AN IMPROVED ILLUMINATION NORMALIZATION APPROACH BASED ON WAVELET TRANFORM FOR FACE RECOGNITION FROM SINGLE TRAINING IMAGE PER PERSON

Chun-Nian Fan[1, 2] and Fu-Yan Zhang[1]
[1]*Department of Computer Science and Technology, Nanjing University, Nanjing, China*
[2]*Computer and Software Institute, Nanjing University of Information Science & Technology, Nanjing, China*

Keywords: Face Recognition, Wavelet Analysis, Illumination Normalization, Histogram Equalization.

Abstract: Recent research on face recognition shows that the illumination change is one of the key issues remaining to be addressed. To recognize faces under varying illuminations with single training image per person conditions, we propose an improved wavelet-based normalization method. We use wavelet transform to decompose an image into its low frequency and high frequency components. Then, we apply histogram equalization to the low frequency coefficients and de-noise the high frequency coefficients adaptively. Lastly, the high frequency coefficients are accentuated by multiplying by a scalar so as to enhance edges. A normalized image is obtained from the modified coefficients by inverse wavelet transform. Among others, the proposed method has the following advantages: (1) it does not need any prior information of 3D shape or light sources, and it aims at addressing illumination issue for face recognition from only one training image per person; (2) due to the multiscale nature of wavelet transform, it has better edge-preserving ability in low frequency illumination fields; and (3) it is computationally feasible and fast. We use PCA method to recognize normalized image with only one training image. The experimental results obtained by testing on the Yale face database B demonstrate the effectiveness of our method with significant improvement in the face recognition system.

1 INTRODUCTION

Related research on face recognition in recent years has made great progress (Zhao et al., 2003), a number of FR systems achieved good performance in the latest report of Face Recognition Vendor Test (FRVT 2006), yet many issues still remain to be addressed. Illumination changes are one of the key issues (Adini et al., 1997). To deal with the illumination variation problem, many methods have been proposed, which can be roughly classified into three categories. (1) illumination normalization: these methods use image processing techniques such as histogram equalization (HE), Gamma correction, and logarithmic transformation (Shan et al., 2003; Savvides and Kumar, 2003), to normalize human face image in order to obtain face image's stability under illumination changes. However, these methods have limited success in handling arbitrary illumination changes. (2)invariant feature extraction: this approach attempts to extract facial features which are invariant to illumination variations, such as edge maps, derivatives of the gray-level, Gabor-like filters methods, and wavelet-based method (Adini et al., 1997; Zhang et al., 2009). Empirical studies, however, show that none of these representations are sufficient to overcome image variations due to changes in the direction of illumination. (3)face modeling: some researchers attempt to construct a generative 3-D face model that can be used to render face images with different poses and under varying lighting conditions . A generative model called illumination cone is presented in (Belhumeur et al., 1998; Georghiades and Belhumeur, 2001). One of the drawbacks of the model-based approaches is that a number of images of the same object under varying lighting conditions or 3-D shape information are needed during the training phase. This drawback limits its applications in practical face recognition systems. In addition,

Fan C. and Zhang F. (2010).
AN IMPROVED ILLUMINATION NORMALIZATION APPROACH BASED ON WAVELET TRANFORM FOR FACE RECOGNITION FROM SINGLE TRAINING IMAGE PER PERSON.
In *Proceedings of the International Conference on Computer Vision Theory and Applications*, pages 473-476
DOI: 10.5220/0002785304730476

existing model-based approaches assume that the human face is a convex object, i.e. the casting shadows are not considered. The specularity problem is also ignored even though the human face is not a perfect Lambertian surface.

