Comparative Analysis of Illumination Normalizations on Principal Component Analysis Based Feature Extraction for Face Recognition

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Abstract— Principle Component Analysis (PCA) is an appearance-based technique for extraction of feature extraction that is commonly used in computer vision and image processing. This technique suffers from illumination variations, thus knowing which illumination control method to be used in PCA-based face recognition system is very important. This paper applies three selected normalization techniques; Discrete Cosine Transform (DCT), Adaptive Histogram Equalization (AHE) and Contrast Limited Adaptive Histogram Equalization (CLAHE) to normalize face images. PCA was further used to extract features from the normalized face images. Euclidean distance was used to classify extracted features. The best recognition accuracy of 91.84% was obtained in DCT for ORL Database, while the best accuracy of 76% was achieved in DCT for FERET Database. The highest FAR of 0.9 was achieved in DCT for ORL Database, while the highest FAR of 0.5 was obtained in DCT and AHE for FERET Database. The highest FRR of 0.2821 was achieved in CLAHE for ORL Database, while 0.3000 was obtained in AHE for FERET Database. It was concluded that illumination control approaches have predominant effect on PCA–based facial recognition system.

Keywords— Adaptive Histogram Equalization, Contrast Adaptive Histogram Equalization, Discrete Cosine Transform Illumination Normalization, Principal Component Analysis,

1 INTRODUCTION

Facial recognition, among so many biometric recognition systems is considered a user friendly and confidentially respectful biometric technique with high accuracy (Jafri & Arabnia, 2009) and low intrusiveness (Kashem, Akhter, Ahmed & Alam, 2011). It is a technique of biometric for verifying and identifying a person from digital image or video using dataset of images of face (Joshi & Deshpande, 2015). The performance of recognition of face depends on some major factors like variations in illumination, pose changes, facial exposure, variations in age and occlusions (Reza & Qi, 2016). It takes enormous effort to develop accurate and robust recognition over a broad range of conditions.

Face recognition and verification accuracy deteriorated significantly when there are differences in pose and illumination between images used for enrollment and recognition (Romdhani, Ho, Vetter & Kriegman, 2006). In the midst of these factors, illumination conditions such as shadows, underexposure (too dark) and overexposure (too bright) attracted much attention in the last decade (Abate, Nappi, Riccio& Sabatino, 2007). Illumination remains the most significant factor affecting the image appearance; it often leads to diminished structures or in homogenous intensities of the image due to different object texture surface and the shadows cast from different light source directions.

Normalization of illumination is an essential aspect that must be duly considered in image processing and computer vision (Anila & Devarajan, 2012). Due to the problem of illumination variability in recognition of face using Principal Component Analysis (PCA) method, the same image can appear out rightly different even when it is captured in fixed pose. The challenge of knowing which illumination control methods to be used in facial recognition system based on PCA algorithm is very important.

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This paper applied the most three commonly used methods of illumination control/normalization techniques; Discrete Cosine Transform, Adaptive Histogram Equalization and Contrast Limited Adaptive Histogram Equalization on Principal Component Analysis algorithm to conduct comparative analysis on which of the illumination control techniques perform better.

2 RELATED WORK

Several studies have been proposed for which different techniques are employed by researchers to carrying out illumination normalization. Salkar et al., (2017) presented facial recognition system using local feature description with diverse lighting conditions. Local directional number pattern (LDN) was applied to extract the features from face image. Six-bit binary code was created to produce LDN image. The face image was divided into numerous sections and for each section LDN was calculated and histogram for each section taken. The system was evaluated on three face image datasets; CMU Multi-PIE (Carnegie Mellon University collected Multi-Pose Illumination Expression Database), YALE face image database and Olivetti Research Laboratory Database (ORL). Experimental results showed 70 % of accuracy for recognition.

Reza and Qi (2016) proposed a system which produced illumination-invariant features for images irrespective of their level of illumination. The work combined adaptive homomorphic filtering, simplified logarithmic fractal dimension and complete eight local directional patterns to produce the illumination invariant features. They determined from their experiments that the developed system performed better than nine state of the art techniques and thus results in a better face recognition accuracy.

Dan-ali (2014) came up with a study by conducting comparative analysis on five methods for control of illumination. The study performed a comparative analysis on the system based on diverse distance measure metrics. The performance and execution times of these methods were recorded and computed in terms for efficiency and accuracy. The illumination normalized methods were Gamma Intensity Correction (GIC), Discrete Cosine Transform (DCT), Histogram Remapping using Normal Distribution (HRN), Histogram Remapping using Normal Distribution (HRL) and Anisotropic Smoothing Technique (AS). Experimental results achieved enhanced recognition accuracy, when the better preprocessing method was used on suitable database using the correct classifier.

Kalaiselvi and Nithya (2013) presented an effective preprocessing chain that removes the effects of illumination variations while still keeping information required for recognition. The study combined the strengths of local texture based face representations, robust illumination normalization, distance transform based matching and kernel based feature extraction and multiple feature fusion. Their work was simulated using MATLAB and their experiments showed that their method outperforms several other preprocessing techniques catering for illumination.

