ADAPTIVE REGION-BASED IMAGE ENHANCEMENT METHOD FOR FACE RECOGNITION UNDER VARYING ILLUMINATION CONDITIONS

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ABSTRACT

Illumination changes in face images form a main obstacle in face recognition systems. To deal with this problem, this study presents a novel adaptive region-based image preprocessing scheme that enhances face images and facilitates the face recognition task. This method enhances both the edges and the contrast in face images regionally so as to alleviate the side lighting effects. Compared with the conventional global histogram equalization method, our method is shown to be more suitable for dealing with uneven illuminations in face images. This method is evaluated on the Yale B face database. The experimental results show the advantages of the proposed method with an improvement of 16.1% on average over the histogram equalization method.

1. INTRODUCTION

Face recognition plays an important role in a wide range of applications, such as mug-shot database matching, credit card verification, security system, and scene surveillance. Due to the difficulties in controlling the lighting conditions in practical applications, the resulting variability in image illumination is one of the most challenging problems in face recognition. Over the last decade, numerous algorithms have been proposed for face recognition under varying illuminations [1]-[4]. Unfortunately, most of these methods need to be trained using a set of known face images with fixed pose and under different lighting conditions.

In this paper, we propose a preprocessing illumination adjustment method, where training and thus extra images for training are not needed. Histogram equalization (HE) is commonly used to enhance the image contrast. It converts an image so as to make it have a uniform histogram. However, after processing by HE, the lighting condition of an image with uneven illumination may sometimes become worse, i.e., more uneven. This is because HE is a global transform over the whole image area and therefore, may be less effective when side lighting exists. In our previous paper [5], we have proposed a wavelet-based illumination normalization method that enhances both edges and contrast in face images for face recognition. It outperforms the conventional HE. However, since it is also a global processing method, it has the same limitation as HE. To solve the side lighting problem, we propose processing the face images based on different local regions with different lighting conditions. That is, image enhancement is performed locally on the different face regions in order to alleviate the highlight, shading and shadow effects caused by the uneven illumination. To obtain the best results, the face should be partitioned according to the lighting conditions. The edge map of the face image is used to segment it into regions with different illumination conditions. After the segmentation, HE is conducted on every region of the image independently. We call this method Adaptive Region-based HE, that is ARHE. Also, edge enhancement is carried out regionally according to the different conditions of the regions.

To get the edge map, a wavelet-based edge detection method is proposed. The edge information is used to segment a face image into regions with different illumination intensities.

The whole algorithm is described by the block diagram in Figure 1. In Section 2 the details of a wavelet-based method for obtaining the edge map is proposed. Section 3 illustrates the proposed region-based image enhancement method based on edges and histogram equalization. Section 4 describes our image enhancement experiments on Yale B face images and shows the face recognition results. The conclusions are in Section 5.

2. EDGE MAP GENERATION AND REGION SEGMENTATION

The reason we use edge maps for segmentation is because we have observed that uneven illumination conditions affect the edges intensities. These edges differ from the ones obtained under even illumination conditions as shown in Figure 4 (b). Lack of light or over lighting both weaken the edges in the edge map as shown in Figure 4 (d). Therefore, we examine the edge map. If some edges are weak, it means the illumination in this region may be either over-lighted or under lighted. We differentiate these regions from the evenly lighted regions and apply different edge enhancement as well as contrast enhancement on each region separately.

2.1. Wavelet Decomposition

Edges involve the high frequency components of images. In practice, calculating the high frequency components of an image is achieved by convolving a kernel or mask with the image. The effectiveness of edge detection is decided by the kernel size. Usually the kernel size is chosen by the try and error method. Once the kernel size is fixed, the resolution is fixed.

But more often, edges occur at different resolutions; both strong edges and weak edges exist in the same image. It is difficult to choose a kernel size to extract all the edges. So it is appropriate to extract edges at different scales or resolutions.