Du and Ward present a wavelet-based illumination normalization method(Du and Ward, 2005). In their work, an image is decomposed into its low frequency and high frequency components, then apply histogram equalization to the approximation coefficients and at the same time accentuate the detail coefficients by multiplying by a scalar so as to enhance edges. A normalized image is obtained from the modified coefficients by inverse wavelet transform. However, the obtained high frequency components using wavelet transform are mixed with noise, if we directly enlarge the high frequency components, the noise will also be enlarged, and that will hinder the face recognition process. Therefore, if we de-noise the high frequency components before accentuating, that will remove noise and enhance the edges. In addition, Du and Ward select 1-level wavelet decomposition, which is not the optimal decomposition level. In this paper, an improved wavelet-based illumination normalization method is proposed. Firstly, we decompose an image into its low frequency and high frequency components using 3-level wavelet decomposition. Secondly, we apply histogram equalization to the approximation (low frequency) coefficients. Thirdly, we de-noise the detail (high frequency) coefficients adaptively and accentuate them by multiplying a scalar so as to enhance edges. Lastly, a normalized image is obtained from the modified coefficients by inverse wavelet transform. The resulted image not only enhances contrast, but also enhances edges and details that will facilitate the further face recognition task. The proposed illumination normalization method do not need many traning images per person and then can be apply to face recognition from only one training image per person conditions. That will benefit the practical face recognition system since the current face recognition techniques lies in the difficulties of collecting samples (Tan et al., 2006).

The remainder of this paper is organized as follows: Section 2 describes the proposed approach in detail; Sections 3 and 4 show the experimental results and our conclusions.

2 THE PROPOSED METHOD

The illumination changes mainly affect the low frequency components, and the high frequency components represent detail information such as the location and shape information of the key facial features which is essential to further face recognition (Wei, 2006). Therefore, in this work, we firstly decompose the face image use wavelet transform. Then different band coefficients are manipulated separately. Lastly, we reconstruct the face image using inverse wavelet transform. The resulting image will not only contain the most essential information for pattern recognition, but also greatly reduce the influence of illumination changes.

2.1 Wavelet Decomposition

Wavelet transform is a representation of a signal in terms of a set of basis functions, which is obtained by dilation and translation of a basis wavelet. Since wavelets are short-time oscillatory functions having finite support length (limited duration both in time and frequency), they are localized in both time (spatial) and frequency domains. The joint spatial-frequency resolution obtained by wavelet transform makes it a good candidate for the extraction of details as well as approximations of the images (Li, 2003). For 2D discrete wavelet transform (DWT), an image is represented in terms of translations and dilations of a scaling function and a wavelet function. The scaling and wavelet coefficients can be easily computed using a 2D filter bank consisting of low-pass and high-pass filters.According to (Feng et al., 2000), we choose 3-level db1 wavelets in our work. After applying a 3-level of 2D decomposition, an image is decomposed into subbands of different frequency components as shown in Figure 1 and Figure 2.

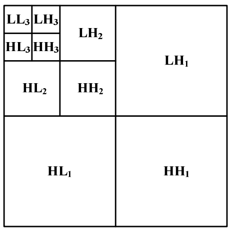

Figure 1: Multi-resolution structure of wavelet decomposition of an image.

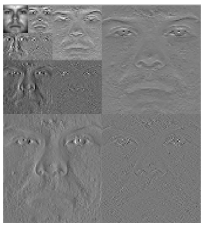

Figure 2: Wavelet decomposition of a face image.

2.2 Histogram Equalization of the Approximation Coefficients

The histogram of an image is usually used to determine which particular gray scale transformation is required to enhance the image contrast. Histogram equalization (HE) is one of the most useful contrast enhancement schemes. When an image's histogram is equalized, image pixel values are mapped to uniformly distributed pixel values, as much as possible. In this paper, we apply histogram equalization to the approximation coefficients, after that, the illumination of the approximation image is also normalized.

2.3 De-noising and Highlighting the Detail Coefficients

There are two thresholding schemes for general wavelet-based image de-noising: hard thresholding and soft thresholding (Donoho, 1995). Soft thresholding eliminates the discontinuity (at the threshold) that is inherent in hard thresholding. In this paper, we employ a soft thresholding operation on the detail coefficients. The de-noising procedure removes the "noise" signal by thresholding only the wavelet coefficients of the detail subbands, while keeping the low resolution coefficients unaltered. Thus, it is able to keep sharp edges information in low frequency illumination fields.

