An Image Enhancement Technique for Poor Illumination Face Images

A. Thamizharasi and J.S. Jayasudha

Abstract Face recognition is used to identify one or more persons from still images or a video image sequence of a scene by comparing input images with faces stored in a database. The face images used for matching the image in the database has to be of good quality with normal lighting condition and contrast. However, face images of poor illumination or low contrast could not be recognized properly. The objective of the work is to enhance the facial features eyes, nose, and mouth for poor contrast facial images for face recognition. The image enhancement is done by first detecting the face part, then applying contrast-limited adaptive histogram equalization technique and thresholding to enhance the facial features. The brightness of the facial features is enhanced by using logarithm transformation. The proposed image enhancement method is implemented on AR database, and the face images appear visually good when compared to original image. The effectiveness of the enhancement method is compared by analyzing the histogram.

Keywords Image enhancement · Facial features · Illumination
Face images · Histogram

1 Introduction

Image processing techniques are used in various fields such as automated inspection of industrial parts and security systems, automated biometrics, i.e., iris recognition, fingerprint features and authentication, face recognition. There is a growing interest in biometric authentication, for use in application areas such as National ID cards, airport security, surveillance, site access. A wide variety of biometrics, such as

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automated recognition of fingerprints, hand shape, hand written signature, and voice, has been used. However, all of these systems need some cooperation from the operator. Face recognition and iris recognition are some of the noninvasive methods of identification of people.

Faces are the most common way people recognize each other. According to many researchers, it is not very convenient for computers to recognize individuals using faces. This is because human beings and computers possess different talents. The computers look at the face as a map of pixels of different gray (or color) levels.

In machine-based face recognition, a gallery of faces is first enrolled in the system and coded for subsequent searching. A probe face is then obtained and compared with each coded face in the gallery; recognition is noted when a suitable match occurs. The challenge of such a system is to perform recognition of the face despite transformations: changes in angle of presentation and lighting, common problems of machine vision, and changes also of expression and age, which are more special to faces. Computerized human face recognition has many practical applications. This includes face recognition in cluttered background like airport, bank ATM card identification, access control and security monitoring. The popular methods used for face recognition are Eigen faces [1], fisher faces [2], ICA [3], 2D PCA, and 2D LDA [4].

2 Related Works

The image enhancement techniques in spatial domain are logarithm transform, gamma transformation, contrast stretching, and histogram equalization (HE) [5]. The image enhancement technique in frequency domain is homomorphic filter [5]. It applies Fourier transform to the logarithm-transformed image.

The log transformations can be defined by the formula $s = c \log r + 1$, where s and r are the pixel values of the output and the input image and c is a constant. During log transformation, the dark pixels in an image are expanded as compared to the higher pixel values. The power law transformations are nth power and nth root transformation. These transformations can be given by the expression: $s = cr^\wedge\gamma$. This symbol γ is called gamma, due to which this transformation is also known as gamma transformation. Variation in the value of γ varies the enhancement of the images. Different display devices or monitors have their own gamma correction, that is why they display their image at different intensity.

The histogram equalization is an approach to enhance a given image. The approach is to design a transformation 'T' such that the gray value in the output is uniformly distributed in [0, 1]. It is also called histogram flattening. Histogram equalization can be described as method in which histogram is modified by spreading the gray level areas. It enhances the contrast of images by transforming the values in an intensity image or the values in the color map of an indexed image, so that the histogram of the output image approximately matches a specified histogram. This method usually increases the global contrast of images. Histogram equalization often produces unrealistic effects in photographs; however, it is very useful for scientific images like thermal, satellite, or X-ray image. Also histogram equalization can produce undesirable effects (like visible image gradient) when applied to images with low color depth.

The image enhancement technique in this work is based on the concepts of contrast-limited adaptive histogram equalization (CLAHE) and thresholding. These concepts are described below.

2.1 Contrast-Limited Adaptive Histogram Equalization (CLAHE)

In contrast-limited histogram equalization (CLHE), the histogram is cut at some threshold and then equalization is applied. It improves the local contrast of image. Contrast-limited adaptive histogram equalization (CLAHE) is an adaptive contrast histogram equalization method [6], where the contrast of an image is enhanced by applying CLHE on small data regions called tiles rather than the entire image. Each tile's contrast is enhanced, so that the histogram of the output region approximately matches the specified histogram [7]. The resulting neighboring tiles are then stitched back seamlessly using bilinear interpolation. The contrast in the homogeneous region can be limited so that noise amplification can be avoided.

