Plastic Surgery Face Recognition: A comparative Study of Performance

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Abstract

The paper presents a comparative study of performance for face recognition algorithms in order to select the algorithms that have the highest performance and overcome the problems faced in recognition due to plastic surgery. A plastic surgery database that contains face images with different types of surgeries is used.. The work reports the performance evaluation of eleven photometric illumination techniques, five histogram normalization techniques and four feature extraction techniques. A minimum distance classifier has been adopted and four distance similarity measures were used. Face identification/verification techniques are considered in the present work. Experimental results were carried out and it can be concluded that for face identification, the best illumination technique is gradient-face (GRF) normalization technique, histruncate histogram normalization and the best feature extraction technique is gabor kernel fisher analysis GKFA. For face verification, the best illumination technique is gradient-face (GRF) normalization technique, and the best feature extraction technique is gabor principal component analysis (GPCA). For both face identification/verification the minimum distance classifier using Mahalanobis Cosine (MAHCOS) distance gives the best results.

Keywords: *photometric illumination, histogram normalization, holostic feature extraction techniques, mininmum distance classifier.*

1. Introduction

Face recognition technology has become one of the most important biometric technologies, for its non-intrusive nature and its potential applications like personal identification, security access control, surveillance systems, telecommunications, digital libraries, human-computer interaction , military and so on [1].

Five factors can significantly affect the performance of face recognition system: illumination, pose, expression, occlusion and ageing [2]. Another challenging factor that is not much considered before is Plastic surgery[3].

Plastic surgery is generally used for improving the facial appearance, for example, removing birth marks, moles, scars and correcting disfiguring defects. However, it can also be misused by individuals to conceal their identities with the intent to commit fraud or evade law enforcement. Face recognition after plastic surgery can lead to rejection of genuine users or acceptance of impostors. While face recognition is a well studied problem in which several approaches have been proposed to address the challenges of illumination [4], pose [1,5], expression [4], aging [2] and disguise [6, 7], the use of plastic surgery introduces a new challenge to designing future face recognition systems.

In general, plastic surgery can be classified into two distinct categories.

1. Disease Correcting Local Plastic Surgery (Local Surgery): This is the kind of surgery in which an individual undergoes local plastic surgery for correcting defects, anomalies, or improving skin texture.. Such changes may cause errors in automatic face recognition and degrade the system performance.
2. Plastic Surgery for Reconstructing Complete Facial Structure (Global Surgery): Apart from local surgery, plastic surgery can be done to completely change the facial structure which is known as full face lift. This medical procedure is recommended for cases such as patients with fatal burn or trauma. In this type of surgery, the appearance, texture and facial features of an individual are reconstructed and are usually not the same as the original face.

The main objective of the work is to investigate the performance of existing face recognition algorithms on a face database that contains images before and after

surgery. In general, any face recognition system consists of four stages: capturing the face images, segmentation and preprocessing of the face, face feature extraction, and classification. The present work presents a detailed performance evaluation for algorithms most commonly used in each stage. In the present study considers the performance evaluation of eleven photometric illumination techniques, five histogram normalization techniques, four feature extraction techniques and a minimum distance classifier using four distance similarity measures .

The organization of this paper as follows: Section II presents the plastic surgery database used in the present work and the preprocessing steps carried out.. Section III presents the photometric illumination techniques utilized. Section IV presents the histogram normalization techniques. The four selected feature extraction techniques and the classifier are described in Sections V and VI, respectively. Section VII presents performance evaluation metrics. Experimental results are reported in Section VIII. Finally a conclusion is drawn in Section IX.

2. Plastic Surgery Database

The plastic surgery database [8] used in the present work consists of 1800 full frontal face images of 900 subjects. Table 1 summarizes the details of the plastic surgery database, for each individual, there are two frontal face images (before and after plastic surgery). The database contains 519 image pairs corresponding to local surgeries, 381 pairs of global surgery, the local surgery images consists of 194 pairs of nose surgery (Rhinoplasty), 101 pairs of eye-lid-lift-surgery (blepharoplasty) images, 74 pairs of ear-surgery (otoplasty) images , 56 cases of brow-lift (forehead-lift) images, 32 pairs of laser-skin (resurfacing) images, 18 pairs of fat-injections images and 44 pairs of Others (Mentoplasty, Malar Augmentation, Craniofacial, Lip augmentation) images. While the global surgery images consists of 320 pairs of Rhytidectomy (face lift) images and 60 pairs of skin peeling (Skin resurfacing) images. Examples of images from the database are shown in Fig. 1. The images need to be preprocessed for accurate face detection and extraction, resizing as well as reducing the influence of reflections and artifacts. Hence, for each image, the face region in the image is detected and extracted, then a resizing procedure is performed.

