In [1]:

```python
import pandas as pd
import itertools
from sklearn.metrics import confusion_matrix
from tqdm import tqdm
tqdm.pandas()
```

Summary

The Deepface framework we used in our study also uses the OpenCv library during the face detection phase. In the process of recognition and vector expression of the face, it uses deep learning-based facial recognition models (Serengil &Özpinar, 2020). Face recognition models are regular convolutional neural networks models. They represent face photos as vectors. We find the distance between these two vectors to compare two faces. Finally, we classify two faces as same person whose distance is less than a threshold value(Serengil, 2020b).

Using the Google Facenet facial recognition model and the euclidean_l2 metric, we will calculate the threshold values in the Mix Data set.

For the original notebook, see: https://github.com/serengil/deepface/blob/master/tests/Fine-Tuning-Threshold.ipynb

Mix Data set

In [2]:

```python
idendities = {
    "Laura_Harrier": ["img1.jpg", "img2.jpg", "img3.jpg", "img4.jpg"],
    "Zendaya": ["img5.jpg", "img6.jpg", "img7.jpg", "img8.jpg"],
    "Tom_Holland": ["img9.jpg", "img10.jpg", "img11.jpg", "img12.jpg"],
    "Andrew_Garfield": ["img13.jpg", "img14.jpg", "img15.jpg", "img16.jpg"],
    "Jodie_Comer":["img17.jpg", "img18.jpg", "img19.jpg", "img20.jpg"],
    "Emma_Stone": ["img21.jpg", "img22.jpg", "img23.jpg", "img24.jpg"],
    "Will_Smith": ["img25.jpg", "img26.jpg", "img27.jpg", "img28.jpg"],
    "Lance Reddick": ["img29.jpg", "img30.jpg", "img31.jpg", "img32.jpg"],
    "Lee_Jung_jae": ["img33.jpg", "img34.jpg", "img35.jpg", "img36.jpg"],
    "Choi_Min_sik": ["img37.jpg", "img38.jpg", "img39.jpg", "img40.jpg"],
    "HoYeon Jung": ["img41.jpg", "img42.jpg", "img43.jpg", "img44.jpg"],
    "Sandra_Oh": ["img45.jpg", "img46.jpg", "img47.jpg", "img48.jpg"]
}
```

Positive samples

Find different photos of same people

In [3]:

```python
positives = []

for key, values in idendities.items():

    #print(key)
    for i in range(0, len(values)-1):
        for j in range(i+1, len(values)):
            #print(values[i], " and ", values[j])
            positive = []
```

```
            positive.append(values[i])
            positive.append(values[j])
            positives.append(positive)
```

In [4]:

```
positives = pd.DataFrame(positives, columns = ["file_x", "file_y"])
positives["decision"] = "Yes"
```

Negative samples

Compare photos of different people

In [5]:

```
samples_list = list(idendities.values())
```

In [6]:

```
negatives = []

for i in range(0, len(idendities) - 1):
    for j in range(i+1, len(idendities)):
        #print(samples_list[i], " vs ",samples_list[j])
        cross_product = itertools.product(samples_list[i], samples_list[j])
        cross_product = list(cross_product)
        #print(cross_product)

        for cross_sample in cross_product:
            #print(cross_sample[0], " vs ", cross_sample[1])
            negative = []
            negative.append(cross_sample[0])
            negative.append(cross_sample[1])
            negatives.append(negative)
```

In [7]:

```
negatives = pd.DataFrame(negatives, columns = ["file_x", "file_y"])
negatives["decision"] = "No"
```

Merge Positives and Negative Samples

In [8]:

```
df = pd.concat([positives, negatives]).reset_index(drop = True)
```

In [9]:

```
df.shape
```

Out[9]:

```
(1128, 3)
```

In [10]:

```
df.decision.value_counts()
```

Out[10]:

```
No     1056
Yes      72
Name: decision, dtype: int64
```

In [11]:

```
df.file_x = "dataset/"+df.file_x
df.file_y = "dataset/"+df.file_y
```

DeepFace

In [12]:
```python
from deepface import DeepFace
```

In [13]:
```python
instances = df[["file_x", "file_y"]].values.tolist()
```

In [14]:
```python
model_name = "Facenet"
distance_metric = "euclidean_l2"
```

In [199…
```python
resp_obj = DeepFace.verify(instances, model_name = model_name, distance_metric = dis
```

```
Verification: 100%|██████████████████████████████████████████████████|
1128/1128 [24:21<00:00,  1.30s/it]
```

In [200…
```python
distances = []
for i in range(0, len(instances)):
    distance = round(resp_obj["pair_%s" % (i+1)]["distance"], 4)
    distances.append(distance)
```

In [201…
```python
df["distance"] = distances
```

Analyzing Distances

In [202…
```python
tp_mean = round(df[df.decision == "Yes"].mean().values[0], 4)
tp_std = round(df[df.decision == "Yes"].std().values[0], 4)
fp_mean = round(df[df.decision == "No"].mean().values[0], 4)
fp_std = round(df[df.decision == "No"].std().values[0], 4)
```