2.2 Thresholding

Thresholding is the one of the simplest, computationally faster method which is used in image processing for image segmentation [5]. Given image 'f', the object can be extracted from its background with threshold 'T' and create image 'g' using Eq. 1.

$$g(x, y) = \begin{cases} 1 & \text{if} f(x, y) > T \\ 0 & \text{if} f(x, y) \leq T \end{cases} \tag{1}$$

The above method is called as global threshold. However, if image has noise or illumination, global threshold would not give good results and variable thresholding has to be applied [5]. An optimal global thresholding is proposed by Otsu [5].

3 Proposed Method

The image enhancement is done by following steps: The input color image is first converted into gray scale image. The gray scale image is then converted into black and white image (binary image) using Otsu's global threshold method. The isolated black pixels are the noise pixels, and they are removed from binary image. The first white pixel from the top row is the object pixel that shows the starting of the face image and the last white pixel is the end of the face image. The distance between first white pixel from top and last white pixel is face length. The distance from the first white pixel from left-hand side of the image and last white pixel is face width. The face length is the major axis of ellipse and face width is the minor axis of the ellipse. The center pixels 'x_0' and 'y_0' are calculated from face length and face width. A translation invariant elliptical mask is created over the binary mask 'BM' using the center pixels 'x_0' and 'y_0', major axis, and minor axis. The equation of ellipse is given in Eq. 2. The 'x' intercept 'a' is half of face length and 'y' intercept 'b' is half of face width.

$$\frac{(x - x_0)^2}{a^2} + \frac{(y - y_0)^2}{b^2} = 1 \tag{2}$$

An elliptical color and gray face image will be created by adding elliptical binary mask and original image 'I'.

The proposed method is implemented in AR database. The experimental work is done using AR database. The details of AR database are given below. The AR database [8] contains images of 100 persons taken in two different sessions. 50 are men and 50 are women [8]. In each session, photographs were taken in 13 different conditions. They are neutral expressions (anger, scream, and smile), illumination (right, left, and both sides) and occlusions (eye occlusion, eye occlusion with left illumination, eye occlusion with right illumination, mouth occlusion, mouth occlusion with left illumination, and mouth occlusion with right illumination). All the images are cropped to an image size of 160 × 120 pixels.

The image enhancement method is implemented using MATLAB R2013a [9]. Figure 1 shows the original image, and Fig. 2 shows the elliptical face image. The elliptical color face image is converted into gray scale image. Figure 3 shows the elliptical gray scale image. These steps give the detected face image as an ellipse. The next step is to highlight the facial features eyes, nose, and mouth.

The contrast-limited adaptive histogram equalization (CLAHE) is applied on the elliptical gray scale image to adjust the contrast variations in the image. The image obtained is 'f'. This image is then converted into binary image using threshold technique. The mean of the image 'f' is 'GT'. Image 'g' is obtained using Eq. 3 with image 'f' and threshold 'GT'.

Fig. 1 Original color image

Fig. 2 Elliptical color face image

Fig. 3 Elliptical gray scale image

$$g(x, y) = \begin{cases} 1 & \text{if } f(x, y) > GT \\ 0 & \text{if } f(x, y) \le GT \end{cases} \quad (3)$$

The binary image 'g', thus, created contains salt and pepper noise. The median filter is applied to remove the noise, and the output image 'G' is obtained. Figure 4 shows the elliptical binary image. The facial features eyebrows, eyes, nose, and mouth are highlighted clearly.

In Fig. 4, both the background pixels and facial features pixels are black pixels. The next step is to differentiate the black pixels in the face area and non-face area. The black pixels till the first white pixel from top, left, right, and bottom are filled with gray pixel intensity value 128. Figure 5 shows the output image obtained by the above step. The original gray scale image is shown in Fig. 6. The original gray scale image is now processed to obtain the enhanced image using the following steps.

The gamma transformation $g = f.^\wedge\gamma$ with γ equal to 1.1 is applied. The brightness of the gray scale image is adjusted by darkening the pixel intensities at facial features eyebrows, eyes, nose and mouth. The brightness in the non-facial features like foreground and chin are increased. The salt and pepper noise if any is removed by applying median filter. The logarithm transformation $c * \log(f + 0.8)$ is applied to compress the dark pixels and lighten the light pixels. The final step is to apply the average filter to smoothen the image. The image obtained is the enhanced image. Figure 7 shows the enhanced image. The original gray scale image has low contrast and the output image's facial features are enhanced.

