face-verification-recognition

April 5, 2020

1 Face Verification and Recognition with Inception

Project created during the Deep Learning Specialization course on www.coursera.org

[1]:
```
import warnings
warnings.filterwarnings(action='ignore')
from keras.layers import Conv2D, ZeroPadding2D, Activation, Input
from keras.models import Model
from keras.layers.normalization import BatchNormalization
from keras.layers.pooling import MaxPooling2D, AveragePooling2D
from keras.layers.core import Lambda, Flatten, Dense
from keras import backend as K
K.set_image_data_format('channels_first')
import cv2
import os
import sys
from tqdm import tqdm
import numpy as np
import tensorflow as tf
import matplotlib.pyplot as plt
from numpy import genfromtxt
import PIL
from PIL import Image
from collections import defaultdict
from inception_blocks import *

%load_ext autoreload
%autoreload 2

plt.rcParams["figure.figsize"] = (2,2)
np.set_printoptions(threshold=sys.maxsize)
```

```
Using TensorFlow backend.
```

1.1 Data preparation

[2]:
```
directory = './images'
```

Image preprocessing

[3]:
```
# Preprocess image to match model input size

def preprocess_image(image_path):

    # Read the image; flag=1 loads a color image
    img = cv2.imread(image_path, 1)

    # Resize image to match the model input size
    img = cv2.resize(img, (96, 96))

    # OpenCV uses BGR ordering. '...' skips previous dimensions, '::-1' returns␣
↪all pixels reversed
    img = img[...,::-1]

    # Rearrange image dimensions (channels n_C first) and normalize pixel values
    img = np.around(np.transpose(img, (2,0,1))/255.0, decimals=12)

    # Convert the image to fit the model input type
    img = np.array([img])

    return img
```

1.2 Inception model

Building model

[4]:
```
# Built Inception model (implementation used in FaceNet)

def model(input_shape):

    # Define the input as a tensor with shape input_shape
    X_input = Input(input_shape)
    X = ZeroPadding2D((3, 3))(X_input)

    # First Block
    X = Conv2D(64, (7, 7), strides = (2, 2), name = 'conv1')(X)
    X = BatchNormalization(axis = 1, name = 'bn1')(X)
    X = Activation('relu')(X)
    X = ZeroPadding2D((1, 1))(X)
    X = MaxPooling2D((3, 3), strides = 2)(X)

    # Second Block
```

```
    X = Conv2D(64, (1, 1), strides = (1, 1), name = 'conv2')(X)
    X = BatchNormalization(axis = 1, epsilon=0.00001, name = 'bn2')(X)
    X = Activation('relu')(X)

    X = ZeroPadding2D((1, 1))(X)

    # Third Block
    X = Conv2D(192, (3, 3), strides = (1, 1), name = 'conv3')(X)
    X = BatchNormalization(axis = 1, epsilon=0.00001, name = 'bn3')(X)
    X = Activation('relu')(X)
    X = ZeroPadding2D((1, 1))(X)
    X = MaxPooling2D(pool_size = 3, strides = 2)(X)

    # First Inception block
    X = inception_block_1a(X)
    X = inception_block_1b(X)
    X = inception_block_1c(X)

    # Second Inception Block
    X = inception_block_2a(X)
    X = inception_block_2b(X)

    # Third Inception Block
    X = inception_block_3a(X)
    X = inception_block_3b(X)

    # Top layer
    X = AveragePooling2D(pool_size=(3, 3), strides=(1, 1),␣
↪data_format='channels_first')(X)
    X = Flatten()(X)
    X = Dense(128, name='dense_layer')(X)

    # L2 normalization
    X = Lambda(lambda  x: K.l2_normalize(x,axis=1))(X)

    # Create model instance
    model = Model(inputs = X_input, outputs = X, name='FaceRecoModel')

    return model
```

[5]:
```
model = model(input_shape=(3, 96, 96))
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/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 /usr/local/lib/python3.6/site-
```

```
packages/keras/backend/tensorflow_backend.py:4074: The name tf.nn.avg_pool is
deprecated. Please use tf.nn.avg_pool2d instead.
```

[6]:
```
#model.summary()
```

Defining loss function (if we were to train the model from scratch)