After de-noising, we multiply each element in the detail coefficient matrix with a scale factor (>1) to enhance edges. Different scale factors will lead to different results. Figure 3 shows the face recognition rates using different scale factor, and we can see that the optimal scale factor is near 3.

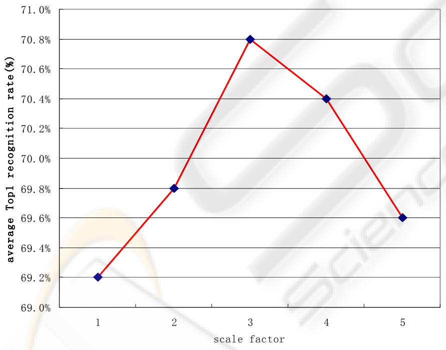

Figure 3: Face recognition rate using different scale factor.

（a） (b) (c) (d)

Figure 4: Reconstructed images comparison (a) original; (b) histogram equalized; （c） wavelet-based method normalized; (d) the proposed method normalized.

2.4 Image Reconstruction

The enhanced image is reconstructed from the histogram equalized approximation coefficients and the enlarged detail coefficients in all three directions using inverse wavelet transform. The results of applying the proposed method on two different images of two different persons are shown in Figure 4. The enhanced images using the proposed method are sharper and have more details and more suitable for face recognition intuitively.

3 EXPERIMENTS

To evaluate the performance of the proposed illumination normalization method, we test it on the Yale face database B (Lee et al., 2005). The Yale face database B contains 5760 single light source images of 10 subjects. Each subject has 9 poses and each pose has 64 different illumination conditions. Since this paper mainly deals with the illumination problem, we only choose the 64 frontal pose images captured under 64 different lighting conditions for each of the ten persons. The images are divided into five subsets according to the light-source directions (azimuth and elevation): Subset 1 (angle < 12 degrees from optical axis), Subset 2 (20 < angle < 25 degrees), Subset 3 (35 < angle < 50 degrees), Subset 4 (60 < angle < 77 degrees), and Subset 5 (others).

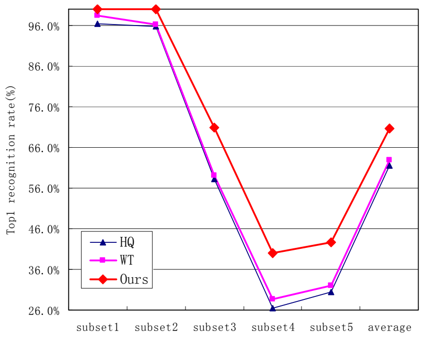

Figure 5: Top 1 recognition rate comparisons.

In our experiment, we directly use PCA method for face recognition with only single training sample. The face image with normal illumination in subset 1 (only one image for each person) is chosen as the gallery and each of the images in the 5 subsets is matched to the images in the gallery so as to find a best match. All test image data are manually aligned, cropped, and re-sized to 168x192 images. The recognition rates use the Euclidean distance nearest-neighbor classifier. We compare the face recognition performance of different methods including histogram equalization, the wavelet-based method (Du and Ward, 2005), and our method. Conforming to the FERET test rules (Phillips et al., 1998), we have not only tested the Top 1 recognition rate, but also tested the Top 3 recognition rate.

The recognition rates are illustrated in Figure 5 and Figure 6. It is shown from Figure 5 and Figure 6 that our proposed method outperforms the histogram equalization method and the wavelet-based method at every single subset.

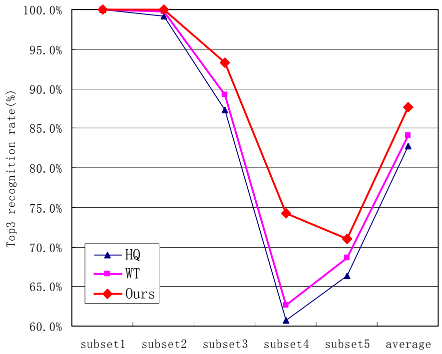

Figure 6: Top 3 recognition rate comparisons.