Two pre-processing steps were applied to the images:

1. A background removal process where the face region in the image is detected and cropped to extract the face from the surrounding background.
2. Image size normalization where the size of the detected and cropped face image is set to200 x200 as shown in Fig.2.

Table 1: Plastic Surgery Database [8]

Type	Plastic Surgery Procedure	Number of subjects
Global	Face-Lift Surgery (rhytidectomy)	321
	Skin peeling (skin resurfacing)	60
Local	Nose Surgery (Rhinoplasty)	194
	Eye-Lid-Lift surgery (blepharoplasty)	101
	Ear-Surgery (otoplasty)	74
	Brow-Lift (Forehead)	56
	Laser-skin (resurfacing)	32
	Fat-injections	18
	Others(Mentoplasty, Lip augmentation)	44

Fig. 1. Examples of images from the plastic surgery database before and after plastic surgery.

Fig.2. a)Example of face images before processing , b)Face images after cropping and c) resizing

3. Photometric Illumination Normalization Techniques

As the appearance of a face image is severely affected by illumination conditions that hinder the face recognition process, Photometric normalization techniques are used to compensate for illumination induced appearance changes.
Eleven photometric illumination techniques were selected and their performance was evaluated in the present study. These are [9]: the single-scale-retinex algorithm (SSR), the multi-scale-retinex algorithm (MSR), the single-scale self quotient image (SSQ), the multi-scale self quotient image (MSQ), the homomorphic-filtering based normalization technique (HOMO), a wavelet-based normalization technique (WAV), the DCT- based normalization technique (DCT), a normalization technique based on steerable filters (SF), the Gradient-faces approach (GRF), wavelet-denoising-based normalization technique (WD), adaptive single scale retinex technique (ASR).

4. Histogram Normalization Techniques

Five histogram normalization techniques were considered. These are [9]: Rank Histogram (RH), Histogram Truncation and Stretching (HT), Normal Distribution (ND), Lognormal Distribution (LN), Exponential Distribution (EX).

5. Feature Extraction Techniques

In the present work, four techniques were considered for feature extraction. The principal component analysis (PCA) which is one of the most powerful and popular linear methods for dimensionality reduction and feature extraction [10], the kernel principal component analysis (KPCA) [11], the kernel Fisher analysis (KFA) [12], and the Gabor face representation [13-17] were selected and their performance on the face verification/identification was investigated.

6. Classifier

The *k*-Nearest Neighbor classifier (k =1) was adopted for classification [18], four distance similarity measures were used: Euclidean distance (EUC), Cosine distance (COS), city block (CTB) distance and the Mahalanobis Cosine (MAHCOS) distance.

7. Performance Evaluation

Assessment of the different techniques carried out in the present work was performed as follows. For the verification experiments, Detection Error Trade-off (*DET*) curves, which plot the false acceptance error (*FAR*) against the false rejection error rate (*FRR*) using different thresholds were used as well as the half total error rate (*HTER*). The FAR and FRR are defined as follows [20]:

$$FAR = \frac{n_{ai}}{n_i} 100\% \quad (1)$$

$$FRR = \frac{n_{rc}}{n_c} 100\% \quad (2)$$

where *HTER* is given by:

$$HTER = 0.5(FAR+FRR) \quad (3)$$

where n_{ai}: number of accepted impostor, n_i: number of all impostor identity claims made, n_{rc}: number of rejected geniune, and n_c: number of all genuine identity claims made.
For the identification experiments, results are provided in the form of the rank-one recognition rate (*ROR*):

$$ROR = \frac{n_{si}}{n_s} 100\% \quad (4)$$

where n_{si}: number of images successfully assigned to the right identity and n_s is the overall number of images trying to assign an identity to.

8. Experimental Results

Four experiments are conducted in this work and the results are reported here.

Experiment1: Without Any Processing.
In this experiment, the performance of the three holistic feature extraction techniques (PCA, KPCA and KFA) was evaluated. The three holistic feature extraction techniques were performed directly on the preprocessed image sets without any illumination normalization technique. The HTER and ROR rates are depicted in Table 2 using MAHCOS distance which gives the highest rates. Fig.3. shows the DET curves using MAHCOS distance. The results obtained for both verification/ identification systems showed that PCA gives the best recognition rates in case of Blepharoplasty, Otoplasty, fat-injections and Rhtidectomy plastic surgeries using MAHACOS distance measure, while KFA gives the best rates in case of resurfacing and forehead-lift plastic surgeries using MAHACOS distance measure. An overall best rates are obtained using PCA and MAHCOS distance measure.