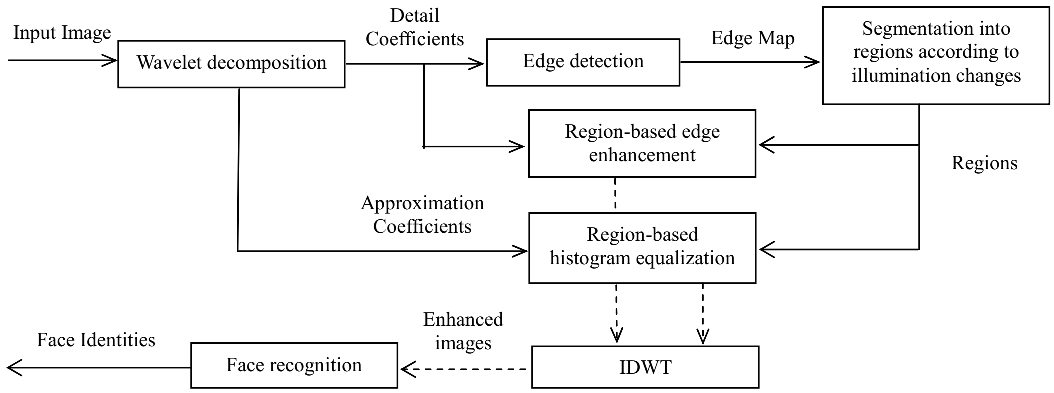

Figure 1. Block diagram of the proposed adaptive region-based image enhancement method for face recognition

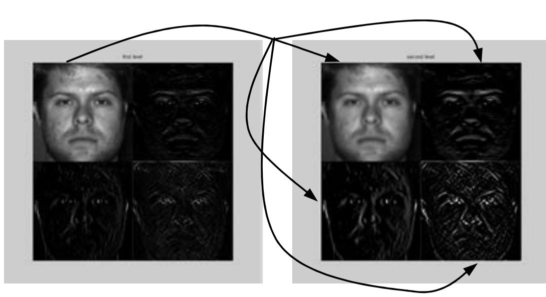

Figure 2. 2-level redundant wavelet decomposition

Wavelet-based image analysis provides multiple representations of a single image. It decomposes an image into approximation coefficients and multi-resolution detail coefficients. Contrast enhancement can be done by histogram equalization carried on the approximation coefficients. Meanwhile, edge enhancement can be achieved by processing the detail coefficients at different scales.

So wavelet decomposition of an image provides a better solution to the edge extraction problem. Here we use the redundant wavelet transform. The decomposition procedure for a redundant wavelet transform is different from the normal one in that the scaling of the wavelet is not achieved by sub-sampling the image in each step, but rather by an up-sampling of the filters. The four wavelet sub-bands at scale *j* are of the same size as the original image, and all filters used at scale *j* are up-sampled by a factor of 2^j (padding $2^j - 1$ zeros) compared with those at scale zero. Figure 2 shows the 2-level redundant wavelet decomposition of a face image.

2.2. Edge Detection

The edges of an image are full of high frequency information that will scatter into several scales or resolutions. In order to take advantage of the multi-resolution property of wavelet transforms, two corresponding sub-bands at adjacent resolutions are multiplied to enhance image edges and suppress noise. This is based on the fact that edge structures present at each scale while noise decreases rapidly along the scales.

Multiplication of the corresponding detail coefficients of two adjacent levels is shown in Figure 3. We compute LH1×LH2, HL1×HL2, and HH1×HH2. The edge map E is obtained by

$$E = \sqrt{(LH1 \times LH2) + (HL1 \times HL2) + (HH1 \times HH2)} \qquad (1)$$

Figure 4 shows two sample edge maps.

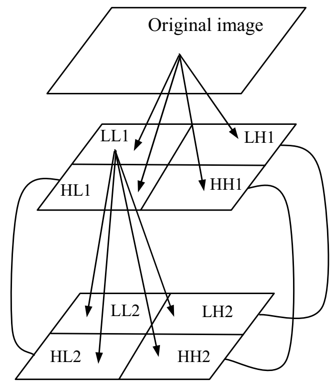

Figure 3. Edge generation by multiplying the two adjacent levels' detail coefficients

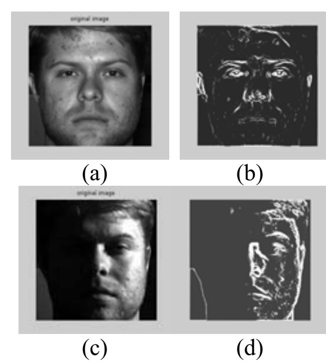

Figure 4. (a) and (c) original images; (b) and (d) edge maps

2.3. Region Segmentation

Now we use our observation that under uneven illumination conditions the edges have different intensity strengths. Lack of light or over lighting both weaken the edges. Therefore, we examine the edge map. If some edges in the edge map are weak, it means the illumination in this region may be either over-lighted or under lighted. We differentiate these regions from the evenly lighted regions. Then we apply edge enhancement as well as contrast enhancement on each region separately.

