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PREPROCESSING TECHNIQUE FOR FACE RECOGNITION APPLICATIONS UNDER VARYING ILLUMINATION CONDITIONS

Strictly as per the compliance and regulations of:

Preprocessing Technique for Face Recognition Applications under Varying Illumination Conditions

S.Anila [α] & Dr.N.Devarajan [σ]

Abstract - In the last years, face recognition has become a popular area of research in computer vision, it is typically used in network security systems and access control systems but it is also useful in other multimedia information processing areas. Performance of the face verification system depends on many conditions. One of the most problematic is varying illumination condition. In this paper, we discuss the preprocessing method to solve one of the common problems in face images, due to a real capture system i.e. lighting variations. The different stages include gamma correction, Difference of Gaussian (DOG) filtering and contrast equalization. Gamma correction enhances the local dynamic range of the image in dark or shadowed regions while compressing it in bright regions and is determined by the value of γ. DOG filtering is a grey scale image enhancement algorithm that eliminates the shadowing effects. Contrast equalization rescales the image intensities to standardize a robust measure of overall intensity variations. The technique has been applied to Yale-B data sets, Face Recognition Grand Challenge (FRGC) version 2 Experiment 4 and a real time created data set.

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I. Introduction

A biometric recognition system is an automated system that verifies or identifies a person's identity using a person's physiological characteristics and/or behavioral characteristics [Jain et al., 2004]. Face recognition has been growing rapidly in the past few years for its multiple uses in the areas of Law Enforcement, Biometrics, Security, and other commercial uses. As one of the most successful applications of image analysis and understanding, face recognition has recently gained significant attention, especially during the past several years. There are at least two reasons for such a trend: the first is the wide range of commercial and law enforcement applications and the second is the availability of feasible technologies after several years of research [Zhao et al, 2003].

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Face is one of the most common parts used by people to recognize each other. Over the course of its evolution, the human brain has developed highly specialized areas dedicated to the analysis of the facial images.

While face recognition has increased in reliability significantly it is still not accurate all the time. The ability to correctly classify the image depends on a variety of variables including lighting, pose (Gross and Brajovic, 2003), facial expressions (Georghiades et al, 2001) and image quality (Shan et al, 2003). In the past decades, face recognition has been an active research area and many types of algorithms and techniques have been proposed to equal this ability of human brain. It is however questioned whether the face itself is a sufficient basis for recognizing a person from large population with great accuracy. Indeed, the human brain also relies on much contextual information and operates on limited population. This is evidenced by the emergence of specific face recognition conferences such as AFGR[1997, 1999] and AVBPA[1995-1998] and systematic empirical evaluation of Face Recognition Techniques [FRT], including the FERET [Phillips et al. [1997], [Rizvi et al 1998] and XM2VTS[Messer et al., 1999] protocols.

The most problematic perturbation affecting the performance of face recognition systems are strong variations in pose and illumination. Variation between images of different faces in general is smaller than taken from the same face in a variety of environments. More specifically the changes induced by illumination could be larger than the differences between individuals, causing systems based on comparing images to misclassify the identity of the input image [Adini et al., 1997]. i.e. The differences between images of one face under different illumination conditions are greater than the differences between images of different faces under the same illumination conditions.

The face verification system authenticates a person's claimed identity and decides that claimed identity is correct or not. In this case it has limited user group and in the most cases it can be forced or demand frontal pose orientations. But, still there are many problems with illumination condition. Face recognition tests revealed that the lighting variant is one of the bottlenecks in face recognition/verification. If lighting