Experiment 2: Using Gabor Filters.
The effect of using Gabor filters was investigated.. In this experiment Gabor representation of

Table 2: HTER and ROR rates obtained from Experiment 1 using MAHCOS. (PS= Plastic Surgery Type) and (HFE = Holistic Feature Extraction).

	PS / HFE	Resur-facing	Foreh-ead-Lift	Bleph-aropla-sty	Otopl-asty	Fat-Inject-ions	Rhyt-i-decto-my
HTER	PCA	0.080	0.072	0.090	0.172	0.258	0.161
	KPC-A	0.184	0.152	0.101	0.223	0.400	0.149
	KFA	0.077	0.068	0.093	0.182	0.270	0.187
ROR	PCA	68.9%	60.4%	59.6%	49.3%	43.8%	32%
	KPC-A	48.3%	52.8%	54.3%	47.9%	37.5%	34%
	KFA	68.9%	60.4%	58.5%	47.9%	43.8%	25%

the face image was calculated followed by one of the holistic feature extraction techniques without any illumination normalization, HTER and ROR rates are depicted in Table3- MAHCOS distance (highest performance). While Fig.4. shows the DET curves for the best results obtained using MAHCOS distance. The results obtained for both verification and identification systems showed that the best rates are obtained using GPCA in case of resurfacing, Blepharoplasty, Otoplasty and Rhytidectomy using MAHCOS distance, while KFA gives best rates in case of forehead-lift and fat-injections using MAHCOS distance measure. The overall highest rates have been obtained using GPCA feature extraction technique and MAHCOS distance.

Experiment3: Using Photometric Illumination Techniques

Experiment 3 was carried out to investigate the effect of using photometric illumination normalization techniques on face recognition, a photometric illumination normalization technique was first applied to each set of the six plastic surgery datasets. Then Gabor representation of the face image calculated and then followed by the use of holistic feature extraction technique. Table 4 and Table 5 shows the HTER and ROR results respectively, of performing 11 photometric illumination techniques: GRF, WAV, MSQ, SSQ, DCT, SF, HOMO, MSR, WD, SSR, ASR each time with one of the three holistic feature extraction techniques and MAHCOS distance which gives the highest performance. The results obtained for verification system shows that the best illumination normalization and feature extraction techniques are GRF and GPCA respectively, in case of resurfacing and rhytidectomy using MAHCOS distance measure, while GRF and GKFA are best illumination normalization and feature extraction respectively, in case of forhead-lift, blepharoplasty, otoplasty and fat-injections using MAHCOS distance measure. For verification system, the best illumination normalization and feature extraction techniques are GRF and GPCA respectively, in case of resurfacing, blepharoplasty, fat-injections and rhytidectomy using MAHCOS distance measure, while GRF and GKFA are best illumination normalization and feature extraction respectively, in case of forhead-lift and otoplasty using MAHCOS distance measure.

Experiment4: Using Histogram normalization Techniques

Experiment 4 investigates the effect of performing five histogram normalization techniques: normal, rank, exponential, lognormal and Histruncate histogram respectively. It consists of four stages: Firstly, photometric illumination normalization was performed. Secondly, Gabor representation was calculated from the resulted images, followed by histogram normalization then the holistic feature extraction technique was applied. The results obtained for verification system shows that rank histogram is the best normalization technique in case of forehead-lift, fat-injections and rhytidectomy plastic surgery, lognormal histogram in case of blepharoplasty and otoplasty while exponential histogram is the best choice in case of resurfacing. For verification system , rank histogram is the best normalization technique in case of forehead-lift, blepharoplasty and rhytidectomy plastic surgery, histruncate histogram in case of otoplasty plastic surgery. In case of resurfacing plastic surgery, normal, rank and lognormal histograms give the same best result.

Table 3: Experiment 2: HTER and ROR rates using MAHCOS. (PS= Plastic Surgery Type) and (HFE = Holistic Feature Extraction).

