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Illumination Normalization Preprocessing for face recognition

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***Abstract*—This paper describes an illumination normalization technique which works at the pre-processing stage where the face image is first divided into equal sub-regions. Each sub-region is then processed separately for illumination normalization. Then the segments are joined back followed by further processing like noise removal and contrast enhancement. The proposed technique is tested on Yale dataset and compared with some previous illumination normalization techniques.**

Keywords-* *Illumination; Face; Preprocessing; Normalization; Yale

I. INTRODUCTION

Illumination and pose variation are probably one of the main problems for face recognition. A source of light can affect the facial features and some of them may appear to diminish in certain cases. A lot of work has been done in the last few years to solve this problem [1] [2]. However, the results have shown that the illumination factor still affects the process of face recognition considerably.

The minor changes due to illumination can affect the face recognition performance, as a result of which the same algorithm gives different results in different environments. Figure 1 represents the general face recognition approach with an additional illumination normalization module.

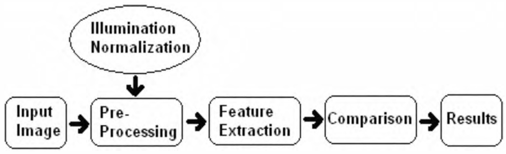

Figure 1. General Face recognition system with Preprocessing of Illumination Normalization

II. EXISTING TECHNIQUES

In the past, many face recognition approaches had been used to tackle the face image illumination problems. Such approaches can be found under three categories:[4] [5]

Model based approaches are based on "low dimensional linear sub-spaces" to reduce illumination effects in an image. These approaches were presented by Belhumeur et. al. [3] (The Illumination Cone Method), and Ramamoorthi [2] (The Spherical Harmonic method) etc. The drawback of such approaches is that many images are required to build the linear space which is a difficult task in handling large database.

Processing or preprocessing approaches used preprocessing steps for illumination normalization. The advantage of these techniques is that they are free from any training. These approaches were presented by Shashua and Riklin-Raviv(2001)[3] (Quotient Image method (QI)), Wang (2004) [7] (Self-Quotient Image(SQI)), Xie and Lam (2006) [8] [9]. In addition to these, some other techniques of image processing like Gamma correction and Histogram equalization etc. had also been used for normalization of illuminated images.

In Features based approaches, the face is recognized using illumination invariant features. These approaches were presented by Adini (1997) [10], (using 2D Gabor-like filters), Shashua [11] (the discrete cosine transform (DCT) for compensating illumination variations), Ojala et al., (1996) (Local Binary Pattern) etc.

III. PROBLEM WITH GENERAL PURPOSE PREPROCESSING ALGORITHMS

Several general purpose preprocessing algorithms have been used extensively for face illumination normalization. Some of the mostly used are Histogram equalization, Gamma correction and Logarithmic transforms.

These algorithms are applied on the image (in this particular case, the face image) and the resulting image is enhanced [12]. This means that the illumination gets normalized. But the major drawback or problem with these methods is that the over all quality of the face image is degraded significantly. The degradation in quality can become a problem for the process of face recognition.

IV. PROPOSED TECHNIQUE

To handle the illumination normalization problem for facial recognition, this paper proposes two approaches to improve the image quality of a degraded image (due to poor lighting conditions).

A. Four Segments Approach

The four segments approach is explained in the following steps.

Step 1: The process initiates by splitting up the face image into four sub images. The reason of dividing the face into segments is that each segment could be handled and processed separately for illumination variation. For example, when only a small portion of face is poorly illuminated, then that portion will fall in one of the smaller segments of face image and will be processed independently from the rest of the face. The nose in the face is taken as center for dividing a face image into four segments and it

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acts as a cross point of four sub images. Figure 2 shows such architectural division.

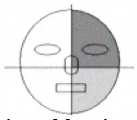

Figure 2. Architectural division of face into four sub images by keeping nose as center point

Figure 3 shows the division of original face into four sub images with nose as center point.

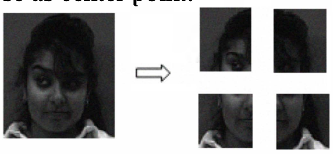

Figure 3. Division of original face into four sub images by keeping nose as the center point

Step 2: Once the sub images are obtained, their individual illumination normalization is done with a transfer function known as probability density function (PDF) similar to histogram equalization. Its mathematical form is given below [13].

$$S_k = c(r_k) = \sum_{i=0}^{k} P(r_i) \tag{1}$$

where $0 \leq S_k \leq 1$ and k=0, 1, 2,..., L-1 = range of grey levels,

$P(r_i)$ represents the probability density function, (ri) shows the input grey levels and $C(r_k)$ is the cumulative density function. Also note that if number of pixels having grey levels r_i is represented by n_i and n is the total number of pixels in the input image f(x, y), the above equation would be rewritten as. [13]

$$S_k = \sum_{i=0}^{k} n_i/n \tag{2}$$

The individual processing of each segment is shown in Figure 4.