Global Journal of Computer Science and Technology (F) Volume XII Issue XI Version I Year 2012

conditions are different from the gallery, identity decision is wrong in many cases. There are two approaches to this problem. Model- based, and preprocessing-based (Adini et al.,1997) and (Rabia Jafri and Hamid R.Arabnia, 2009). Model-based approach makes an attempt to model the light variation. Unfortunately, this requires large amount of training data and sometimes fail when there is a complicated lighting configuration. The second approach using preprocessing method removes lighting influence effect without any additional knowledge. So these methods are not practical enough for recognition systems in most cases. But, the approaches based on image processing techniques transform images directly without any assumptions or prior knowledge. Therefore, they are commonly used in practical systems for their simplicity and efficiency. Except the traditional method such as histogram equalization (HE) (Dalal and Triggs, 2005), histogram specification (HS), logarithm transformation (LOG), new methods belonging to this category such as Gamma Intensity Correction (GIC) and self-quotient image (SQI) (Wang et al., 2004) have been proposed recently with impressive performance improvement for illumination problem.

We can also carry out some analysis. For example, the popular Eigen subspace projections used in many systems as features have been analyzed under illumination variation [Adini et al., 1997]. The conclusions suggest that significant illumination changes cause dramatic changes in the projection coefficient vectors, and hence can seriously degrade the performance of subspace based methods [Zhao, 1999]. In direct appearance-based approaches, training examples are collected under different lighting conditions and directly (i.e. without undergoing any lighting preprocessing) used to learn a global model of the possible illumination variations, for example a linear subspace or manifold model, which then generalizes to the variations seen in new images [Belhumeur and Kriegman, 1998], [Basri and Jacobs, 2003], [Lee et al., 2005], [Chen et al.,2000] and [Zhang and Samaras 2003].

The robustness of several popular linear subspace methods and of Local Binary Patterns (LBP) can be substantially improved by including a very simple image preprocessing stage based on gamma correction, Difference of Gaussian filtering and robust variance normalization [Tan and Triggs, 2010]. The INface (Illumination Normalization techniques for robust Face recognition) toolbox in its current form is a collection of functions which perform illumination normalization and, hence, tackle one of the greatest challenges in face recognition [V. ˇStruc and N Paveˇsi´c, 2009]. The proposed method is presented in the conference [Anila and Devarajan, 2011].

II. Typical Preprocessing Methods

The methods based on image processing techniques for illumination problem commonly attempt to normalize all the face images to a canonical illumination in order to compare them under the "identical" lighting conditions. These methods can be formulated as a uniform form:

$$I' = T(I) \qquad (1)$$

Where 'I' is the original image, T is the transformation operator I'is the image after the transform. The transform T is expected to weaken the negative effect of the varying illumination and the image I'can be used as a canonical form for a face recognition system. Therefore, the recognition system is expected to be insensitive to the varying lighting conditions. Histogram equalization (HE), Histogram specification (HS) and logarithm transform (LOG) are the most commonly used methods for gray-scale transform. Gamma Intensity Correction (GIC) and Multi Scale Retinex (MSR) were supposed to weaken the effect of illumination variations in face recognition. All these methods are briefly introduced in the following sections and compared with the proposed method.

a) Histogram Equalization (HE) And Histogram Specification (HS)

Histogram Normalization is one of the most commonly used methods for preprocessing. In image processing, the idea of equalizing a histogram is to stretch and redistribute the original histogram using the entire range of discrete levels of the image, in a way that an enhancement of image contrast is achieved. The most commonly used histogram normalization technique is histogram equalization where one attempts to change the image histogram into a histogram that is constant for all brightness values. This would correspond to a brightness distribution where all values are equally probable. For image I(x,y) with discrete k gray values histogram is defined by i.e. the probability of occurrence of the gray level i is given by:

$$p(i) = \frac{n_i}{N} \qquad (2)$$

Where $i \in 0, 1\ldots k-1$ grey level and N is total number of pixels in the image. Transformation to a new intensity value is defined by:

$$I_{out} = \sum_{i=0}^{k-1} \frac{n_i}{N} = \sum_{i=0}^{k-1} p(i) \qquad (3)$$

Output values are from domain of [0, 1].To obtain pixel values in to original domain, it must be rescaled by the $K-1$ value. Fig.1 shows the histogram equalization.