	PS / HFE	Resur-f-acing	Foreh-ead-Lift	Bleph-aropl asty	Otopl-asty	Fat-Inject-ions	Rhyti-decto-my
HTER	PCA	0.015	0.071	0.036	0.040	0.108	0.067
	KPC-A	0.016	0.088	0.056	0.085	0.158	0.087
	KFA	0.016	0.071	0.046	0.055	0.104	0.079
ROR	PCA	89.6%	79.2%	73.4%	65.7%	68.7%	68.6%
	KPC-A	89.6%	69.8%	71.2%	61.6%	68.7%	63.4%
	KFA	89.6%	81.1%	72.3%	63.0%	68.7%	21.5%

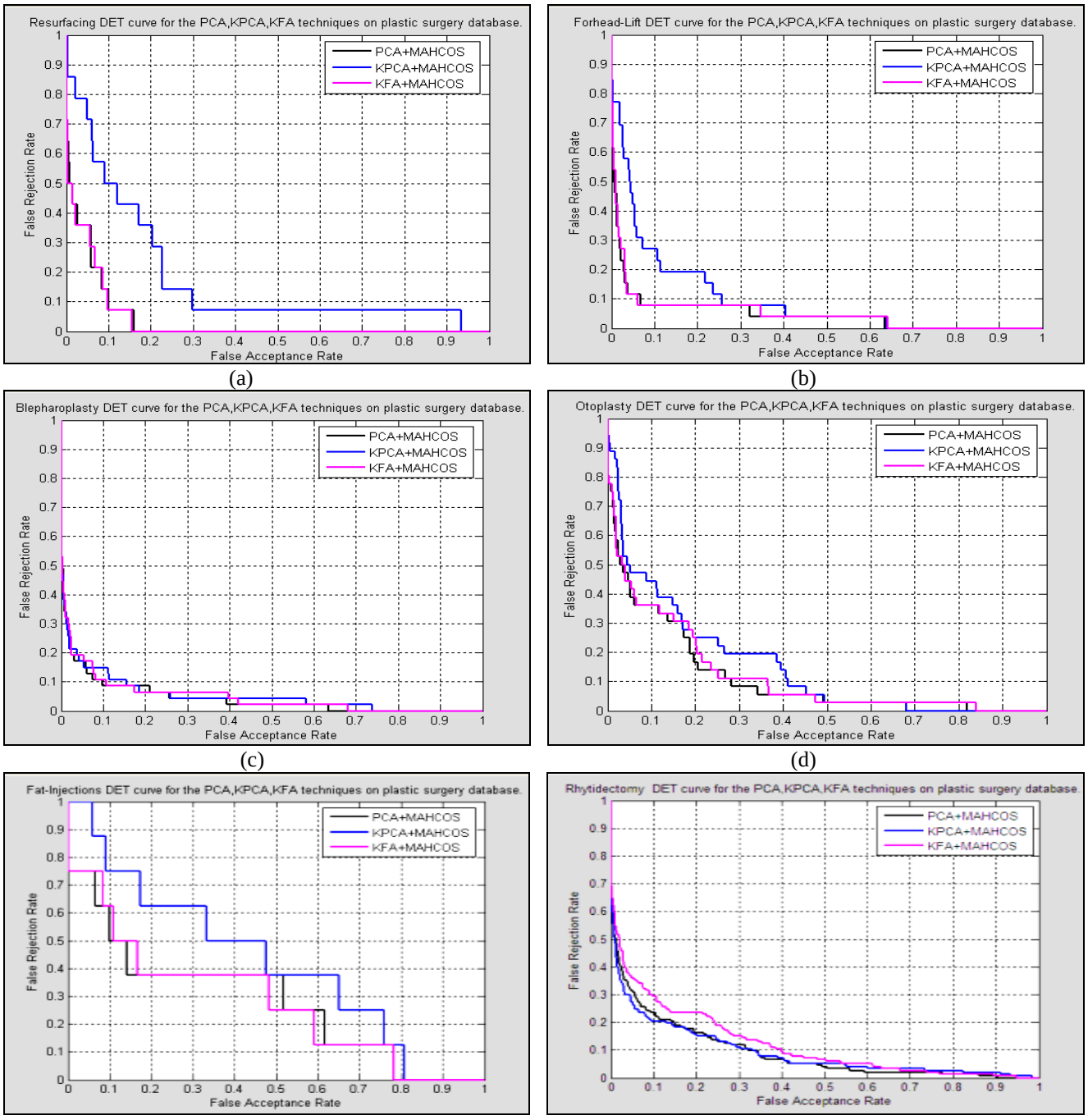

Fig.3. DET plots of the 3 holistic algorithms(a)Resurfacing, (b)Forehead- Lift, (c) Blepharoplasty, (d)Otoplasty,(e)Fat-injection and (f) Rhytidectomy surgery images using MAHCOS distance.

9. Conclusions

This paper has been concerned with the performance evaluation of the existing identification/verification approaches used in the recognition of human face. Specifically, the main objective is to identify the best face identification/verification techniques that give the highest performance for human face images for different plastic surgery.