[7]:
```
# Triplet loss -
# - encodings of two images of the same person should be similar
# - encodings of two images of different people should be different

def compute_triplet_loss(y_true, y_pred, alpha=0.2):

    anchor, positive, negative = y_pred[0], y_pred[1], y_pred[2]

    pos_dist = tf.reduce_sum(tf.square(tf.subtract(anchor, positive)), axis=-1)

    neg_dist = tf.reduce_sum(tf.square(tf.subtract(anchor, negative)), axis=-1)

    loss = tf.reduce_sum(tf.maximum((pos_dist - neg_dist + alpha), 0))

    return loss
```

Model compilation (if we were to train the model from scratch)

[8]:
```
# Compile the model

model.compile(optimizer = 'adam',
              loss = compute_triplet_loss,
              metrics = ['accuracy'])
```

Loading pretrained weights source: https://github.com/iwantooxxoox/Keras-OpenFace

[9]:
```
WEIGHTS = [
  'conv1', 'bn1', 'conv2', 'bn2', 'conv3', 'bn3',
  'inception_3a_1x1_conv', 'inception_3a_1x1_bn',
  'inception_3a_pool_conv', 'inception_3a_pool_bn',
  'inception_3a_5x5_conv1', 'inception_3a_5x5_conv2', 'inception_3a_5x5_bn1',␣
↪'inception_3a_5x5_bn2',
  'inception_3a_3x3_conv1', 'inception_3a_3x3_conv2', 'inception_3a_3x3_bn1',␣
↪'inception_3a_3x3_bn2',
  'inception_3b_3x3_conv1', 'inception_3b_3x3_conv2', 'inception_3b_3x3_bn1',␣
↪'inception_3b_3x3_bn2',
  'inception_3b_5x5_conv1', 'inception_3b_5x5_conv2', 'inception_3b_5x5_bn1',␣
↪'inception_3b_5x5_bn2',
```

```
        'inception_3b_pool_conv', 'inception_3b_pool_bn',
        'inception_3b_1x1_conv', 'inception_3b_1x1_bn',
        'inception_3c_3x3_conv1', 'inception_3c_3x3_conv2', 'inception_3c_3x3_bn1',␣
      ↪'inception_3c_3x3_bn2',
        'inception_3c_5x5_conv1', 'inception_3c_5x5_conv2', 'inception_3c_5x5_bn1',␣
      ↪'inception_3c_5x5_bn2',
        'inception_4a_3x3_conv1', 'inception_4a_3x3_conv2', 'inception_4a_3x3_bn1',␣
      ↪'inception_4a_3x3_bn2',
        'inception_4a_5x5_conv1', 'inception_4a_5x5_conv2', 'inception_4a_5x5_bn1',␣
      ↪'inception_4a_5x5_bn2',
        'inception_4a_pool_conv', 'inception_4a_pool_bn',
        'inception_4a_1x1_conv', 'inception_4a_1x1_bn',
        'inception_4e_3x3_conv1', 'inception_4e_3x3_conv2', 'inception_4e_3x3_bn1',␣
      ↪'inception_4e_3x3_bn2',
        'inception_4e_5x5_conv1', 'inception_4e_5x5_conv2', 'inception_4e_5x5_bn1',␣
      ↪'inception_4e_5x5_bn2',
        'inception_5a_3x3_conv1', 'inception_5a_3x3_conv2', 'inception_5a_3x3_bn1',␣
      ↪'inception_5a_3x3_bn2',
        'inception_5a_pool_conv', 'inception_5a_pool_bn',
        'inception_5a_1x1_conv', 'inception_5a_1x1_bn',
        'inception_5b_3x3_conv1', 'inception_5b_3x3_conv2', 'inception_5b_3x3_bn1',␣
      ↪'inception_5b_3x3_bn2',
        'inception_5b_pool_conv', 'inception_5b_pool_bn',
        'inception_5b_1x1_conv', 'inception_5b_1x1_bn',
        'dense_layer'
    ]
```

