 4, 320)	960	conv2d_1293[0][0]
batch_normalization_1297 (Batch	(None, 4, 4, 192)	576	conv2d_1297[0][0]
activation_1293 (Activation)	(None, 4, 4, 320)	0	batch_normalization_
activation_1297 (Activation)	(None, 4, 4, 192)	0	batch_normalization_
max_pooling2d_55 (MaxPooling2D)	(None, 4, 4, 768)	0	mixed7[0][0]
mixed8 (Concatenate)	(None, 4, 4, 1280)	0	activation_1293[0][0 activation_1297[0][0 max_pooling2d_55[0][
conv2d_1302 (Conv2D)	(None, 4, 4, 448)	573440	mixed8[0][0]
batch_normalization_1302 (Batch	(None, 4, 4, 448)	1344	conv2d_1302[0][0]
activation_1302 (Activation)	(None, 4, 4, 448)	0	batch_normalization_
conv2d_1299 (Conv2D)	(None, 4, 4, 384)	491520	mixed8[0][0]
conv2d_1303 (Conv2D)	(None, 4, 4, 384)	1548288	activation_1302[0][0
batch_normalization_1299 (Batch	(None, 4, 4, 384)	1152	conv2d_1299[0][0]
batch_normalization_1303 (Batch	(None, 4, 4, 384)	1152	conv2d_1303[0][0]
activation_1299 (Activation)	(None, 4, 4, 384)	0	batch_normalization_
activation_1303 (Activation)	(None, 4, 4, 384)	0	batch_normalization_
conv2d_1300 (Conv2D)	(None, 4, 4, 384)	442368	activation_1299[0][0
conv2d_1301 (Conv2D)	(None, 4, 4, 384)	442368	activation_1299[0][0
conv2d_1304 (Conv2D)	(None, 4, 4, 384)	442368	activation_1303[0][0
conv2d_1305 (Conv2D)	(None, 4, 4, 384)	442368	activation_1303[0][0