4 CONCLUSIONS

This paper presents an improved wavelet-based illumination normalization method for face recognition from only one training image per person. The proposed approach has not only enhanced contrast, but also enhanced edges and details that will facilitate the further face recognition task. There is no need to any prior information of 3D shape and light sources. Moreover, due to the multiscale nature of wavelet transform, it has better edge-preserving ability in low frequency illumination fields. In addition, it is computationally feasible and fast. The experimental results obtained by testing on the Yale face database B demonstrate the effectiveness of our method with significant improvement in the face recognition system.

REFERENCES

Adini, Yael, Yael Moses and Shimon Ullman. (1997). Face Recognition: The Problem of Compensating for Changes in Illumination Direction. *IEEE Transactions on Pattern Analysis and Machine Intelligence,* 19(7), 721-732.

Belhumeur, P. N. and D. J. Kriegman. (1998). What is the set of images of an object under all possible illumination conditions. *International Journal of Computer Vision*, 28(3), 245–260.

Donoho, D. L. (1995). De-noising by Soft-thresholding. *IEEE Transaction on Information Theory*, 41(3), 613-627.

Du, Shan and Rabab Ward. (2005). Wavelet-based illumination normalization for face recognition. *In IEEE International Conference on Image Processing(ICIP 2005).*

Feng, G. C., P. C. Yuen and D.Q. Dai (2000). Human face recognition using PCA on wavelet subband. *Journal of Electronic Imaging*, 2(9), 226-233.

Georghiades, Athinodoros S. and Peter N. Belhumeur. (2001). From Few to Many Illumination Cone Models for Face Recognition Under Variable Lighting and Pose. *IEEE Transactions On Pattern Analysis And Machine Intelligence*, 23(6), 643-660.

Lee, K.-C.J., Ho, and D. J. Kriegman. (2005). Acquiring linear subspaces for face recognition under variable lighting. *IEEE Transactions On Pattern Analysis And Machine Intelligence*, 27(5), 684–698.

Li Bicheng，Luo Jianshu. (2003). *Wavelet Analysis and Its Application*. Beijing：Publishing House of Electronics Industry.

Phillips P. J., et al. (2007) FRVT 2006 and ICE 2006 Large-Scale Results *[Online]. Available: http://www.frvt.org/FRVT2006/*

Phillips P. J., Wechsler H., Huang J.and Rauss P. J. (1998). The FERET database and evaluation procedure for face recognition algorithms. *Image and Vision Computing*, 16(5), 295-306.

Savvides，M. and V. Kumar. (2003). Illumination normalization using logarithm transforms for face authentication. *In Proc. IAPR AVBPA*, 549–556.

Shan, Shiguang, Wen Gao, Bo Cao and Debin Zhao. (2003). Illumination normalization for robust face recognition against varying lighting conditions. *In Proceedings of the IEEE International Workshop on Analysis and Modeling of Faces and Gestures (AMFG'03).*

Tan, X., Chen, S., Zhou, Z.-H. & Zhang, F. (2006) Face recognition from a single image per person: A survey. *Pattern Recognition*, 39, 1725-1745.

Wei Wang, Jiatao Song, Zhongxiu Yang, Zheru Chi. (2006). Wavelet-based Illumination Compensation for Face Recognition using Eigenface Method. *In Proceedings of the 6th World Congress on Intelligent Control and Automation*, June 21 - 23, Dalian, China.

Zhang, Taiping, Bin Fang, Yuan Yuan, Yuan Yan Tang, Zhaowei Shang, Donghui Li and Fangnian Lang. (2009). Multiscale facial structure representation for face recognition under varying illumination. *Pattern Recognition* 42, 251-258.

Zhao, WenYi, R. CHELLAPPA, P. J. PHILLIPS and A. ROSENFELD. (2003). Face Recognition: A Literature Survey. *ACM Computing Surveys*, 35(4), 399–458.