3 Research Methodology

The comparative analysis system considered three selected illumination normalization approaches; Contrast Limited Adaptive Histogram Equalization, Discrete Cosine Transform and Adaptive Histogram Equalization. This study acquired face images from two publicly available face image datasets; Olivetti Research Laboratory (ORL Database) and Face Recognition Technology (FERET Database). 100 face images were used from the two datasets. The second phase handled the image normalization, which is the major focus of the study, which involved the illumination normalization techniques. Three illumination normalization techniques aforementioned were applied to pre-process the face images from the two databases. Principal Component Analysis (PCA) was applied for extraction of facial features from the face images. The extracted feature subspace was passed into Euclidean distance measure for classification of face into matched or mismatched. Finally, comparative analysis was conducted to show the effect of illumination normalization methods on the PCA extracted facial feature. The process of comparative analysis is shown in Figure 1.

3.1 Performance Evaluation of the Comparative Analysis

The measurement metrics used in this study are shown in the following equations:

$$\text{Recognition Accuracy (\%)} = \frac{TP+TN}{TP+TN+FP+FN} \times 100 \quad (1)$$

$$FAR = \frac{number\ of\ false\ acceptance}{number\ of\ identification\ attempts} = \frac{FP}{FP+TN} \quad (2)$$

$$FRR = \frac{False\ rejection}{number\ of\ identification\ attempts} = \frac{FN}{TP+FN} \quad (3)$$

Where True Positive (TP) denotes the total number of authorized face images that are correctly recognized by the system, False Positive (FP) that is the total number of unauthorized face images wrongly recognized by the system, True Negative (TN) represents the total number of authorized images correctly unrecognized and False Negative (FN) is the total number of unauthorized images that are wrongly unrecognized.

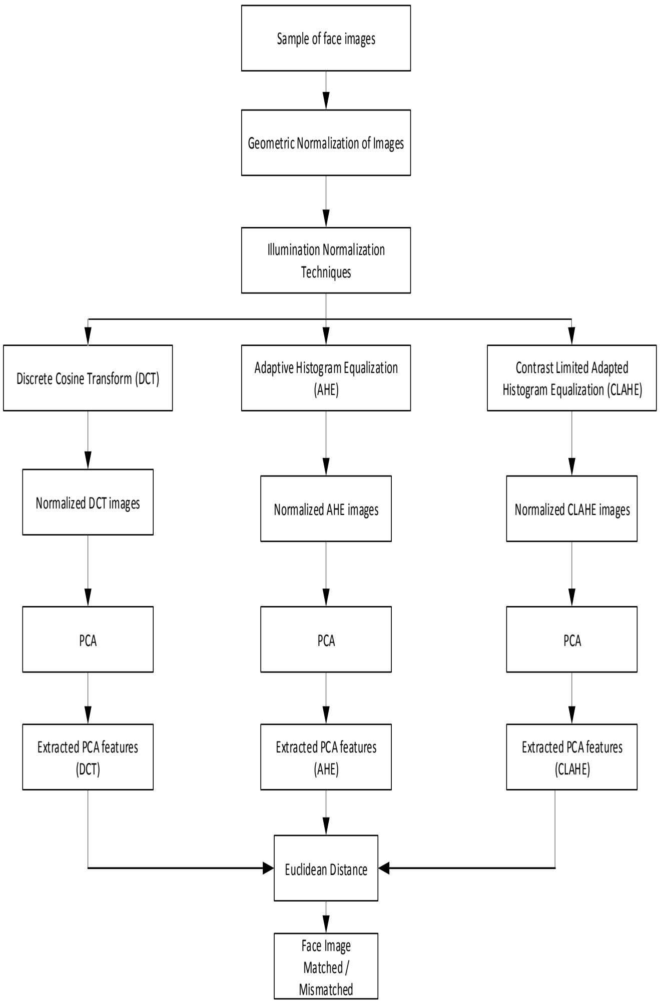

Fig. 1: Block Diagram of the System

4 Results and Discussion

4.1 Results of Recognition Accuracy (RA)

The results of the recognition accuracy are given for the two datasets; Olivetti Research Database of images and FERET face image database. Results are represented in Table 1.

Table 1. Recognition Accuracy

Illumination Normalization Method	Recognition Accuracy (%)	
	ORL Database	FERET Database
DCT	91.84	76
AHE	79.59	74
CLAHE	77.47	68

From Table 1, the best recognition accuracy of 91.84% was obtained in DCT technique compared with the AHE technique with 79.59% and CLAHE technique with 77.47%. Thus, the result showed that the DCT technique performed effectively well in term of recognition accuracy for ORL Database. Also for FERET Database, the best recognition accuracy of 76% was obtained in DCT method compared with the AHE method with 74%

and CLAHE technique with 68%. Thus, the experimental results of the recognition accuracy showed that the DCT technique outperformed other techniques for the two image datasets in term of recognition accuracy.