Fig. 4 Elliptical binary image

Fig. 5 Face segmentation

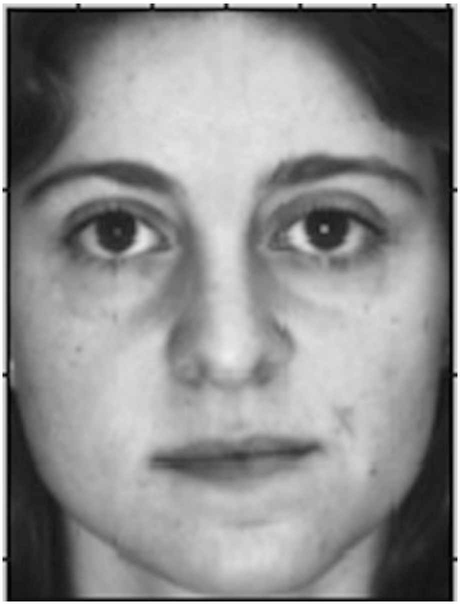

Fig. 6 Original gray scale image

Fig. 7 Enhanced image

4 Results and Discussion

The result of the proposed method in Fig. 7 is compared with the results of histogram equalization image, CLAHE image, log transformation image, and gamma transformation image. The histogram-equalized image, CLAHE image, log transformation image, and gamma transformation image for the same image are shown in Figs. 8, 9, 10, and 11, respectively. The histogram equalization method is useful in images with backgrounds and foregrounds that are both bright or both dark. The enhanced image shown in Fig. 7 is visually good with good contrast when compared to images in Figs. 8, 9, 10, and 11.

However, the histogram analysis of the enhanced image and the existing methods are done here to compare the effectiveness of enhancement. Figure 12 shows the histogram of original gray scale image, Fig. 13 shows the histogram of the enhanced image, Fig. 14 shows the histogram of histogram-equalized image, and Fig. 15 shows the histogram of CLAHE image.

From the histogram analysis, it is found that in Fig. 12, the gray levels are at various levels. In Fig. 14, the histogram is equally spread and brightness is adjusted globally. The non-facial features are also enhanced here. From Fig. 15, it is found that in CLAHE method contrast is high. The histogram of enhanced image in Fig. 13 shows that the image contrast is good. The facial features and non-facial features are visually separable and the histogram also proves the same.

Fig. 8 Histogram equalized image

Fig. 9 CLAHE image

Fig. 10 Log transform image

Fig. 11 Gamma transformation image

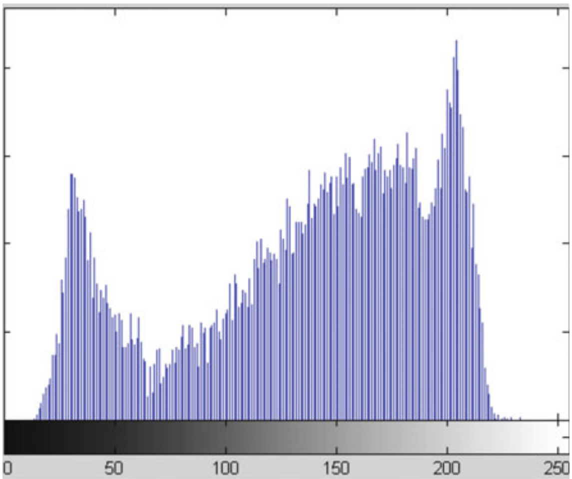

Fig. 12 Histogram of gray scale image

5 Conclusion

There are lots of image enhancement techniques available in the literature. The human face images under poor illumination could not be recognized effectively. An image enhancement particularly suitable for face images with poor illumination or contrast is proposed here. The facial features eyebrows, eyes, nose, and mouth are

