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Illumination Normalization using 2D Wavelet

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Abstract

Pose, expression and illumination variation are some challenges in face verification research area. When lighting condition changes, the appearance of a face varies intensely. In this paper, an illumination normalization method for face verification under various lighting conditions is presented. In the proposed approach, 2D wavelet is applied on the Yale database B and XM2VTS human face databases for illumination normalization in face verification. The performance of the method under illumination variations is improved compared to other pervious methods. Moreover, this procedure is very effective to compensate the shadows and also is very simple and it implements easily in real-time face verification system.

Keywords: Face verification; illumination variation; 2D wavelet

1. Introduction

One of the most ordinarily used biometric technique is human face verification[1]. Recently, robust face verification such as face identification systems invariant to expression, pose, and illumination variation has been concentrated by several researchers in image processing area. Illumination variation is still a hard problem in face verification research area. When the lighting condition is changed, the same face appears variously. More specifically, the changes caused the by variation of lighting could be larger than the difference between of the appearance individuals. Previous research enforced that significant illumination changes can make dramatic changes in the projection coefficient vectors, and hence can seriously reduce the performance of face verification. Fluctuation in appearance caused by illumination significantly influences the face identification performance and accuracy. Reflections and shadows are two main categories of appearance variation due to illumination variation. Specular reflection and diffuse reflections are two parts of reflection which have quite different characters. Two subparts of shadow category are attached shadow and cast shadow [2].

To increase the accuracy and performance of face identification, producing a face image with normal illumination for training any probe image is very important. A technique has been proposed to produce such images without an expressed appearance model for variation lighting[3, 4]. In this approach, the fluctuation by illumination is regarded as interclass variation. A method using basic images has been suggested in[5, 6]. This technique is appropriate for normalizing the face images which contain diffuse reflection components. Simple fitting to the model and need only a few images for processing, are the advantages of this method. Quotient Image (QI) technique is used by Shashua et al.[6]. In their method, for each pixel which is illumination invariable, the ratio of albedo between an image of face and linear collection of basic images was applied. The QI assumes that all discovered image intensities are rendered by diffuse reflection.

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However, this method is good only for diffuse reflection and is impossible to compensate other components using this method.A method to remove cast shadow and specular reflection from a face image is proposed by Okabe et al.[5]. They used random sample consensus for choosing basic images, which applied for estimating attached shadow and diffuse reflection. Basic images were produced from three face images obtained across fix pose and different lighting conditions[7] or from four faces images achieved under moving position of face and a constant light source[8]. Hence, requirement of several face images for each person in the registration stage of training is the disadvantage of this method. Self-Quotient Image (SQI), to normalize image with illumination variation using one face image is proposed by Wang et al[9]. Each pixel of the SQI comprises the ratio of the albedo at that pixel and a smoothed value of the albedo in a local region. This method is used only for diffuse reflection. Gonzales et al.[17] proposed homomorphic filtering which acts on the frequency domain of the image based on the illumination reflectance model. In order to enhance the contrast in dark regions and decrease contrast in bright regions, they took the log of each pixel. Contrast enhancement was achieved by using homomorphic filtering after passing probe image through a logarithm function and Fourier transformed. Homomorphic filter operate on the reflectance and illumination components separately. It increases reflectance components which is high frequency and decrease illumination components which is low frequency. Brajovic[10]. The luminance function was estimated and then they smoothed the image. After that they modified the input image by estimating the reflectance function. Their method has a single parameter which needs controls and tuning the performance of normalization.