average_pooling2d_124 (AverageP	(None, 4, 4, 1280)	0	mixed8[0][0]
conv2d_1298 (Conv2D)	(None, 4, 4, 320)	409600	mixed8[0][0]
batch_normalization_1300 (Batch	(None, 4, 4, 384)	1152	conv2d_1300[0][0]
batch_normalization_1301 (Batch	(None, 4, 4, 384)	1152	conv2d_1301[0][0]
batch_normalization_1304 (Batch	(None, 4, 4, 384)	1152	conv2d_1304[0][0]
batch_normalization_1305 (Batch	(None, 4, 4, 384)	1152	conv2d_1305[0][0]
conv2d_1306 (Conv2D)	(None, 4, 4, 192)	245760	average_pooling2d_12
batch_normalization_1298 (Batch	(None, 4, 4, 320)	960	conv2d_1298[0][0]
activation_1300 (Activation)	(None, 4, 4, 384)	0	batch_normalization_
activation_1301 (Activation)	(None, 4, 4, 384)	0	batch_normalization_
activation_1304 (Activation)	(None, 4, 4, 384)	0	batch_normalization_
activation_1305 (Activation)	(None, 4, 4, 384)	0	batch_normalization_
batch_normalization_1306 (Batch	(None, 4, 4, 192)	576	conv2d_1306[0][0]
activation_1298 (Activation)	(None, 4, 4, 320)	0	batch_normalization_
mixed9_0 (Concatenate)	(None, 4, 4, 768)	0	activation_1300[0][0] activation_1301[0][0]
concatenate_26 (Concatenate)	(None, 4, 4, 768)	0	activation_1304[0][0] activation_1305[0][0]
activation_1306 (Activation)	(None, 4, 4, 192)	0	batch_normalization_
mixed9 (Concatenate)	(None, 4, 4, 2048)	0	activation_1298[0][0] mixed9_0[0][0] concatenate_26[0][0] activation_1306[0][0]
conv2d_1311 (Conv2D)	(None, 4, 4, 448)	917504	mixed9[0][0]
batch_normalization_1311 (Batch	(None, 4, 4, 448)	1344	conv2d_1311[0][0]
activation_1311 (Activation)	(None, 4, 4, 448)	0	batch_normalization_
conv2d_1308 (Conv2D)	(None, 4, 4, 384)	786432	mixed9[0][0]
conv2d_1312 (Conv2D)	(None, 4, 4, 384)	1548288	activation_1311[0][0]
batch_normalization_1308 (Batch	(None, 4, 4, 384)	1152	conv2d_1308[0][0]
batch_normalization_1312 (Batch	(None, 4, 4, 384)	1152	conv2d_1312[0][0]
activation_1308 (Activation)	(None, 4, 4, 384)	0	batch_normalization_
activation_1312 (Activation)	(None, 4, 4, 384)	0	batch_normalization_
conv2d_1309 (Conv2D)	(None, 4, 4, 384)	442368	activation_1308[0][0]
conv2d_1310 (Conv2D)	(None, 4, 4, 384)	442368	activation_1308[0][0]

```
conv2d_1313 (Conv2D)            (None, 4, 4, 384)    442368      activation_1312[0][0
conv2d_1314 (Conv2D)            (None, 4, 4, 384)    442368      activation_1312[0][0
average_pooling2d_125 (AverageP (None, 4, 4, 2048)   0           mixed9[0][0]
conv2d_1307 (Conv2D)            (None, 4, 4, 320)    655360      mixed9[0][0]
batch_normalization_1309 (Batch (None, 4, 4, 384)    1152        conv2d_1309[0][0]
batch_normalization_1310 (Batch (None, 4, 4, 384)    1152        conv2d_1310[0][0]
batch_normalization_1313 (Batch (None, 4, 4, 384)    1152        conv2d_1313[0][0]
batch_normalization_1314 (Batch (None, 4, 4, 384)    1152        conv2d_1314[0][0]
conv2d_1315 (Conv2D)            (None, 4, 4, 192)    393216      average_pooling2d_12
batch_normalization_1307 (Batch (None, 4, 4, 320)    960         conv2d_1307[0][0]
activation_1309 (Activation)    (None, 4, 4, 384)    0           batch_normalization_
activation_1310 (Activation)    (None, 4, 4, 384)    0           batch_normalization_
activation_1313 (Activation)    (None, 4, 4, 384)    0           batch_normalization_
activation_1314 (Activation)    (None, 4, 4, 384)    0           batch_normalization_
batch_normalization_1315 (Batch (None, 4, 4, 192)    576         conv2d_1315[0][0]
activation_1307 (Activation)    (None, 4, 4, 320)    0           batch_normalization_
mixed9_1 (Concatenate)          (None, 4, 4, 768)    0           activation_1309[0][0
                                                                 activation_1310[0][0
concatenate_27 (Concatenate)    (None, 4, 4, 768)    0           activation_1313[0][0
                                                                 activation_1314[0][0
activation_1315 (Activation)    (None, 4, 4, 192)    0           batch_normalization_
mixed10 (Concatenate)           (None, 4, 4, 2048)   0           activation_1307[0][0
                                                                 mixed9_1[0][0]
                                                                 concatenate_27[0][0]
                                                                 activation_1315[0][0
global_average_pooling2d_3 (Glo (None, 2048)         0           mixed10[0][0]
dense_32 (Dense)                (None, 1024)         2098176     global_average_pooli
dense_33 (Dense)                (None, 29)           29725       dense_32[0][0]
==================================================================================
Total params: 23,930,685
Trainable params: 23,896,253
Non-trainable params: 34,432
__________________________________________________________________________________
```

Setting up a callback funtion in order to stop training at a particular threshold:

```
# Creating a callback to stop model training after reaching a threshold accuracy

LOSS_THRESHOLD = 0.2
ACCURACY_THRESHOLD = 0.95

class ModelCallback(tf.keras.callbacks.Callback):
  def on_epoch_end(self, epoch, logs={}):
    if logs.get('val_loss') <= LOSS_THRESHOLD and logs.get('val_acc') >= ACCURACY_THRESHOLD:
      print("\nReached", ACCURACY_THRESHOLD * 100, "accuracy, Stopping!")
      self.model.stop_training = True

callback = ModelCallback()
```

Training the model generated using Inception v3 and o
Connected layers

Fitting the model to the training dataset:

```
history = model.fit_generator(
    train_generator,
    validation_data=validation_generator,
    steps_per_epoch=100,
    validation_steps=50,
    epochs=50,
    callbacks=[callback]
)
```