4.2 Results of False Acceptance Rate and False Rejection Rate

The results for false rejection rate and false acceptance are shown in Table 2 for FERET and ORL face image database respectively.

Table 2. False Acceptance and False Rejection Rates

Illumination Normalization Technique	ORL Database		FERET Database	
	FAR	FRR	FAR	FRR
DCT	0.9	0.0769	0.5	0.0780
AHE	0.6	0.2564	0.5	0.3000
CLAHE	0.7	0.2821	0.3	0.2000

4.3 Summary and Discussion of Results

Tables 3, shows the comparative analysis of the various illumination normalization techniques of PCA-based extracted features. It was observed that the DCT gave the highest FAR of 0.9 for ORL database, while the highest FAR of 0.5 was achieved in DCT and AHE for FERET Database. The best FRR of 0.0769 was obtained in DCT technique for ORL database, while the best FRR of 0.0750 was achieved in DCT technique for FERET database. The best recognition accuracy of 91.84 % was achieved in DCT image for ORL database, also 76 % was obtained in DCT image of FERET database.

Table 3. Comparative Analysis

Illumination Normalization Technique	ORL Database			FERET Database		
	FAR	FRR	RA (%)	FAR	FRR	RA (%)
DCT	0.9	0.0769	91.84	0.5	0.0750	76
AHE	0.6	0.2564	79.59	0.5	0.3000	74
CLAHE	0.7	0.2821	77.47	0.3	0.2000	68

5 Conclusion

Illumination has been identified to be one of the major problems in facial recognition system relying on Principal Component Analysis for feature extraction. Several approaches of illumination normalization have been employed such as Discrete Cosine Transform, Contrast Limited Adaptive Histogram Equalization and Adaptive Histogram Equalization. All these techniques have not really considered comparatively the impact of illumination control techniques. This paper carried out a comparative analysis to investigate the influence of illumination normalization methods on PCA-based face recognition system. Experimental results showed the best recognition accuracy of 91.84 % in Discrete Cosine Transform for ORL and 76 % for FERET. The lowest False Rejection Rate (FRR) of 0.0769 was recorded in Discrete Cosine Transform for ORL database. Finally, the best recognition accuracy and FRR were obtained in DCT technique for the two face datasets, thus revealed that this technique performed efficiently in controlling and reducing the problem of illumination for PCA-based feature extraction method of face recognition. Future work should consider the effect of illumination normalization methods on feature-based techniques of facial recognition system. Also, the number of face image dataset should be further increased in order to validate experimental results.

References

Abate, A. F., Nappi, M., Riccio, D., & Sabatino, G. (2007). 2D and 3D face recognition: A survey. *Pattern Recognition Letters*, *28*(14), 1885–1906. http://doi.org/10.1016/j.patrec.2006.12.018

Anila, S., & Devarajan, N. (2012). Preprocessing Technique for Face Recognition. *Global Journal of Computer Science and Technology Graphics & Vision*, *12*(11), 13–18.

Dan-ali, A. M. (2014). What is the Right Illumination Normalization for Face Recognition ? *International Journal of Advanced Research in Artificial Intelligence*, *3*(12), 24–28.

Jafri, R., & Arabnia, H. R. (2009). A Survey of Face Recognition Techniques. *Journal of Information Processing Systems*, *5*(2), 41–68.

Joshi, A. G. & Deshpande, A. S. (2015). Review of Face Recognition Techniques. *International Journal of Advanced Research in Computer Science and Software Engineeering*, *5*(1), 71–75.

Kalaiselvi, P., Nithya, S., & P.Kalaiselvui. (2013). Face Recognition System under Varying Lighting Conditions. *Iosr-Jce*, *14*(3), 79–88. Retrieved from http://www.iosrjournals.org/iosr-jce/papers/Vol14-issue3/M01437988.pdf?id=7441.

Kashem, M. A., Akhter, N., Ahmed, S., & Alam, M. (2011). Face Recognition System Based on Principal Component Analysis (PCA) with Back Propagation Neural Networks (BPNN). *International Journal of Scientific & Engineering Research*, *2*(6), 1–10.

Reza, M., & Qi, X. (2016). Face recognition under varying illuminations using logarithmic fractal dimension-based complete eight local directional patterns. *Neurocomputing*, *199*, 16–30. http://doi.org/10.1016/j.neucom.2016.01.094.

Romdhani, S., Ho, J., Vetter, T., & Kriegman, D. J. (2006). Face Recognition Using 3-D Models: Pose and Illumination. *Proceedings of the IEEE*, *94*(11), 1977–1999. http://doi.org/10.1109/JPROC.2006.886019.

Salkar, S. R., Patankar, N. S., Chintamani, R. D., & Deshmu, Y. S. (2017). Illumination Invariant Face Recognition using Local Directional Number Pattern (LDN). *International Journal of Engineering Development and Research*, *5*(2), 303–308.