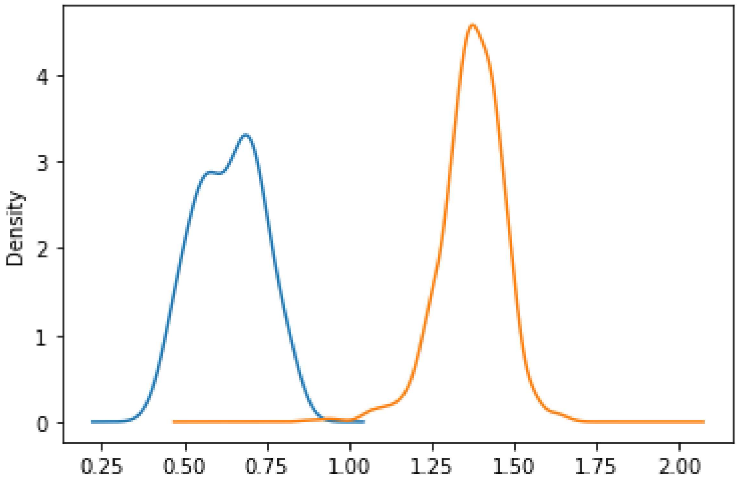
In [205…
```python
print("Mean of true positives: ", tp_mean)
print("Std of true positives: ", tp_std)
print("Mean of false positives: ", fp_mean)
print("Std of false positives: ", fp_std)
```

```
Mean of true positives:  0.6354
Std of true positives:  0.1015
Mean of false positives:  1.3722
Std of false positives:  0.0948
```

Distribution

In [206…
```python
df[df.decision == "Yes"].distance.plot.kde()
df[df.decision == "No"].distance.plot.kde()
```

Out[206…
```
<AxesSubplot:ylabel='Density'>
```



Sigma

In [196…

```
sigma = 3
#2 sigma corresponds 95.45% confidence, and 3 sigma corresponds 99.73% confidence

threshold = round(tp_mean + sigma * tp_std, 4)
#hreshold = 0.680#comes from c4.5 algorithm
print("threshold: ", threshold)
```

```
threshold:  0.9399
```

In [182…

```
df[df.decision == 'Yes'].distance.max()
```

Out[182…

```
0.8381
```

In [183…

```
df[df.decision == 'No'].distance.min()
```

Out[183…

```
0.8703
```

Evaluation

In [184…

```
df["prediction"] = "No"
```

In [185…

```
idx = df[df.distance <= threshold].index
df.loc[idx, 'prediction'] = 'Yes'
```

In [186…

```
df.head(5)
```

Out[186…

	file_x	file_y	decision	distance	prediction
0	dataset/img1.jpg	dataset/img2.jpg	Yes	0.5013	Yes
1	dataset/img1.jpg	dataset/img3.jpg	Yes	0.4271	Yes
2	dataset/img1.jpg	dataset/img4.jpg	Yes	0.4808	Yes
3	dataset/img2.jpg	dataset/img3.jpg	Yes	0.5103	Yes

	file_x	file_y	decision	distance	prediction
4	dataset/img2.jpg	dataset/img4.jpg	Yes	0.4825	Yes

In [187…

```
cm = confusion_matrix(df.decision.values, df.prediction.values)
```

In [188…

```
cm
```

Out[188…

```
array([[1056,    0],
       [  26,   46]], dtype=int64)
```

In [189…

```
tn, fp, fn, tp = cm.ravel()
```

In [190…

```
tn, fp, fn, tp
```

Out[190…

```
(1056, 0, 26, 46)
```

In [191…

```
recall = tp / (tp + fn)
precision = tp / (tp + fp)
accuracy = (tp + tn)/(tn + fp +  fn + tp)
f1 = 2 * (precision * recall) / (precision + recall)
```

In [192…

```
print("Precision: ", 100*precision,"%")
print("Recall: ", 100*recall,"%")
print("F1 score ",100*f1, "%")
print("Accuracy: ", 100*accuracy,"%")
```

```
Precision:  100.0 %
Recall:  63.888888888888886 %
F1 score  77.96610169491525 %
Accuracy:  97.69503546099291 %
```

In [198…

```
df.to_csv("threshold_pivot_mix_Facenet.csv", index = False)
```

Test results

Threshold = 0.68

Precision: 100.0 % Recall: 63.88 % F1 score 77.96 % Accuracy: 97.69 %

Threshold = 0.7369 (1 sigma)

Precision: 100.0 % Recall: 86.11 % F1 score 92.53 % Accuracy: 99.11 %

Threshold = 0.8384 (2 sigma)

Precision: 100.0 % Recall: 100.0 % F1 score 100.0 % Accuracy: 100.0 %

Threshold = 0.9399 (3 sigma)

Precision: 96.0 % Recall: 100.0 % F1 score 97.95 % Accuracy: 99.73 %

Threshold = 1.16

Precision: 72.72 % Recall: 100.0 % F1 score 84.21 % Accuracy: 97.60 %

In [ ]:

```

```