Variable illumination on wavelets via the process of wavelet decomposition was improved by Jin et al. [11]. They regarded the approximation component image as an estimate of global illumination changes in improved variable illumination on wavelet. They set each pixel of the luminance image to the same gray value which is the mean of three-level approximation component image and removed the illumination variation. They demonstrated that the light adaptability of face verification can improved with less restricted conditions. Another wavelet-based illumination compensation method was presented by Shan and Ward[12]. Firstly, they used wavelet transform to a probe image with a one level db10 wavelet then they applied HE toward contrast enhancement and got satisfactory results. Goh et al.[13] proposed a preprocessing method for face identification based on wavelet-based illumination invariant algorithm. They regarded a face image as the two-dimensional image and focused on the two-dimensional wavelet transform. The decomposition the input image into four components is the aim of 2-D discrete wavelet transform (DWT).These four parts are: An approximate, vertical, horizontal and diagonal subbands. DWT breaks up the facial image into multiresolution representation in order to keep the least coefficient possible without losing useful information of image. The low and high-frequency components are separated by this method. In their method, the logarithm transform is applied to convert the product of the illumination reflectance model (IRM) into a sum of reflectance (high frequency) and luminance(low frequency). After that, these researchers set the coefficient located in wavelet approximation subband to zero in order to reduce the illumination effects. Inverse of the DWT and inverse of the logarithm was used to reconstructing the image.

This paper proposes a method to normalize input face image in the wavelet domain. In this method, an input image is decomposed into its high frequency and low frequency components. After setting low frequency components to zero and approximating new coefficients, image is reconstructed by wavelet inverse transform. The resultant image has not only enhanced edges and details but also enhanced contrast and also by this method the shadow problems is compensated.

1.1. Face Verification

Face verification methods are tools for distinguishing a true identity from a false one. Through face verification, a probe image is compared with a template image whose identity is known already. Figure.1 describes a face verification system. Face detection and location, Face alignment and Normalization, Feature extraction, Face matching and score generation and Decision are the 6 different parts of a complete face verification system.

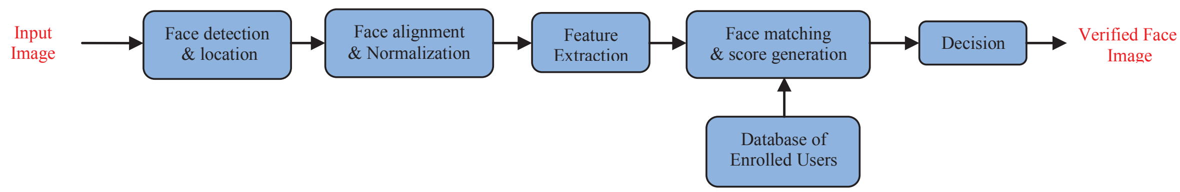

Fig1. Face Verification Flow

- ***Image capture:*** A probe image which is referred to the claimant's face is snapped by means of a digital camera.

- ***Free detection and location:*** Probe image has two major parts; the face of the claimant and the cluttered background scene. In this stage, the face of the claimant is discovered from the image supplied for the computer.
- ***Face alignment and normalization:*** In this step, the scale and location of every face in the image is approximately calculated. Normalization process has two parts: geometric normalization and photometric normalization. Geometric normalization is necessary because the size of the face in probe image varies due to the distance between the camera and the person. So the face is cropped from the image and the size is changed to a known fixed size. Photometric normalization is essential to take the unwanted lighting effects off from the probe image. Photometric normalization can be done either before or before and after the geometric one. In order to make face localization easier, it, as well can occur in the past or before and after the detection step.
- ***Feature extraction:*** In this step, the useful information of how to recognize the faces is provided.
- ***Face matching and score generation:*** Then the image resulted from extraction and normalization is compared with one or more previously saved gallery images. In this step the score given to the probe image indicates how compatible the probe image is with the gallery ones.
- ***Decision:*** The Judgment of the probe image is based on comparison of its score with a threshold.

The reminder of this paper is organized as follows: Section 2 briefly explains illumination variation. In section 3, the illumination normalization using 2D wavelet transform is described. Section 4 and 5 show the experimental results, and conclusions.