The investigated techniques for each stage are not novel techniques; they are previously proposed and studied in literature. The selected techniques were applied onto a Plastic surgery database representing 6 types of facial

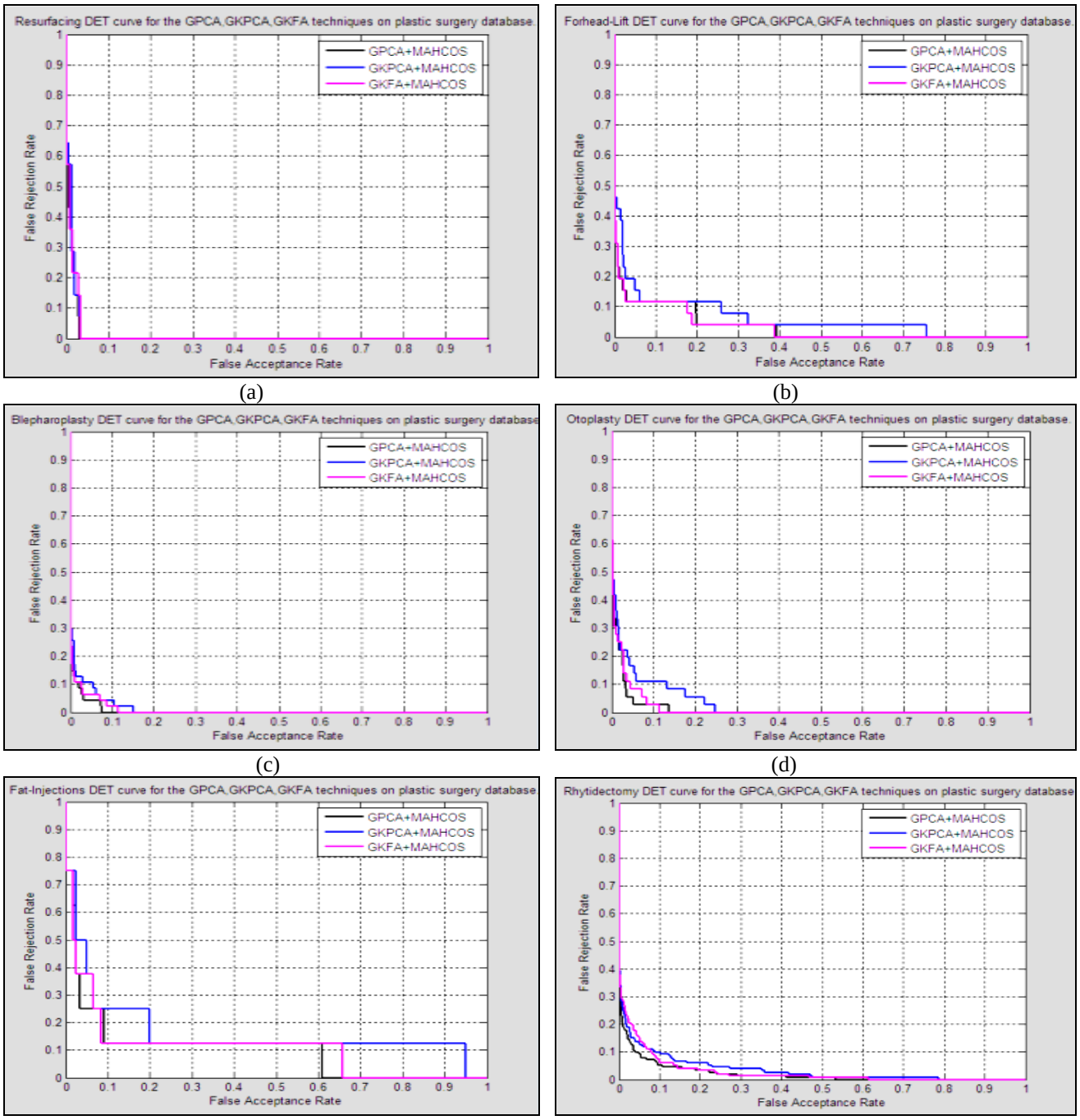

Fig.4. DET plots of the GPCA, GKPCA and GKFA (a)Resurfacing, (b)Forehead- Lift, (c) Blepharoplasty, (d)Otoplasty,(e)Fat-injection and (f) Rhytidectomy surgery images using MAHCOS distance.

plastic surgery: Brow-lift (Forehead-Lift), Eye-Lid-Left (blepharoplasty), ear (Otoplasty) ,Fat-Injections and Face-Lift (Rhytidectomy) surgery.

A face preprocessing step was first performed where the face region in the image is detected and extracted. Then a resizing procedure was performed.