Our algorithm for segmenting the regions is shown in Figure 5.

1. Partition an edge map into blocks, e.g., 4×4.
2. For each block, compute the average edge amplitude:
   a. If the edges in the block are weak (e.g., less than a pre-defined threshold), merge it with adjacent weak blocks using the eight nearest neighbours method and then mark it with 0;
   b. Otherwise, mark it with 1.
3. For a region marked with 0:
   a. If its average grey-scale & standard deviation are both similar to any of the regions marked with 1, then, mark them back to 1. This step removes the regions that have weak edges not due to light, but due to a natural solid color, e.g., the cheeks;
   b. Otherwise, this region is affected by illumination changes.
4. For the regions marked with 1, consider them as one whole region, the normal region.
5. End.

Figure 5. Region segmentation algorithm

3. REGION BASED IMAGE ENHANCEMENT FOR FACE RECOGNTION

Our proposed approach enhances both edges and contrast, and is region-based method.

3.1. A Region-based Edge Enhancement, EdgeE

Edge enhancement attempts to emphasize the fine details in the original image. The perceptibility of edges and small features can be improved by raising the amplitude of high frequency components in the image. In this section, we introduce an adaptive edge enhancement method, EdgeE, based on the region segmentation. We propose to use different enlargement factors for the different regions based on their original edge amplitudes to make the edges of even strengths.

Let m_i denote the average edge amplitude of the i^{th} region of the original edge map E. The enhanced edge map EE_k for each region k can be calculated by

$$EE_k(x,y) = \frac{E_k(x,y)}{m_k} \times \max\{m_1, m_2, ..., m_n\} \times \alpha \quad (2)$$

$$where \quad (x,y) \in region \quad k$$

α is a scaling factor, it is greater than 1.

3.2. Region-based Contrast Enhancement

Contrast enhancement is usually achieved by histogram equalization on the whole image to redistribute gray levels uniformly. In this paper, a region-based histogram equalization is used to enhance the contrast. The regions are segmented as discussed in Section 2. Histogram equalization is applied separately on each region to avoid over lighting the already normally lighted regions or under lighting the dark regions. If there is no sub-region in one image, i.e., the segmentation method does not result in more than one region, then the edge map is automatically partitioned into four equal regions and HE is carried out separately on each of these regions.

3.3. Face Recognition

After a preprocessing that consists of the following steps: edge detection, region segmentation, contrast enhancement and edge enhancement, a face recognition scheme is used. In the experiments below, the face recognition employs the Euclidean distance nearest-neighbor classifier to find the image in the database with the best match.

4. EXPERIMENTAL RESULTS

4.1. Yale Face Database B

To evaluate the performance of the proposed image preprocessing method, we test it on the Yale Face Database B [2], which was built by the Center for Computational Vision and Control at Yale University. It contains 5760 single light source images of 10 subjects (persons). Each subject has 9 poses and each pose has 64 different illumination conditions. Since this paper mainly deals with the illumination problem, we only chose the frontal pose images captured under 64 different lighting conditions, for each of the ten persons. Example images of one person in frontal pose are shown in Figure 6. 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).

4.2. Image Enhancement Results

The illumination results after applying the above preprocessing scheme are shown in Figure 7 and Figure 8. The histogram equalized image (c) in Figure 8 shows that when uneven lighting exists, the global histogram equalization method makes the already normally lighted regions over lighted while the dark regions are still dark. Our region-based method processes each region separately so that all regions become visible enough for automatic face recognition.

4.3. Recognition Results

In our experiments, Subset 1 (7 images for each person) is chosen as the gallery and each of the images in the remaining 4 subsets is matched to each of the images in the gallery so as to find the best match using the Euclidean distance nearest-neighbor classifier.

The abbreviations for the different preprocessing algorithms are:

HE: conventional global Histogram Equalization

RHE: uniform Regional Histogram Equalization (divide images into 4 equal sub-regions.)

ARHE: Adaptive Region-based Histogram Equalization

Edge only: recognition using edge maps only

EdgeE: proposed adaptive region-based Edge Enhancement

The recognition rates are illustrated in Table 1 and Figure 9. It is shown from Table 1 that our proposed method outperforms the histogram equalization method in every single subset.

5. CONCLUSIONS

We propose a novel preprocessing face recognition method for images with uneven illuminations. Both edges and contrast are enhanced regionally to alleviate the side lighting effects on face recognition. The image regions are segmented based on the edge map. Results of face recognition using the proposed preprocessing procedure followed by the Euclidean distance nearest-neighbor classifier show an improvement of 16.1% over HE on average.