2. Illumination Variation

Different face verification methods have been suggested up till now. There have been advances in this area which demonstrate that the frontal and normal lighting conditions result in accurate and satisfactory images. But still face verification remains a difficulty in real conditions because sometimes the influence of changing the light is greater than the differences among people's faces. In comparison between illumination and pose variation, changes in lighting can make greater differences than posing. Changes in lighting can induce variations in the images of the same face and subsequently decreases the reliability of the face verification. Variations in lighting have made face verification a challenging issue. In order to provide a clearer aspect of the influence of lighting, the appearances are categorized into two major categories: reflections and shadows. Reflection consists of diffuse reflection and also specular reflection. Defuse reflection occurs when the object scatters the light while specular reflection happens when the object reflects the incident light. When the incident light is blocked by the object, attached shadow takes places but cast shadow is a situation whereby another object blocks the incident light. Figure.2 demonstrates the variations of facial appearance components due to the illumination differences.

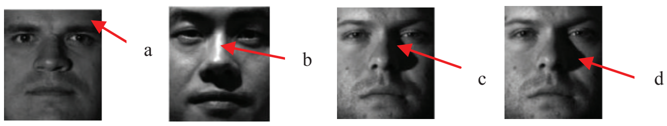

Fig2. Different components of facial appearance due to illumination variation. A) Diffuse reflection, b) Specular reflection, c) Attached shadow, d) Cast shadow

Many methods have been proposed to make changes in lighting condition ineffective on face images. There are three approaches for this purpose. First, preprocessing and normalization in which the face image is normalized by means of preprocessing on the pixel values by applying information from the local area around that pixel. Local Binary Patterns[12,13] and Histogram Equalization[14] are good examples of these techniques. Though these methods are simple and direct but they failed to suggest a model for global illumination conditions. Invariant feature extraction methods, on the other hand, help to extract the facial features that could not be affected by changes in lighting. Edge map and Gabor- like filers[15] are the examples. Finally, the third technique is physical face modeling which deals with estimation of a global physical model of the illumination mechanism and its interaction with the facial surface. Quotient Image[6], Spherical harmonics[16], 3D morphable [17] and Discrete Cosine Transform[18] are some examples.

3. Illumination Normalization using 2D wavelet transform

4. Lambertian Model

An gray level image , in the simple situation , can be assumed to be equivalent to the product of the luminance $L(x,y)$ and the reflectance $R(x,y)$[14], i.e.,

$$I(x,y)=R(x,y).L(x,y) \tag{1}$$

The information about the object of the structure, the scene, or edges of the image are embodied in the reflectance component and luminance component includes the geometric properties of the scene, for example, intensity of a light source which falling on the object. The Fourier transform of product of reflection and luminance is inseparable then, Equation (1) cannot be used directly to separate the frequency components of reflectance and luminance.

The luminance component of an image is generally characterized by slow fluctuations with no discontinuities. The reflectance component is discrete sharply at the edges between patches then this component desires to vary abruptly. The frequency spectrum of luminance component shows that this component drops mostly on the low-frequency domain. Therefore, slowly variation of $L(x,y)$ and vary abruptly of $R(x,y)$, is a common assumption in this model.

3.2. Wavelet Analysis

Wavelet transform is a very good tool for decomposition image. A diversity of channels which represent the feature of probe image by various frequency sub-bands at multi-scale is provided by this method. Also, the good time and frequency resolution at low and high frequency, respectively and high temporal localization is offered by this method. Therefore, wavelet transform is used to extract the local characteristics from a still image[15]. For 2D discrete wavelet transform (DWT), an image is displayed in terms a wavelet function and dilations and translation of a scaling functions. On the other hands, signal in the wavelet transform, can be declared by scaling and wavelet basis functions at different scale.[12]

$$f(x) = \sum_k a_{j,k}\, \varnothing_{j,k}(x) + \sum_j \sum_k d_{j,k}\, \psi_{j,k}(x) \tag{2}$$

Where $\varnothing_{j,k}$ are scaling functions at scale j and $\psi_{j,k}$ are wavelet functions at scale j, $a_{j,k}$, $d_{j,k}$ are scaling coefficients and wavelet coefficients.