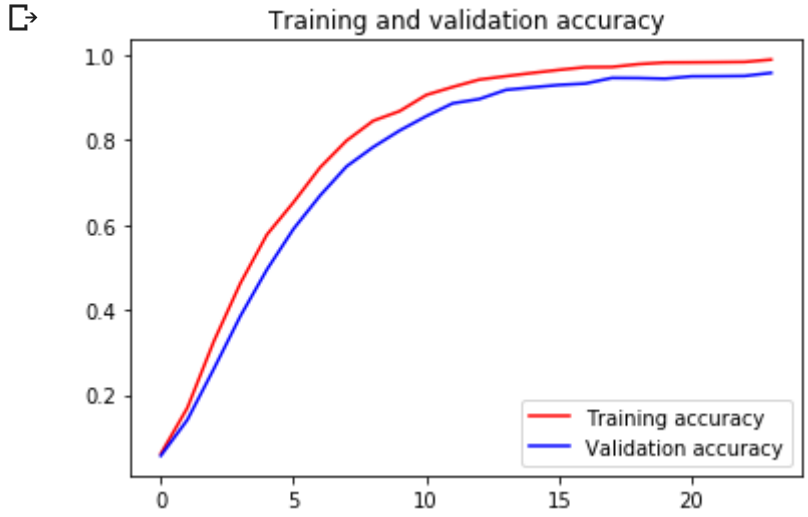
```
Epoch 1/50
 99/100 [============================>.] - ETA: 1s - loss: 3.3806 - acc: 0.0609Epoch
100/100 [==============================] - 191s 2s/step - loss: 3.3793 - acc: 0.0614
Epoch 2/50
 99/100 [============================>.] - ETA: 1s - loss: 3.1511 - acc: 0.1690Epoch
100/100 [==============================] - 152s 2s/step - loss: 3.1502 - acc: 0.1695
Epoch 3/50
 99/100 [============================>.] - ETA: 1s - loss: 2.8907 - acc: 0.3259Epoch
100/100 [==============================] - 153s 2s/step - loss: 2.8890 - acc: 0.3264
Epoch 4/50
 99/100 [============================>.] - ETA: 1s - loss: 2.5872 - acc: 0.4631Epoch
100/100 [==============================] - 154s 2s/step - loss: 2.5856 - acc: 0.4628
Epoch 5/50
 99/100 [============================>.] - ETA: 1s - loss: 2.2674 - acc: 0.5767Epoch
100/100 [==============================] - 154s 2s/step - loss: 2.2664 - acc: 0.5772
Epoch 6/50
 99/100 [============================>.] - ETA: 1s - loss: 1.9731 - acc: 0.6518Epoch
100/100 [==============================] - 155s 2s/step - loss: 1.9700 - acc: 0.6530
Epoch 7/50
 99/100 [============================>.] - ETA: 1s - loss: 1.6848 - acc: 0.7344Epoch
100/100 [==============================] - 155s 2s/step - loss: 1.6815 - acc: 0.7348
Epoch 8/50
 99/100 [============================>.] - ETA: 1s - loss: 1.4070 - acc: 0.7981Epoch
100/100 [==============================] - 154s 2s/step - loss: 1.4083 - acc: 0.7981
Epoch 9/50
 99/100 [============================>.] - ETA: 1s - loss: 1.1633 - acc: 0.8452Epoch
100/100 [==============================] - 155s 2s/step - loss: 1.1624 - acc: 0.8447
Epoch 10/50
 99/100 [============================>.] - ETA: 1s - loss: 0.9675 - acc: 0.8666Epoch
100/100 [==============================] - 156s 2s/step - loss: 0.9655 - acc: 0.8675
Epoch 11/50
 99/100 [============================>.] - ETA: 1s - loss: 0.7750 - acc: 0.9057Epoch
100/100 [==============================] - 154s 2s/step - loss: 0.7745 - acc: 0.9056
Epoch 12/50
 99/100 [============================>.] - ETA: 1s - loss: 0.6286 - acc: 0.9239Epoch
100/100 [==============================] - 152s 2s/step - loss: 0.6279 - acc: 0.9244
Epoch 13/50
 99/100 [============================>.] - ETA: 1s - loss: 0.5067 - acc: 0.9418Epoch
100/100 [==============================] - 156s 2s/step - loss: 0.5058 - acc: 0.9417
Epoch 14/50
 99/100 [============================>.] - ETA: 1s - loss: 0.4175 - acc: 0.9495Epoch
100/100 [==============================] - 154s 2s/step - loss: 0.4180 - acc: 0.9497
Epoch 15/50
 99/100 [============================>.] - ETA: 1s - loss: 0.3576 - acc: 0.9572Epoch
100/100 [==============================] - 153s 2s/step - loss: 0.3567 - acc: 0.9573
Epoch 16/50
 99/100 [============================>.] - ETA: 1s - loss: 0.2912 - acc: 0.9651Epoch
100/100 [==============================] - 154s 2s/step - loss: 0.2927 - acc: 0.9645
Epoch 17/50
 99/100 [============================>.] - ETA: 1s - loss: 0.2552 - acc: 0.9710Epoch
100/100 [==============================] - 153s 2s/step - loss: 0.2551 - acc: 0.9709
Epoch 18/50
 99/100 [============================>.] - ETA: 1s - loss: 0.2180 - acc: 0.9716Epoch
100/100 [==============================] - 153s 2s/step - loss: 0.2184 - acc: 0.9714
Epoch 19/50
 99/100 [============================>.] - ETA: 1s - loss: 0.1817 - acc: 0.9781Epoch
100/100 [==============================] - 153s 2s/step - loss: 0.1811 - acc: 0.9781
Epoch 20/50
 99/100 [============================>.] - ETA: 1s - loss: 0.1653 - acc: 0.9818Epoch
100/100 [==============================] - 155s 2s/step - loss: 0.1650 - acc: 0.9819
Epoch 21/50
```

```
 99/100 [============================>.] - ETA: 1s - loss: 0.1524 - acc: 0.9822Epoch
100/100 [==============================] - 153s 2s/step - loss: 0.1526 - acc: 0.9822
Epoch 22/50
 99/100 [============================>.] - ETA: 1s - loss: 0.1345 - acc: 0.9826Epoch
100/100 [==============================] - 153s 2s/step - loss: 0.1342 - acc: 0.9827
Epoch 23/50
 99/100 [============================>.] - ETA: 1s - loss: 0.1269 - acc: 0.9831Epoch
100/100 [==============================] - 155s 2s/step - loss: 0.1271 - acc: 0.9833
Epoch 24/50
 99/100 [============================>.] - ETA: 1s - loss: 0.1102 - acc: 0.9886Epoch
 50/100 [==============>..............] - ETA: 49s - loss: 0.1926 - acc: 0.9575
Reached 95.0 accuracy, Stopping!
100/100 [==============================] - 155s 2s/step - loss: 0.1100 - acc: 0.9887
```