As for the feature extraction stage. four feature extraction techniques were selected. These are: the principal component analysis (PCA), the kernel principal component analysis (KPCA), the kernel fisherfaces analysis (KFA) and the Gabor technique.

In general, identification and verification modes are two main goals of every security system based on the needs of the environment. In the verification mode, the system checks if the user data that was entered is correct or not but

in the identification stage, the system tries to discover who the subject is without any input information. Hence, verification is a one-to-one search but identification is a one-to-many comparison. For verification purposes, a decision with high confidence level is made to verify whether the user is authenticated or imposter. To identify a person's identity, the face image needs to be matched with the stored images. Therefore, the nearest neighbor classifier was adopted for both identification and verification modes of the proposed system using four distance similarity measures. These are: Euclidean distance, cosine distance, city block distance, and Mahalanobis Cosine distance similarity measure.

The performance metrics adopted in the present study are as follows. For face verification experiments, the false acceptance error rate (FAR), false rejection error rate (FRR) and the half total error rate (HTER)were computed, as well as Detection Error Trade-off (DET) curves. However, for the identification experiments results were compared in the form of the so-called rank one recognition rate (ROR).

Four experimental studies were carried out in the present comparative study. In the first experiment, the three holistic feature extraction techniques (PCA, KPCA and KFA) were applied directly on facial plastic surgery. The results obtained for both verification/ identification systems showed that PCA gives the best recognition rates in case of Blepharoplasty, Otoplasty, fat-injections and Rhtidectomy plastic surgeries using MAHACOS distance measure, while KFA gives the best rates in case of resurfacing and forehead-lift plastic surgeries using MAHACOS distance measure. An overall best result is obtained using PCA and MAHCOS distance measure.

Extracting the Gabor features prior to performing holistic approaches in the second experiment gives a noticeable improvement in the recognition rates on all facial plastic surgery sets. The results obtained for both verification and identification systems showed that the highest recognition rates and minimum error rate are obtained using GPCA in case of resurfacing, Blepharoplasty, Otoplasty and Rhytidectomy using MAHCOS distance, while KFA gives best rates in case of forehead-lift and fat-injections using MAHCOS distance measure. An overall best results have been obtained using GPCA feature extraction technique and MAHCOS distance.

In an attempt to reduce the effect of illumination conditions that hinder the face recognition process, two experiments were carried out to investigate the effect of using photometric illumination normalization and histogram normalization on facial plastic surgery.

This effect was investigated in the third and fourth experiments. The third experiment investigates the effect

TABLE 4. HTER rates resulted from Experiment 3 using MAHCOS. (PS= Plastic Surgery Type),(HFE = Holistic Feature Extraction) and (PIT= Photometric Illumination Technique) .

PIT	PS / HFE	Resurf-acing Surgery	Forehe-ad-Lift	Blepha-roplasty	Otopla-sty	Fat-Injecti-ons Surgery	Rhytid-ectomy
GRF	PCA	0.0140	0.0592	0.0142	0.0469	0.083	0.0444
	KPCA	0.0536	0.0876	0.0304	0.0801	0.162	0.0919
	KFA	0.0140	0.0473	0.0137	0.0471	0.066	0.0487
WAV	PCA	0.0166	0.0666	0.0245	0.0592	0.100	0.0603
	KPCA	0.0395	0.1076	0.0358	0.1047	0.141	0.0747
	KFA	0.0140	0.0643	0.0341	0.0617	0.095	0.0687
MSQ	PCA	0.0242	0.0839	0.0487	0.0733	0.108	0.0830
	KPCA	0.0217	0.0954	0.0633	0.1209	0.175	0.0959
	KFA	0.0293	0.0917	0.0542	0.0826	0.104	0.1051
SSQ	PCA	0.0408	0.0740	0.0528	0.0835	0.112	0.0854
	KPCA	0.0255	0.0847	0.0645	0.1368	0.170	0.1012
	KFA	0.0434	0.0843	0.0620	0.0885	0.112	0.1186
DCT	PCA	0.0816	0.1006	0.0673	0.1121	0.229	0.1208
	KPCA	0.0816	0.1087	0.0729	0.1593	0.225	0.1209
	KFA	0.0842	0.0962	0.0824	0.1196	0.229	0.1686
SF	PCA	0.0536	0.1039	0.0581	0.0891	0.158	0.0992
	KPCA	0.0472	0.1254	0.0686	0.1308	0.150	0.1306
	KFA	0.0536	0.1084	0.0599	0.0912	0.158	0.1214
HOMO	PCA	0.0714	0.1043	0.0501	0.0741	0.166	0.0961
	KPCA	0.0829	0.1398	0.0503	0.1190	0.212	0.1156
	KFA	0.0689	0.1087	0.0556	0.0870	0.162	0.1310
MSR	PCA	0.1237	0.1302	0.0844	0.1921	0.175	0.1898
	KPCA	0.1454	0.1609	0.1197	0.2133	0.175	0.1803
	KFA	0.1237	0.1379	0.0984	0.2118	0.183	0.2893
WD	PCA	0.0485	0.0965	0.0755	0.1005	0.216	0.1065
	KPCA	0.0842	0.1187	0.0835	0.1429	0.258	0.1179
	KFA	0.0536	0.0947	0.0738	0.1049	0.225	0.2175
SSR	PCA	0.1237	0.1287	0.0880	0.1931	0.179	0.1869
	KPCA	0.1403	0.1564	0.1194	0.2110	0.179	0.1765
	KFA	0.1237	0.1394	0.0972	0.2087	0.187	0.2837
ASR	PCA	0.0268	0.1257	0.0773	0.1269	0.279	0.1302
	KPCA	0.0804	0.1391	0.1030	0.1775	0.262	0.1319
	KFA	0.0319	0.1232	0.0795	0.1306	0.283	0.1798