A 2D filter bank consisting of high and low pass filters computes the wavelet and scaling coefficients. LL (Low-Low), that is produced by the approximation coefficients; LH (Low-High), HL (High-low), and HH(High-High), which the detail coefficients generates them are four sub-bands of an image which is one level 2D decomposed. These are shown in figure 3.[12]

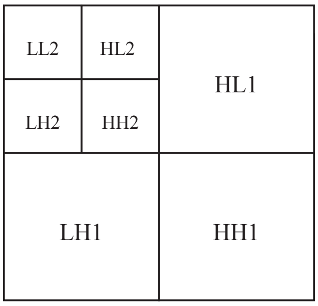

Fig3. Multi-resolution structure of wavelet decomposition of an image

Several frequency components in multi-resolution are the results of using wavelet transform on the given image. Two assumptions [16] are necessary to compensate the luminance and reflectance components .Firstly, the illumination components are lie in low frequency bands because these components are characterized by slow spatial variation. Secondly, the reflection component is a high frequency component and represents the edge or structure of an image.

In this study, the 2D wavelet transform is applied to remove luminance component, which reside in low frequency sub-band. In proposed method, which is shown in Figure.4, firstly, logarithm transformation to convert the product of the illumination reflectance model into a sum of reflectance(high pass) and luminance (low pass), is used toward an input image. Therefore, Eq. (1) becomes:[13]

$$\log I(x,y) = \log R(x,y) + \log L(x,y) \tag{3}$$

Then, 2D wavelet transform is executed to separate the two components by applying a suitable wavelet filter. The decomposition is iteratively used over the approximation image. The extraction of reflectance component is depended on the level of decomposition repetition. Then, the wavelet filter and the level of decomposition are the two parameters to be determined. In the next step, the coefficient placed in low frequency subband (wavelet approximation) to remove the luminance component is set to zero. After that, reconstruction is executed applying the inverse of DWT over DWT and followed by exponentialization on the image (inverse of logarithm).

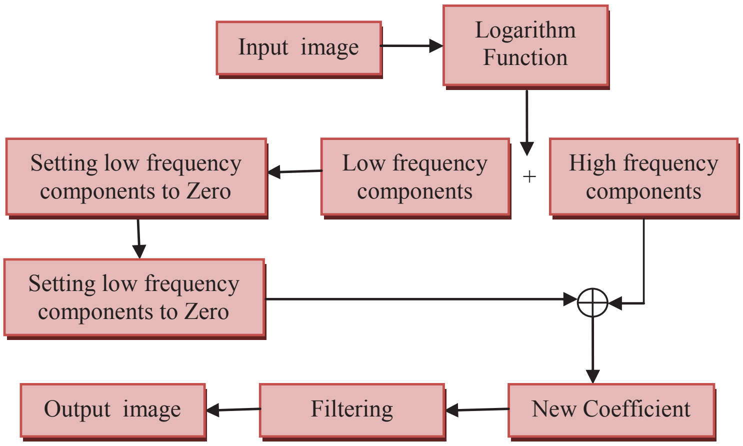

Fig4. Block diagram of proposed method

5. Experiments and results

In this study, XM2VTS[17] and Yale database B [18] are used. Yale database B was gathered to doing systematic testing of different face recognition and verification techniques under illumination and pose variations. There are 5850 images of 10 persons, which were recorded in nine different poses and 64 various lighting conditions in this database. The database is divided into five subsets according to the angle between the camera axis and the light source. The aim of gathering XM2VTS database was to develop of identity verification systems by using face and voice data. This database includes 295 subjects, which recorded at four sessions. Training, evaluation, and test sets are three parts of XM2VTS database. In order to produce of basic images, frontal face images, which taken under various light sources are used. In proposed method, which is shown in Figure4, we used the logarithm transformation toward an input image to change the product of luminance and reflectance into sum of high-pass and low-pass components, which respectively are reflectance and luminance. In order to separating these two components, a satisfactory wavelet filter was applied. The decomposition is interactively used over low-frequency components (approximation image). The more reflectance and luminance component can be obtained, when the more the decomposition levels being repeated. So, the wavelet filter and the level of decomposition are the two important parameters to be determined. After that, the coefficient located in low-frequency components are set to minority amount, and the DC amount is set to the maximum amount in order to compensate illumination variation, especially shadow and gain better contrast. The modified coefficients return into the primary image using recursive function. After that, reconstruction is executed applying the inverse of 2D discrete wavelet transform and inverse of the logarithm. In the last stage of normalization, histogram equalization is used in order achieve better contrast. Figure5. Shows the examples of different images synthesized by proposed method.