Plotting the results

Training Accuracy vs Validation Accuracy:

```
import matplotlib.pyplot as plt
acc = history.history['acc']
val_acc = history.history['val_acc']
loss = history.history['loss']
val_loss = history.history['val_loss']

epochs = range(len(acc))

plt.plot(epochs, acc, 'r', label='Training accuracy')
plt.plot(epochs, val_acc, 'b', label='Validation accuracy')
plt.title('Training and validation accuracy')
plt.legend(loc=0)
plt.figure()


plt.show()
```



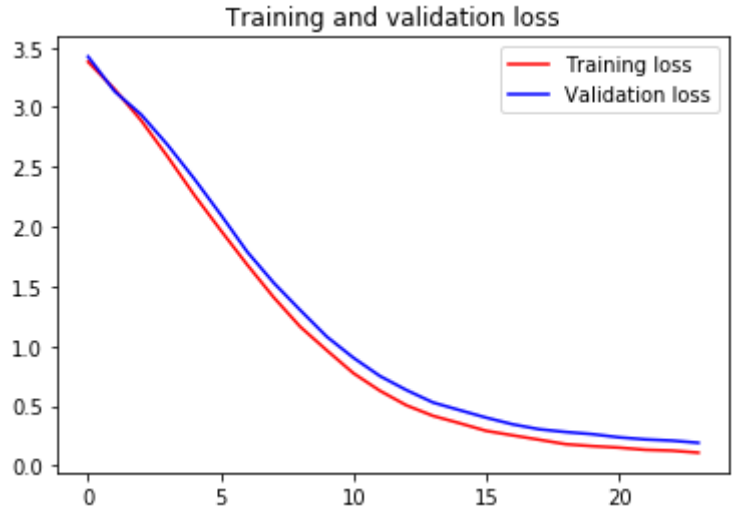

```
<Figure size 432x288 with 0 Axes>
```

Training Loss vs Validation Loss

```
plt.plot(epochs, loss, 'r', label='Training loss')
plt.plot(epochs, val_loss, 'b', label='Validation loss')
plt.title('Training and validation loss')
```

```
plt.legend(loc=0)
plt.figure()
```

```
<Figure size 432x288 with 0 Axes>
```




```
<Figure size 432x288 with 0 Axes>
```

Saving the model

As we were satisfied with our results we save our model:

```
# Saving the model
MODEL_NAME = 'models/asl_alphabet_{}.h5'.format(9575)
model.save(MODEL_NAME)
```

Testing our model

Plotting images along with their respective actual and predicted classes:

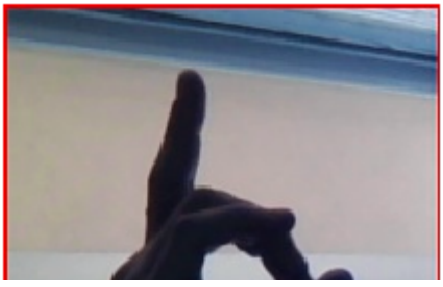
```
import cv2
import numpy as np
import os
import matplotlib.pyplot as plt

classes = os.listdir(TRAINING_DIR)
classes.sort()

for i, test_image in enumerate(os.listdir(TEST_DIR)):
    image_location = TEST_DIR + test_image
    img = cv2.imread(image_location)
    img = cv2.resize(img, (IMAGE_SIZE, IMAGE_SIZE))
    plt.figure()
    plt.axis('Off')
    plt.imshow(img)
    img = np.array(img) / 255.
    img = img.reshape((1, IMAGE_SIZE, IMAGE_SIZE, 3))
    img = data_generator.standardize(img)
    prediction = np.array(model.predict(img))
    actual = test_image.split('_')[0]
    predicted = classes[prediction.argmax()]
    print('Actual class: {} \n Predicted class: {}'.format(actual, predicted))
    plt.show()
```

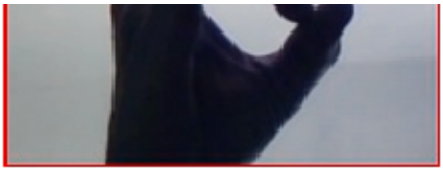
```
Actual class: V
Predicted class: V
```

```
Actual class: O
Predicted class: O
```

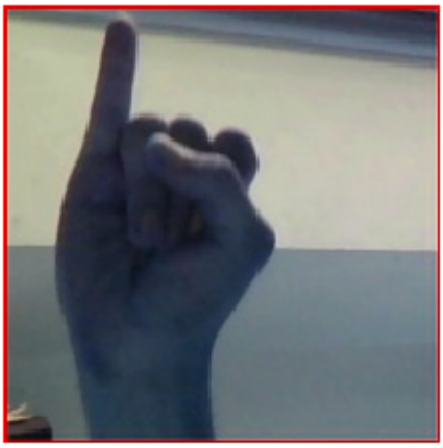
```
Actual class: B
Predicted class: B
```

```
Actual class: D
Predicted class: D
```





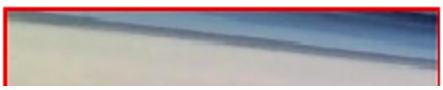
```
Actual class: I
Predicted class: I
```



```
Actual class: U
Predicted class: U
```

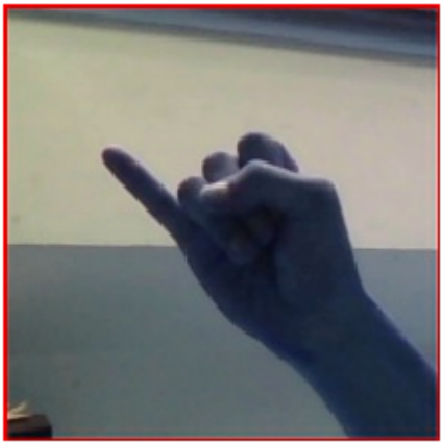
```
Actual class: T
Predicted class: T
```

```
Actual class: P
Predicted class: P
```



```
Actual class: S
Predicted class: S
```