The widespread histogram equalization cannot correctly improve all parts of the image. When the original image is irregularly illuminated, some details on resulting image will remain too bright

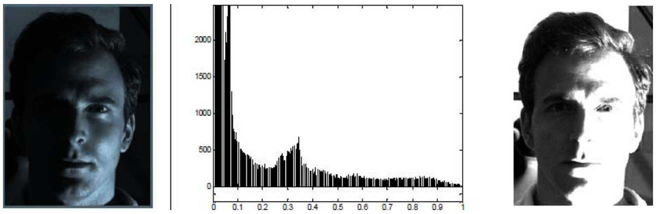

Fig.1 : An original image, its histogram, Linear histogram equalization from left to right

or too dark. These are most commonly used techniques of histogram adjustment. HE is to create an image with uniform distribution over the whole brightness scale and HS is to make the histogram of the input image have a predefined shape.

b) LOG

LOG is another frequently used technique of gray Scale transform. It simulates the logarithmic sensitivity of the human eye to the light intensity. Although LOG is one of the best methods in dealing with the variations in lighting on the three databases; it decreases the recognition rates on the other subsets of the CAS-PEAL database greatly. One possible reason is that the difference between the mean brightness values of the transformed images belonging to the same person is too large.

c) GIC

The Gamma Intensity Correction (GIC) corrects the overall brightness of a face image to a pre-defined canonical face image. Thus the effect of varying lighting is weakened.

d) SQI

SQI is based on the reflectance-illumination model: I = RL, where I is the image, R is the reflectance of the scene and L is the lighting. The lighting L can be considered as the low frequency component of the image I and can be estimated by a low-pass filter F , i.e., L ~ F * I . Thus we can get the self-quotient image as

$$R = \frac{I}{F*I} \qquad (4)$$

It uses a weighted Gaussian filter that convolutes with only the large part in edge regions. Thus the halo effects can be reduced. When the lighting variations are large (such as the “illum” subset of the CMU-PIE database), the edges induced by lighting are prominent and this method can work well. However, when lighting variations are not so obvious, the main edges are induced by the facial features. If this kind of filter is still used, the useful information for recognition will be weakened. This is a possible reason that it decreases the recognition rates on the FERET and CAS-PEAL datasets while increasing the recognition rates on the CMU-PIE database.

Fig.2 gives some examples (under varying lighting conditions) of the images after these transformation operations.

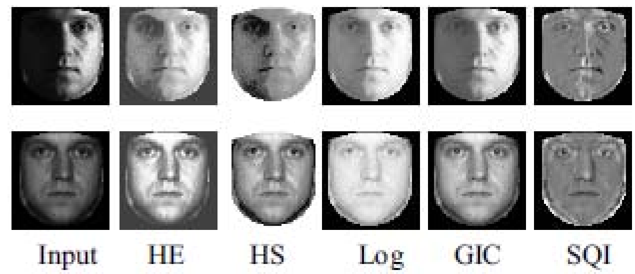

Fig. 2 : Example Effects of the Typical Preprocessing Methods

From Fig.2, the results show that HE, HS and GIC are better than the other two methods. (Some images in the FERET database had been processed. Therefore HE has little improvement on it.) Furthermore, they need no complex operations and the complexity of time and space is not high. However, the above example shows that these preprocessing approaches do not always work well on different datasets. Furthermore, some approaches may hurt the recognition of face images with normal lighting, though they do facilitate the recognition of face images with illumination variations. So it is necessary to improve the preprocessing method for varying light condition face images in order to guide the application to practical systems. The strengths of gamma correction, DOG filter and contrast equalization techniques have been combined and the net effect has been utilized in the proposed technique.

III. Proposed Technique

The proposed method combines the features of gamma correction, DOG filtering and contrast equalization techniques. Over all stages of proposed preprocessing method is shown in Fig.3.