[10]:
```
    conv_shape = {
        'conv1': [64, 3, 7, 7],
        'conv2': [64, 64, 1, 1],
        'conv3': [192, 64, 3, 3],
        'inception_3a_1x1_conv': [64, 192, 1, 1],
        'inception_3a_pool_conv': [32, 192, 1, 1],
        'inception_3a_5x5_conv1': [16, 192, 1, 1],
        'inception_3a_5x5_conv2': [32, 16, 5, 5],
        'inception_3a_3x3_conv1': [96, 192, 1, 1],
        'inception_3a_3x3_conv2': [128, 96, 3, 3],
        'inception_3b_3x3_conv1': [96, 256, 1, 1],
        'inception_3b_3x3_conv2': [128, 96, 3, 3],
        'inception_3b_5x5_conv1': [32, 256, 1, 1],
        'inception_3b_5x5_conv2': [64, 32, 5, 5],
        'inception_3b_pool_conv': [64, 256, 1, 1],
        'inception_3b_1x1_conv': [64, 256, 1, 1],
        'inception_3c_3x3_conv1': [128, 320, 1, 1],
        'inception_3c_3x3_conv2': [256, 128, 3, 3],
        'inception_3c_5x5_conv1': [32, 320, 1, 1],
```

```
    'inception_3c_5x5_conv2': [64, 32, 5, 5],
    'inception_4a_3x3_conv1': [96, 640, 1, 1],
    'inception_4a_3x3_conv2': [192, 96, 3, 3],
    'inception_4a_5x5_conv1': [32, 640, 1, 1,],
    'inception_4a_5x5_conv2': [64, 32, 5, 5],
    'inception_4a_pool_conv': [128, 640, 1, 1],
    'inception_4a_1x1_conv': [256, 640, 1, 1],
    'inception_4e_3x3_conv1': [160, 640, 1, 1],
    'inception_4e_3x3_conv2': [256, 160, 3, 3],
    'inception_4e_5x5_conv1': [64, 640, 1, 1],
    'inception_4e_5x5_conv2': [128, 64, 5, 5],
    'inception_5a_3x3_conv1': [96, 1024, 1, 1],
    'inception_5a_3x3_conv2': [384, 96, 3, 3],
    'inception_5a_pool_conv': [96, 1024, 1, 1],
    'inception_5a_1x1_conv': [256, 1024, 1, 1],
    'inception_5b_3x3_conv1': [96, 736, 1, 1],
    'inception_5b_3x3_conv2': [384, 96, 3, 3],
    'inception_5b_pool_conv': [96, 736, 1, 1],
    'inception_5b_1x1_conv': [256, 736, 1, 1],
}
```

[11]:
```
# Helper function: create dictionary of weights

def create_weights_dict(directory):

    fileNames = filter(lambda f: not f.startswith('.'), os.listdir(directory))
    paths = {}
    weights_dict = {}

    for n in fileNames:
        paths[n.replace('.csv', '')] = directory + '/' + n

    for name in tqdm(WEIGHTS):

        if 'conv' in name:
            conv_w = genfromtxt(paths[name + '_w'], delimiter=',', dtype=None)
            conv_w = np.reshape(conv_w, conv_shape[name])
            conv_w = np.transpose(conv_w, (2, 3, 1, 0))
            conv_b = genfromtxt(paths[name + '_b'], delimiter=',', dtype=None)
            weights_dict[name] = [conv_w, conv_b]

        elif 'bn' in name:
            bn_w = genfromtxt(paths[name + '_w'], delimiter=',', dtype=None)
            bn_b = genfromtxt(paths[name + '_b'], delimiter=',', dtype=None)
            bn_m = genfromtxt(paths[name + '_m'], delimiter=',', dtype=None)
            bn_v = genfromtxt(paths[name + '_v'], delimiter=',', dtype=None)
            weights_dict[name] = [bn_w, bn_b, bn_m, bn_v]
```

```
            elif 'dense' in name:
                dense_w = genfromtxt(directory+'/dense_w.csv', delimiter=',',␣
↪dtype=None)
                dense_w = np.reshape(dense_w, (128, 736))
                dense_w = np.transpose(dense_w, (1, 0))
                dense_b = genfromtxt(directory+'/dense_b.csv', delimiter=',',␣
↪dtype=None)
                weights_dict[name] = [dense_w, dense_b]

        return weights_dict
```

[12]:
```
# Load pretrained weights from files

def load_weights(model, directory):

    # Load weights from csv files (which was exported from Openface torch model)
    weights = WEIGHTS
    weights_dict = create_weights_dict(directory)

    # Set layer weights of the model
    for name in tqdm(weights):
        if model.get_layer(name) != None:
            model.get_layer(name).set_weights(weights_dict[name])
```

[13]:
```
weights_dir = './weights'
load_weights(model, weights_dir)
```

```
100%|| 75/75 [01:15<00:00,  1.00s/it]
100%|| 75/75 [00:18<00:00,  4.14it/s]
```

1.3 Encoding images

Encoding by making a prediction

[14]:
```
def encode(image_path):
    img = preprocess_image(image_path)
    return model.predict_on_batch(img)
```