of eleven photometric illumination techniques (Gradient (GRF), Wavelet Based (WAV), Multi-Scale Self Quotient (MSQ), Single Scale Self-Quotient (SSQ) , DCT Based (DCT), Steerable Filter Based (SF), Homomorphic Filtering Based (HOMO), Multi-Scale Retinex (MSR), Wavelet Denoising Based (WD), Single Scale Retinex (SSR), Adaptive Single Scale Retinex (ASSR)) using Gabor face representation before using the three holistic feature extraction techniques on facial plastic surgery. It has been found that an overall best rates were obtained, For verification system using GRF illumination

TABLE 5. ROR rates resulted from Experiment 3 using MAHCOS. (PS= Plastic Surgery Type),(HFE = Holistic Feature Extraction) and (PIT= Photometric Illumination Technique) .

PIT	PS / HFE	Resurfacing-	Forehead-Lift	Blepharoplasty	Otoplasty	Fat-Injections	Rhytidectomy
GRF	PCA	96.6%	84.9%	85.1%	78.1%	81.2%	73.2%
	KPCA	93.1%	77.4%	80.9%	72.6%	75.0%	67%
	KFA	89.7%	84.9%	83%	79.5%	81.3%	70.3%
WAV	PCA	96.6%	77.4%	77.7%	74%	75.0%	71.9%
	KPCA	93.1%	71.7%	75.5%	71.2%	62.5%	66.7%
	KFA	96.6%	79.3%	72.3%	76.7%	75.0%	25.2%
MSO	PCA	89.7%	69.8%	73.4%	69.9%	75.0%	60.8%
	KPCA	82.8%	69.8%	72.3%	63.0%	68.7%	60.1%
	KFA	93.1%	67.9%	73.4%	71.2%	75.0%	35.6%
SSO	PCA	89.7%	71.7%	74.5%	61.6%	75.0%	59.5%
	KPCA	82.8%	64.2%	72.3%	60.3%	68.7%	57.2%
	KFA	89.7%	71.7%	74.5%	63.0%	75.0%	18%
DCT	PCA	72.4%	62.3%	66%	57.5%	68.7%	40.9%
	KPCA	58.6%	62.3%	67.0%	53.4%	56.2%	42.5%
	KFA	75.9%	56.6%	58.5%	57.5%	68.7%	0.7%
SF	PCA	75.9%	67.9%	72.3%	61.6%	75.0%	51.6%
	KPCA	75.9%	67.9%	72.3%	54.8%	68.7%	49.7%
	KFA	75.9%	66.0%	70.2%	64.4%	75.0%	37.9%
HOMO	PCA	82.8%	62.3%	69.2%	61.6%	62.5%	46.4%
	KPCA	72.4%	56.6%	67.0%	56.2%	56.3%	47.7%
	KFA	86.2%	62.3%	63.8%	56.2%	62.5%	11.8%
MSR	PCA	41.4%	35.9%	47.9%	38.4%	43.7%	23.2%
	KPCA	37.9%	35.9%	40.4%	35.6%	43.7%	23.5%
	KFA	41.4%	39.6%	44.7%	32.9%	43.7%	0.7%
WD	PCA	72.4%	50.9%	67.0%	54.8%	68.7%	44.4%
	KPCA	55.2%	56.6%	69.1%	46.6%	50.0%	45.4%
	KFA	79.3%	52.8%	64.9%	53.4%	62.5%	1.3%
SSR	PCA	41.4%	35.9%	47.9%	38.4%	43.7%	23.5%
	KPCA	37.9%	35.9%	40.4%	38.4%	43.7%	23.5%
	KFA	41.4%	39.6%	44.7%	34.3%	43.7%	1.3%
ASR	PCA	72.4%	64.2%	62.8%	45.2%	56.2%	37.9%
	KPCA	72.4%	67.9%	59.6%	43.8%	50.0%	38.9%
	KFA	72.4%	66.0%	58.5%	43.8%	56.2%	9.2%