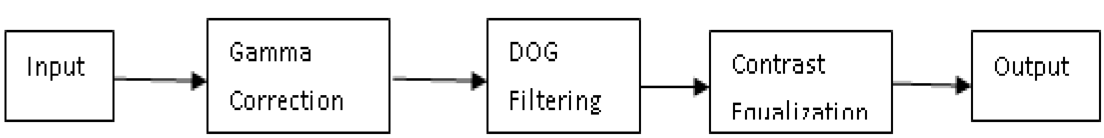

Fig. 3 : The Stages of Proposed Image Preprocessing Method

The rest of the paper is organized as follows. Section II Presents Gamma correction, DOG Filtering and contrast equalization technique with the results and Section III reports the conclusion.

a) Gamma Correction

Gamma Correction is a nonlinear gray-level transformation that replaces gray-level I with the gray level $I^{1/\gamma}$, and is given by,

$$I = I^{1/\gamma} \quad (5)$$

(for > 0) or log(*I*) (for = 0), where ∊ [0, 1] is a user-defined parameter. This enhances the local dynamic range of the image in dark or shadowed regions while compressing it in bright regions.

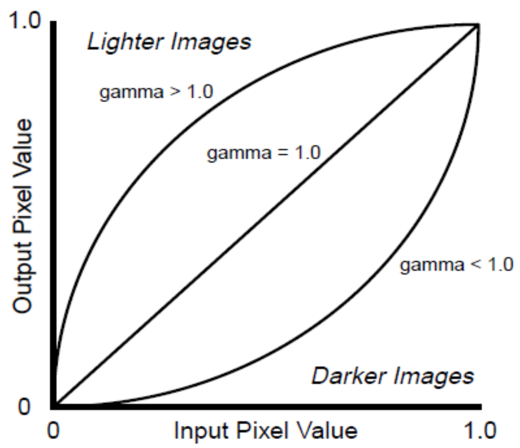

Fig. 4 : Gamma Curve

This curve is valuable in keeping the pure black parts of the image black and the white parts white, while adjusting the values in-between in a smooth manner. Thus, the overall tone of an image can be lightened or darkened depending on the gamma value used, while maintaining the dynamic range of the image. In Figure 4, the pixel values range from 0.0 represents pure black, to 1.0, which represents pure white. As the figure shows, gamma values of less than 1.0 darken an image. Gamma values greater than 1.0 lighten an image and a gamma value equal to 1.0 produces no effect on an image. A power law with exponent in the range [0, 0.5] is a good compromise. Here = 0.2[Tan and Triggs, 2010] is used as the default setting.

b) Difference Of Gaussian(Dog) Filtering

Gamma correction does not remove the influence of overall intensity gradients such as shading effects. In computer vision, Difference of Gaussians is a grayscale image enhancement algorithm that involves the subtraction of one blurred version of an original grayscale image from another, less blurred version of the original. The blurred images are obtained by convolving the original grayscale image with Gaussian kernels having differing standard deviations. Blurring an image using a Gaussian kernel suppresses only high-frequency spatial information. Subtracting one image from the other preserves spatial information that lies between the ranges of frequencies that are preserved in the two blurred images. Thus, the difference of Gaussians is a band-pass filter that discards all but a handful of spatial frequencies that are present in the original grayscale image. As an image enhancement algorithm, the Difference of Gaussian (DOG) can be utilized to increase the visibility of edges and other detail present in a digital image. The Difference of Gaussians algorithm removes high frequency detail that often includes random noise and this approach could be found well suitable for processing images with a high degree of noise.