Database of identities and corresponding encodings

[15]:
```
def create_database(directory):

    images = filter(lambda f: not f.startswith('.'), os.listdir(directory))
    database = defaultdict(list)

    for image in images:
        filename, ext = os.path.splitext(image)
```

```
            identity = ''.join(i for i in filename if i.isalpha()).capitalize()
            encoding = encode(os.path.join(directory, image))
            database[identity].append(encoding)

        return  database
```

[16]:
```
database = create_database(directory)
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/site-
packages/keras/backend/tensorflow_backend.py:422: The name tf.global_variables
is deprecated. Please use tf.compat.v1.global_variables instead.
```

[17]:
```
database.keys()
```

[17]:
```
dict_keys(['Marcelo', 'Jola', 'Ala', 'Michal', 'Marek'])
```

1.4 Testing

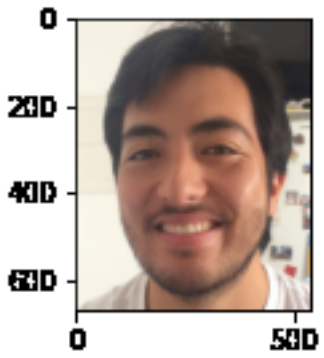
[18]:
```
# Helper function: load image and print true identity that is represents

def load_image(image_path):

    image_path = os.path.join(test_dir, image)

    # Display the image
    img = cv2.imread(image_path)
    RGB_img = cv2.cvtColor(img, cv2.COLOR_BGR2RGB)
    plt.imshow(RGB_img)
    plt.show()

    # Retrieve true identity
    filename = os.path.basename(image_path)
    file, ext = os.path.splitext(filename)
    true_identity = ''.join(i for i in file if i.isalpha()).capitalize()
    print('True identity: {}'.format(true_identity))
```

Face verification

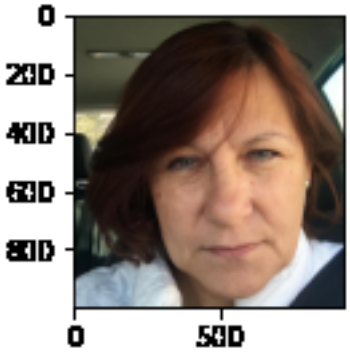
[19]:
```
def verify(image_path, identity, database):

    # Compute the encoding for the image
    encoding = encode(image_path)

    # Compute distance with identity's image
    min_dist = 100
    for each in database[identity]:
```

```
            dist = np.linalg.norm(encoding - each)
            min_dist = min(dist, min_dist)

        if min_dist < 0.6:
            print("System: Verification succeeded (Distance = %.2f)" % min_dist)
            grant_access = True
        else:
            print("System: Verification failed (Distance = %.2f)" % min_dist)
            grant_access = False

        return min_dist, grant_access
```

[20]:
```
test_dir = './test'
images = filter(lambda f: not f.startswith('.'), os.listdir(test_dir))

for image in images:

    image_path = os.path.join(test_dir, image)

    # Load image
    load_image(image_path)

    # Verify if claimed identities are true
    print('\nTest 1')
    claimed_identity = input('System: What is your identity? \nUser:')

    while claimed_identity.capitalize() not in database.keys():
        claimed_identity = input('System: {} is not in the database \n\n What is␣
↪your identity? \nUser:'.format(claimed_identity))

    dist, success = verify(image_path, claimed_identity.capitalize(), database)

    print('\nTest 2')
    claimed_identity = input('System: What is your identity? \nUser:')

    while claimed_identity.capitalize() not in database.keys():
        claimed_identity = input('\nSystem: {} is not in the database. What is␣
↪your identity? \nUser:'.format(claimed_identity))

    verify(image_path, claimed_identity.capitalize(), database)

    print('\n')
```




```
True identity: Marcelo

Test 1

System: What is your identity?
User: Marcelo

System: Verification succeeded (Distance = 0.57)

Test 2

System: What is your identity?
User: Michal

System: Verification failed (Distance = 0.93)
```




```
True identity: Jola

Test 1
```

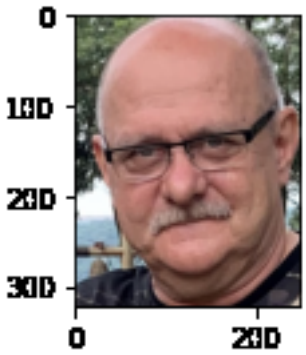
System: What is your identity?
User: Jola

System: Verification succeeded (Distance = 0.56)