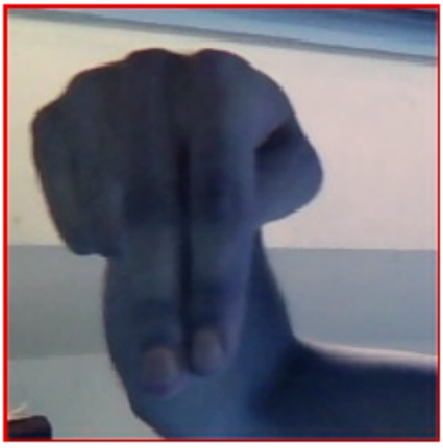
```
Actual class: J
Predicted class: J
```



```
Actual class: nothing
Predicted class: nothing
```

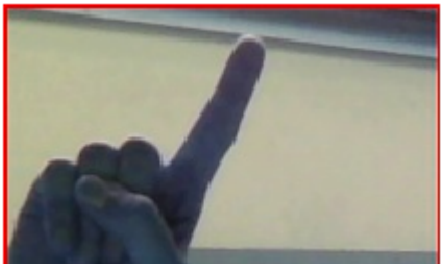
```
Actual class: E
Predicted class: E
```

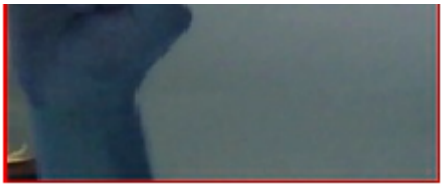
```
Actual class: N
Predicted class: N
```



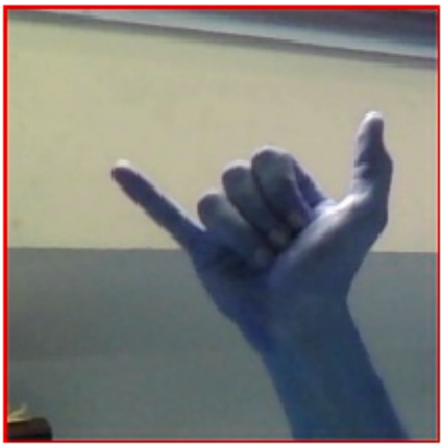
```
Actual class: K
Predicted class: K
```

```
Actual class: Z
Predicted class: Z
```

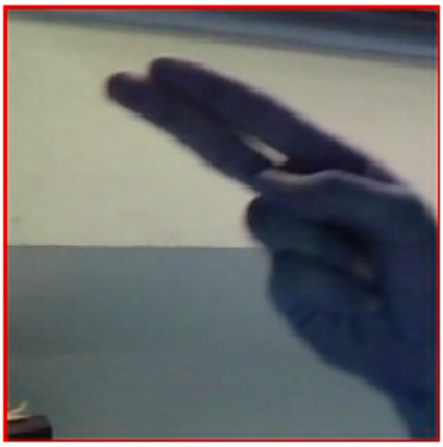




```
Actual class: Y
Predicted class: J
```

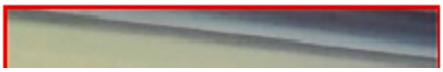


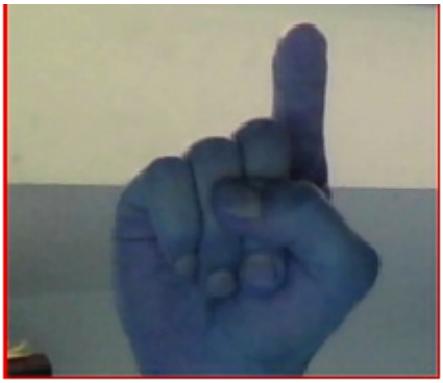
```
Actual class: H
Predicted class: H
```



```
Actual class: L
Predicted class: L
```

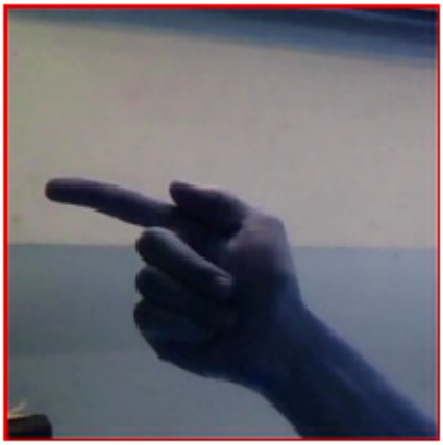
```
Actual class: X
Predicted class: X
```





```
Actual class: A
Predicted class: A
```