In verification step, the verification error rate(ER) decreased from 15.32% to 14.61% for XM2VTS database and reduced from 10.78% to 9.61% for Yale database B.

6. Conclusion

This paper reports the wavelet-based preprocessing illumination invariant method for face verification. The suggested technique adopted the illumination reflectance method to represent illumination facial image. It is shown that wavelet multiresolution analysis is an appropriate method for normalizing lighting variation because the illumination component resides in the low frequency sub-band. Thus, the illumination components are removed from facial image effectively and systematically. According to our experiment, ability to acquire high verification performance in Yale Database B and XM2VTS databases and Using only a single image for each individual in training and very good method for normalizing shadowing in illumination problem are three advantages of this method and disadvantage of this technique is that, this method is not very fast.

In future work, we attempt to apply fusion normalization methods to increase the performance of human face verification under illumination variation.

a b c

Fig5. A) input image b) wavelet output c) wavelet normal show output Acknowledgement

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References

[1]R. Gross, *et al.*, "Face recognition across pose and illumination," *Handbook of Face Recognition,* pp. 193-216, 2005.

[2]M. Nishiyama and O. Yamaguchi, "Face recognition using the classified appearance-based quotient image," 2006, pp.-54.

[3] P. N. Belhumeur, *et al.*, "Eigenfaces vs. fisherfaces: Recognition using class specific linear projection," *Pattern Analysis and Machine Intelligence, IEEE Transactions on,* vol. 19, pp. 711-720, 1997.

[4] M. Nishiyama, *et al.*, "Face recognition with the multiple constrained mutual subspace method," 2005, pp. 27-119.

[5] T. Okabe and Y. Sato, "Object recognition based on photometric alignment using RANSAC," 2003, pp. I-221-I-228 vol. 1.

[6] A. Shashua and T. Riklin-Raviv, "The quotient image: Class-based re-rendering and recognition with varying illuminations," *Pattern Analysis and Machine Intelligence, IEEE Transactions on,* vol. 23, pp. 129-139, 2001.

[7] A. Shashua, "Geometry and photometry in 3D visual recognition," Massachusetts Institute of Technology, 1992.

[8] A. Nakashima, *et al.*, "Constructing illumination image basis from object motion," *Computer Vision—ECCV 2002,* pp. 195-209, 2002.

[9] H. Wang, *et al.*, "Generalized quotient image," 2004, pp. II-498-II-505 Vol. 2.

[10]R. Gross and V. Brajovic, "An image preprocessing algorithm for illumination invariant face recognition," 2003, pp. 1055-1055.

[11]J. Duan, *et al.*, "The methods of improving variable illumination for face recognition," 2004, pp. 3918-3923 vol. 6.

[12]S. Du and R. Ward, "Wavelet-based illumination normalization for face recognition," 2005, pp. II-954-7.

[13]Y. Z. Goh, *et al.*, "Wavelet-based illumination invariant preprocessing in face recognition," *Journal of Electronic Imaging,* vol. 18, p. 023001, 2009.

[14]Y. Adini, *et al.*, "Face recognition: The problem of compensating for changes in illumination direction," *Pattern Analysis and Machine Intelligence, IEEE Transactions on,* vol. 19, pp. 721-732, 1997.

[15]S. G. Mallat, *A wavelet tour of signal processing*: Academic Pr, 1999.

[16]H. Gomez-Moreno, *et al.*, "Extracting illumination from images by using the wavelet transform," 2001, pp. 265-268 vol. 2.

[17]K. Messer, *et al.*, "XM2VTSDB: The extended M2VTS database," 1999, pp. 965-966.

[18]A. S. Georghiades, *et al.*, "From few to many: Illumination cone models for face recognition under variable lighting and pose," *Pattern Analysis and Machine Intelligence, IEEE Transactions on,* vol. 23, pp. 643-660, 2001.