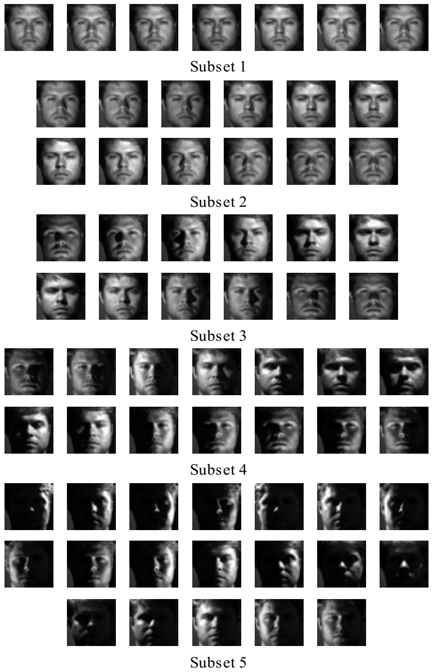

Figure 6. 64 illumination conditions for one person

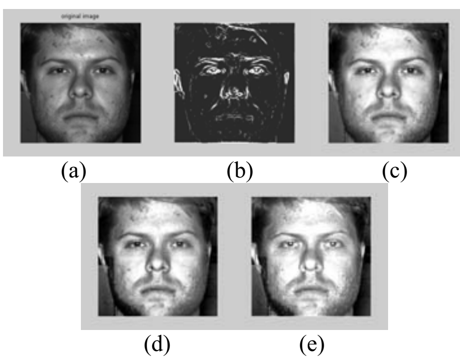

Figure 7. Enhanced images by (c) HE, (d) ARHE and (e) ARHE followed by edge enhancement using an evenly illuminated face image (a); (b) is the edge map

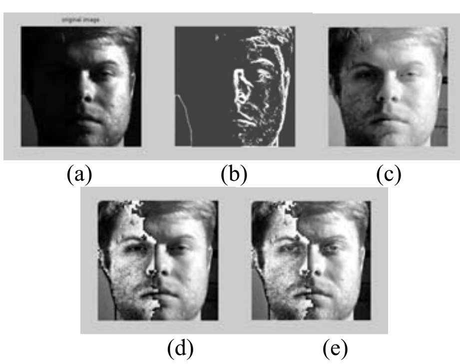

Figure 8. Enhanced images by (c) HE, (d) ARHE and (e) ARHE followed by edge enhancement using an unevenly illuminated face image (a); (b) is the edge map

Table 1. Recognition rate comparisons of different methods

Methods	Subset 2	Subset 3	Subset 4	Subset 5	Average
Raw image	95.83	76.67	46.67	25.24	55.44
HE	100	97.5	75	60	79.47
RHE	100	100	84.17	65.71	84.04
ARHE	100	100	90	80	90.53
Edge only	98.33	99.17	50	17.14	58.42
HE+EdgeE	100	100	90.83	85.71	92.81
ARHE+EdgeE	100	100	95.83	90.48	95.61

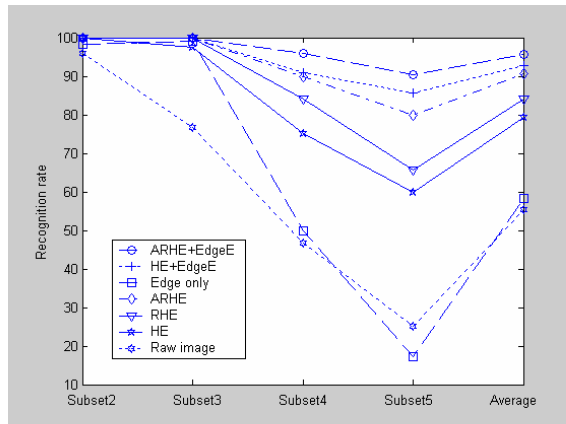

Figure 9. Recognition rate comparisons of different methods

From the above results, it is clear that (1) Edge enhancement plays an important role in face recognition. (2) Recognition based only on edge maps will not reach enough success. (3) Combining together the edge enhancement and contrast enhancement offers more benefit. (4) Adaptive region-based image enhancement outperforms the conventional global one.

6. ACKNOWLEDGEMENT

The authors would like to thank the Natural Sciences and Engineering Council of Canada (NSERC) for their support.

7. REFERENCES

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