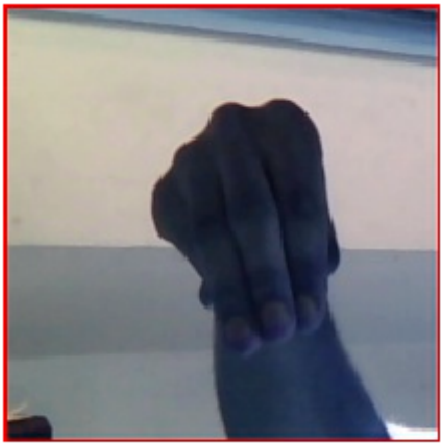
```
Actual class: G
Predicted class: G
```



```
Actual class: W
Predicted class: W
```

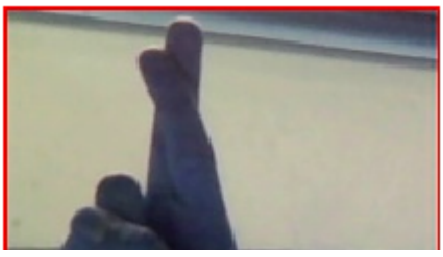
```
Actual class: F
Predicted class: F
```

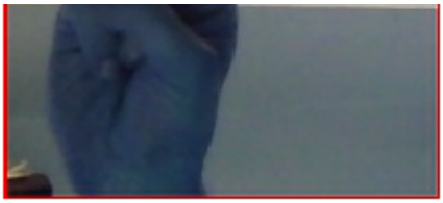
```
Actual class: M
Predicted class: M
```



```
Actual class: C
Predicted class: C
```

```
Actual class: R
Predicted class: R
```





```
Actual class: Q
Predicted class: Q
```

```
Actual class: space
Predicted class: space
```

Calculating test accuracy:

```
test_images = os.listdir(TEST_DIR)
total_test_cases = len(test_images)
total_correctly_classified = 0
total_misclassified = 0
for i, test_image in enumerate(test_images):
    image_location = TEST_DIR + test_image
    img = cv2.imread(image_location)
    img = cv2.resize(img, (IMAGE_SIZE, IMAGE_SIZE))
    img = np.array(img) / 255.
    img = img.reshape((1, IMAGE_SIZE, IMAGE_SIZE, 3))
    img = data_generator.standardize(img)
    prediction = np.array(model.predict(img))
    actual = test_image.split('_')[0]
    predicted = classes[prediction.argmax()]
    print('Actual class: {} - Predicted class: {}'.format(
        actual, predicted), end=' ')
    if actual == predicted:
      print('PASS!')
```

```
        total_correctly_classified += 1
      else:
        print('FAIL!')
        total_misclassified += 1
print("=" * 20)
test_accuracy = (total_correctly_classified / total_test_cases) * 100
test_error_rate = (total_misclassified / total_test_cases) * 100

print('Test accuracy (%):', test_accuracy)
print('Test error rate (%):', test_error_rate)
print('Number of misclassified classes:', total_misclassified)
print('Number of correctly classified classes', total_correctly_classified)
```

```
Actual class: V - Predicted class: V PASS!
Actual class: O - Predicted class: O PASS!
Actual class: B - Predicted class: B PASS!
Actual class: D - Predicted class: D PASS!
Actual class: I - Predicted class: I PASS!
Actual class: U - Predicted class: U PASS!
Actual class: T - Predicted class: T PASS!
Actual class: P - Predicted class: P PASS!
Actual class: S - Predicted class: S PASS!
Actual class: J - Predicted class: J PASS!
Actual class: nothing - Predicted class: nothing PASS!
Actual class: E - Predicted class: E PASS!
Actual class: N - Predicted class: N PASS!
Actual class: K - Predicted class: K PASS!
Actual class: Z - Predicted class: Z PASS!
Actual class: Y - Predicted class: J FAIL!
Actual class: H - Predicted class: H PASS!
Actual class: L - Predicted class: L PASS!
Actual class: X - Predicted class: X PASS!
Actual class: A - Predicted class: A PASS!
Actual class: G - Predicted class: G PASS!
Actual class: W - Predicted class: W PASS!
Actual class: F - Predicted class: F PASS!
Actual class: M - Predicted class: M PASS!
Actual class: C - Predicted class: C PASS!
Actual class: R - Predicted class: R PASS!
Actual class: Q - Predicted class: Q PASS!
Actual class: space - Predicted class: space PASS!
====================
Test accuracy (%): 96.42857142857143
Test error rate (%): 3.571428571428571
Number of misclassified classes: 1
Number of correctly classified classes 27
```