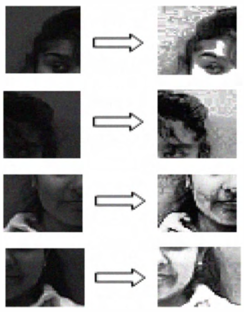

Figure 4. Individual processing of each sub image

Step 3: After the completion of individual normalization of each segment of image, these segments are merged to form the whole image again. The two joining lines (horizontal and vertical) at the center of face image can be seen clearly after the merging of these segmented images as shown in Figure 5. These lines will be considered as noise in the resultant joined image.

Figure 5. Joining of four processed segments

Step 4: Now to address the noise produced by segments' processing of the image especially at joining edges, pixel averaging is used. Each pixel is given a new value which is equal to the average of pixel itself and the eight neighboring pixels. Mathematically pixel averaging can be represented as

$$P_{avg}(x, y) = \frac{f(i,j)+g(i,j)}{9} \tag{3}$$

Pavg (x, y) is the new (average) pixel value. The center pixel is f(i,j) and g(i,j) is the sum of all eight surrounding pixels given as:

g(i ,j) = f(i, j+1) + f(i, j-1) + f(i+1, j) + f(i-1, j) + f(i+1, j+1) + f(i+1, j-1) +f(i-1, j+1) +f(1-1, j-1) (4)

The resultant output image is shown in Figure 6 after the computation of average pixel.

Figure 6. Image after pixel averaging

Step 5: In this step, a combination of filters is applied on image to further reduce the noise and to minimize the prominent lines appeared at the connection boundaries. First a low pass Gaussian is applied followed by the 'Unsharp' filter for contrast enhancement as shown in Figure 7.

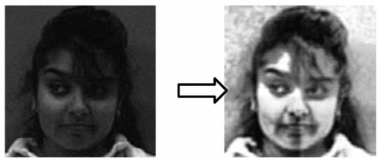

Figure 7. Left: Original image, Right: Final processed image

The final processed image (after applying the Illumination normalization) holds the maximum enriched information for recognition of face. Figure 8 demonstrates the histograms of the final image.

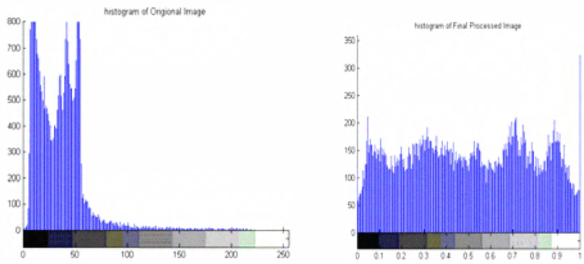

Figure 8. Left: Original image histogram, Right: Final processed image histogram

The data flow diagram of the above proposed system is shown in Figure 9.

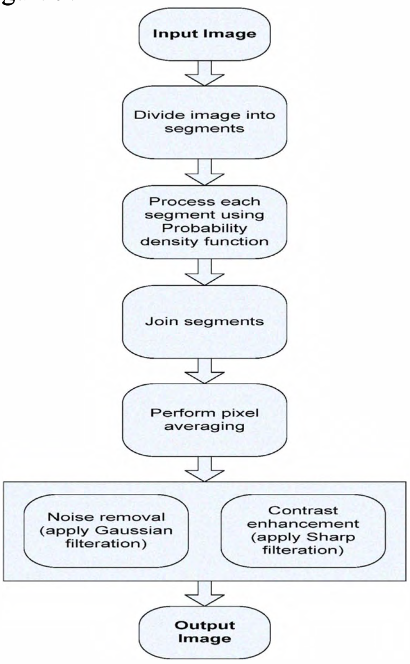

Figure 9. The block diagram of the proposed technique

B. Two Segments Approach

The two segments approach is a case of half face illumination in which one half of the face has sufficient lighting whereas the other half suffers from poor lighting effects. To compute the final processed image, similar procedure is applied as in the four segments approach except that in this case the input image is sub-divided into two segments only as shown in Figure 10.

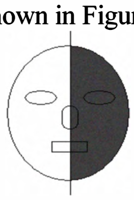

Figure 10. Division of a face into two sub images to handle the severe cases of half illuminated face

Figure 11 shows an image in half illumination condition from Yale database. The picture shows that its right half has almost been washed out.