normalization technique with GKFA feature extraction technique and the MAHCOS distance measure, while for identification system using GRF illumination normalization technique with GPCA feature extraction technique and the MAHCOS distance measure.

In the fourth experiment, the effect of using five histogram normalization techniques (Normal histogram**,** Rank histogram, Exponential histogram, Lognormal Histogram, Histruncate Histogram) after the application of the photometric illumination normalization techniques on facial plastic surgery recognition rates was investigated. It has been found that the four histogram normalization: Normal, Rank and Lognormal histogram showed higher recognition rates than the exponential histogram normalization technique. Histruncate histogram proves to be the best For face verification systems, while rank histogram proves to be the best For face identification systems.

Finally, it can be concluded that for face verification systems, the best results in case of resurfacing are obtained using steerable filters (SF) illumination normalization technique, exponential histogram normalization and gabor principal component analysis (GPCA) feature extraction technique. For forhead-lift, best results are obtained using Gradient faces (GRF) illumination normalization technique, rank histogram and gabor principal component analysis (GPCA) feature extraction technique. For Blepharoplasty, best results are obtained using GRF illumination normalization technique, no histogram normalization and gabor kernel fisher analysis (GKFA)**.** For Otoplasty, best results are obtained using SF illumination normalization, Lognormal histogram and GPCA feature extraction technique. For Fat injection, best results are obtained using GRF illumination normalization, rank histogram and GKFA feature extraction technique. And for Rhytidectomy, best results are obtained using GRF illumination normalization, no histogram normalization and GPCA feature extraction technique.

As a general conclusion for the verification problem and for all types of plastic surgery, best illumination technique is Gradient faces (GRF) Normalization Technique, the best histogram normalization is Histruncate histogram and the best feature extraction technique is GKFA using MAHCOS distance. . MAHCOS distance gives the best results. The minimum error rates reach 0.0140, 0.0173, 0.0451, 0.0463, 0.0549 and 0.0667 in case of resurfacing, Bleharoplasty, forhead-lift, Otoplasty, Rhytidectomy and fat-injections, respectively.

As for face identification systems: best results of resurfacing surgery, are obtained using GRF illumination normalization technique, all types of histogram normalization except exponential and Histruncate histogram normalization and GPCA feature extraction

technique. For forhead-lift, best results are obtained GRF illumination normalization technique, rank histogram and gabor GPCA or GKFA feature extraction techniques. For Blepharoplasty, best results are obtained using wavelet-based (WAV) illumination normalization technique, rank histogram normalization and GPCA or GKFA**.** For Otoplasty, best results are obtained using GRF illumination normalization, histruncate histogram and GPCA or GKFA feature extraction techniques. For Fat injection, best results are obtained using GRF illumination normalization, all types of histogram and GPCA or GKFA feature extraction techniques. And for Rhytidectomy, best results are obtained using WAV illumination normalization, rank histogram normalization and GPCA or GKFA feature extraction techniques. A conclusion can be drawn that for identification purpose and for all types of plastic surgery, best illumination technique is GRF normalization Technique, no histogram normalization and the best feature extraction technique is GPCA. MAHCOS distance gives the best results. This results in a correct recognition rate of 96.55%, 85.11%, 84.91%, 81.25%, 78.08% and 73.20% in case of resurfacing, Blepharoplasty, Forehead-lift, Fat-injections, Otoplasty and Rhytidectomy plastic surgery, respectively.Therefore according to the present comparative study of performance of plastic surgery face recognition algorithms, it is recommended to use GKFA as a feature extraction technique, GRF for illumination normalization technique, histruncate histogram for histogram normalization for face verification systems. As for face identification system, it is recommended to use GPCA for feature extraction technique, GRF as an illumination normalization technique, rank histogram for histogram normalization. For both verfication and identification the 1-nearest neighbour classifier using MAHCOS distance gives satisfactory results..

In conclusion, all the face identification/verification techniques adopted in this paper are promising and could be used and developed to improve a face recognition system performance and to find the nearness between the pre-plastic surgical face to the-post plastic surgical face.

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