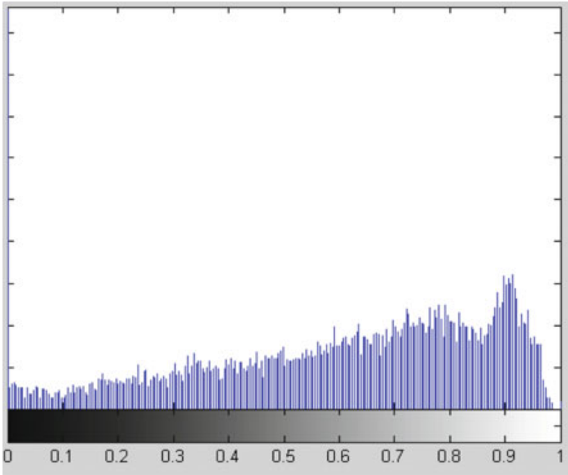

Fig. 13 Histogram of enhanced image

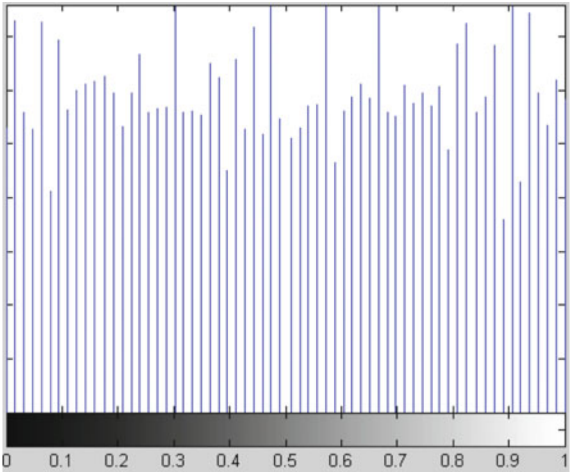

Fig. 14 Histogram of histogram-equalized image

highlighted from non-facial features, and this method could also be employed to extract these components individually. The extracted features could be compared for face part recognition. The brightness of facial features is darkened and the non-facial features are lightened. This process enhances the face image. The proposed method is compared with histogram equalization, CLAHE, logarithm, and gamma transformation methods using histogram. The enhanced method is visually good than other methods, and the histogram shows the image is of good contrast than the original gray scale image and other enhancement methods.

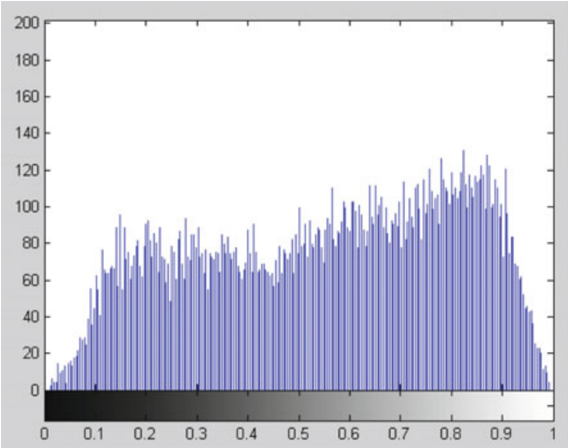

Fig. 15 Histogram of CLAHE image

References

1. Turk, M., and A. Pent land. 1991. Eigen Face for Recognition. *Journal of Cognitive Neuroscience* 3 (1): 71–86.
2. Belhumeur, P.N., J.P. Hespanha, and D.J. Krieg man. 1997. Eigen Faces Vs. Fisher Faces: Recognition Using Class Specific Linear Projection. *IEEE Trans. Pattern Analysis and Machine Intelligence* 19 (7): 711–720.
3. Draper, Bruce A., Kyungim Baek, Marian Stewart Bartlett, and J. Ross Beveridge. 2003. Recognizing Faces with PCA and ICA. *Computer Vision and Image Understanding* 115–137.
4. Wang, X., C. Huang, X. Fang, and J. Liu. 2009. 2DPCA vs. 2DLDA: Face Recognition using Two-Dimensional Method. *Proceedings of International Conference on Artificial Intelligence and Computational Intelligence* 2: 357–360.
5. Gonzalez, Rafael C., and Richard E. Woods. 1993. *Digital Image Processing*, Addison-Wesley.
6. Stark, J.A. 2000. Adaptive Image Contrast Enhancement Using Generalizations of Histogram Equalization. *IEEE Transactions on Image Processing* 9 (5): 889–894.
7. Zuiderveld, K. 1994. Contrast Limited Adaptive Histogram Equalization. In *Graphics Gems IV*, ed. P. Heckbert. Academic Press.
8. Martinez, A., and R. Benavente. 1998. *AR Face Database*. Computer Vision Centre, Technical Report 24.
9. Gonzalez, Rafael C., Richard E. Woods, and Steven L. Eddins. 2009. *Digital Image Processing Using MATLAB*, 2nd ed. ISBN 13:978-0982085400.