The DOG impulse response is defined as:

$$DOG(x, y) = \frac{1}{2\pi\sigma_1{}^2} e^{-\frac{x^2+y^2}{2\sigma_1{}^2}} - \frac{1}{2\pi\sigma_2{}^2} e^{-\frac{x^2+y^2}{2\sigma_2{}^2}} \quad (6)$$

Where the default values of τ_1 and τ_2 are chosen as 1.0 and 2.0 respectively. Since this effect leads to the reduction in the overall contrast produced by the operation and hence the contrast has to be enhanced in the subsequent stages.

c) Contrast Equalization

The final stage of the preprocessing chain rescales the image intensities. It is important to use a robust estimator because the signal typically contains extreme values produced by highlights, small dark regions such as nostrils, garbage at the image borders, etc. One could use (for example) the median of the absolute value of the signal for this, but here a simple and rapid approximation is preferred based on a two stage process as follows:

$$I(x, y) = \frac{I(x,y)}{(mean\ (\min(\tau, |I(x',y')|)^{\alpha}))^{1/\alpha}} \quad (7)$$

$$I(x, y) = \frac{I(x,y)}{(mean\ (|I(x',y')|^{\alpha}))^{1/\alpha}} \quad (8)$$

Here, α is a strongly compressive exponent that reduces the influence of large values, τ is a threshold used to truncate large values after the first phase of normalization, and the mean is over the whole (unmasked part of the) image. By default we use α = 0:1 τ = 10[Tan and Triggs, 2010].

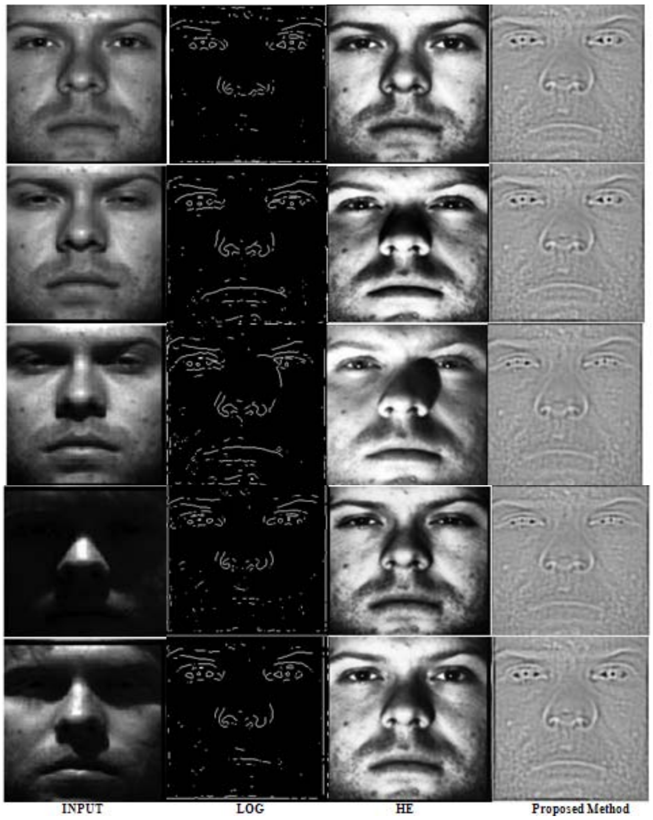

Fig. 5 : Comparison of Various Techniques with Difficult Lighting Condition

Fig.5 shows the different methods of performing the preprocessing. It could be observed that the images are taken under different lighting conditions, varying from very bright to very dark. By comparing, we could observe that the preprocessing performed using the proposed method is better when compared to LOG and HE.

The proposed technique is tested with the different datasets Yale B, FRGC-204 and Real time Database that has been created under difficult and different illumination conditions. For each person five images are created as normal, bright, very bright, dark and very dark. The images are tested with the proposed algorithm, preprocessing is performed which is the first stage of any face recognition system.

Table I : Default Parameter Settings [Tan and Triggs, 2010]

Procedure	Parameter	Value
Gamma correction	γ	0.2
DOG Filtering	σ_0	1
Contrast	σ_1	2
Equalization	α	0.1
	τ	10

IV. Conclusion

A new technique of preprocessing has been proposed for face recognition applications under uncontrolled and difficult lighting conditions. It could be achieved by using a simple, efficient image preprocessing chain whose practical recognition performance will be high when compared to the techniques where face recognition is performed without preprocessing. The technique has been carried out by combining the strengths of gamma correction, Difference of Gaussian filtering and Contrast equalization.

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