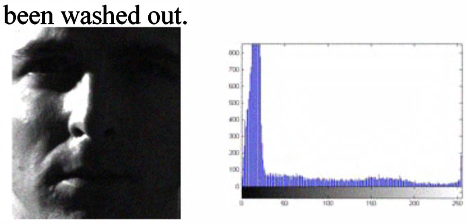

Figure 11. The original half illuminated face and its histogram

After processing the above image by two segments approach, the histogram obtained shows that the processed image is far better than the original one as shown in Figure 12.

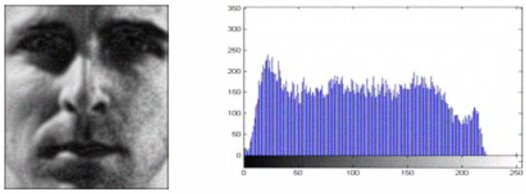

Figure 12. The processed face with half portion approach

V. EXPERIMENTS AND RESULTS

For the purpose of experimentation, the images were taken from Yale database. The facial features of most of these images either lacked suitable amount of light or were completely washed out. The experiments were performed on the following facts.

A total of fifty images were taken, five of each person or class. Processing on the selected images was performed using the proposed as well as previous illumination normalization techniques based on pre-processing i.e., whole histogram equalization and the gamma correction.

The processed images were then tested for face recognition using Principal Component Analysis (PCA) as a face recognition technique and the recognition rate was noted. Shown below is a sample from the experimental dataset with results of proposed technique.

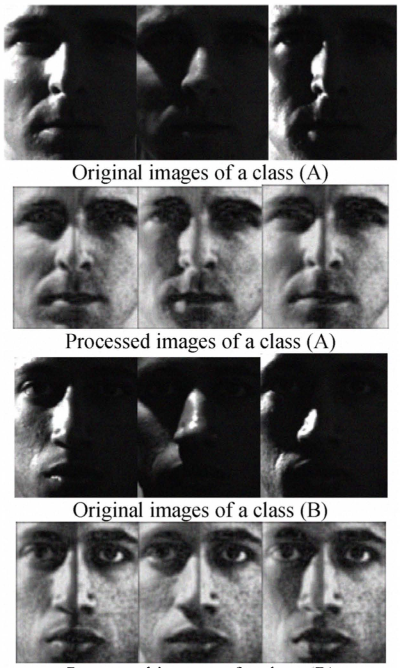

Figure 13. Samples of processed images using proposed technique

The experiment shows that the face recognition rate has been much improved in the proposed technique and has a higher success rate. The results of the experiment are given as follows:-

TABLE I. Comparison of Proposed approach with existing techniques using PCA for face recognition

Technique	**Successfully Recognized**	**Incorrectly Recognized**	**Recognition %age**
Images without Processing	7	43	**14%**
Gamma Correction	17	33	**34%**
Histogram Equalization	22	28	**44%**
Proposed Technique	**34**	**16**	**68%**

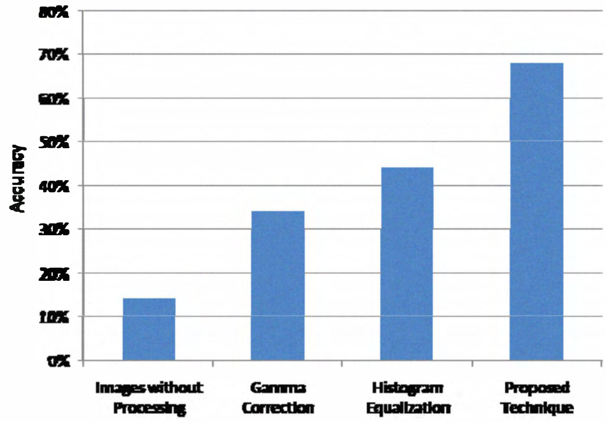

Figure 14. Comparison of Proposed approach with existing techniques

VI. DISCUSSION

The proposed algorithm is effective for removing the illumination factor from an original image. The technique creates lines along connection points of four sub images because of the following two factors:

1- The concatenation coordinates for matrix are not given accurately.
2- Noise created by illumination normalization algorithm. However, this problem is reduced to a certain level where it can be neglected for face recognition algorithm. This is being done by averaging the four pixel intensities in row (x axis) along the vertical center line and averaging the four pixel intensities in column (y axis) along the horizontal center line.

   By doing this, the lines become blurred and seem less noticeable than before. The process is followed by applying the low pass filters for further smoothening of the resultant image.

VII. CONCLUSION

This paper addresses illumination variation problem for face recognition. The proposed technique works at the pre-processing stage of face recognition and divides the input image in small segments. After that, each segment is normalized individually to address illumination issue. After individual processing of segments, the technique joins these segments back to form a single image. Then the computed single image is processed further for noise removal and contrast enhancement. The proposed method is tested on Yale dataset and is compared with some previous illumination methods using PCA as a face recognition technique. The experimental results show that the proposed technique performs better than previous techniques and provides good recognition accuracy.

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