Test 2

System: What is your identity?
User: Ala

System: Verification failed (Distance = 0.71)



True identity: Marek

Test 1

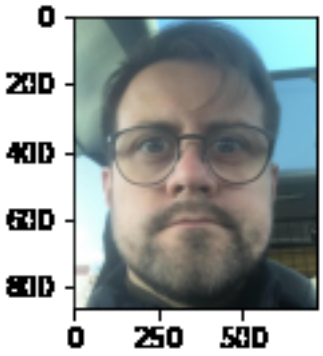
System: What is your identity?
User: Marek

System: Verification succeeded (Distance = 0.59)

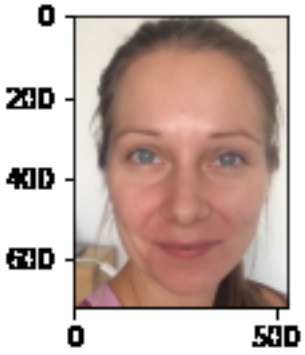
Test 2

System: What is your identity?
User: Michal

System: Verification failed (Distance = 0.90)




```
True identity: Michal

Test 1

System: What is your identity?
User: Michal

System: Verification succeeded (Distance = 0.56)

Test 2

System: What is your identity?
User: Marek

System: Verification failed (Distance = 0.72)
```




```
True identity: Ala

Test 1
```

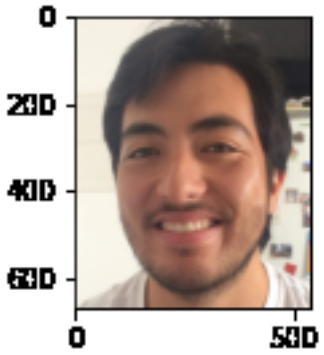
```
System: What is your identity?
User: Ala

System: Verification succeeded (Distance = 0.60)

Test 2

System: What is your identity?
User: Jola

System: Verification failed (Distance = 0.69)
```

Face recognition

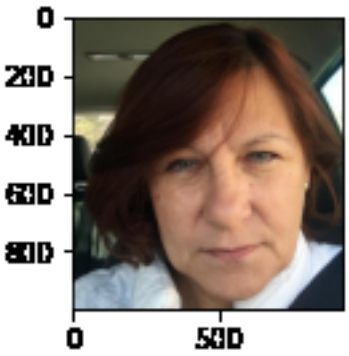
[21]:
```
def recognize(image_path, database):

    # Encode the input image
    encoding = encode(image_path)

    # Initialize min_dist to a large number
    min_dist = 100

    for (name, db_enc) in database.items():

        # Calculate L2 distance between encoding to recognize and current␣
↪encoding from the database
        for each in db_enc:

            dist = np.linalg.norm(encoding - each)

#             print('%s Distance: %.2f' % (name, dist))

            if dist < min_dist:
                min_dist = dist
                identity = name

    # Display predicted identity
    print('Prediction: %s \nDistance: %.2f\n' % (identity, min_dist))

    return min_dist, identity
```

[22]:
```
test_dir = './test'
images = filter(lambda f: not f.startswith('.'), os.listdir(test_dir))

for image in images:

    img_path = os.path.join(test_dir, image)
```

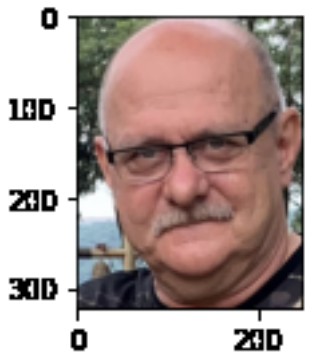
```
# Load image
load_image(image_path)

# Recognize a person
min_dist, identity = recognize(img_path, database)
```




```
True identity: Marcelo
Prediction: Marcelo
Distance: 0.57
```

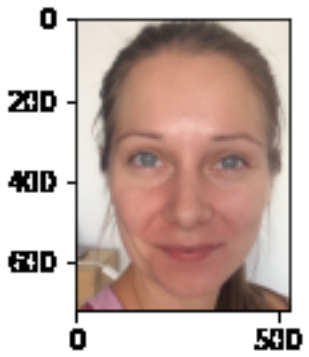



```
True identity: Jola
Prediction: Jola
Distance: 0.56
```




```
True identity: Marek
Prediction: Marek
Distance: 0.59
```


```
True identity: Michal
Prediction: Michal
Distance: 0.56
```



```
True identity: Ala
Prediction: Ala
Distance: 0.60
```

[ ]: