Taxonomy of Filtering Based Illumination Normalization for Face Recognition

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***Abstract*—Presently, the difficulty in managing illumination over the face recognition techniques and smooth filters has emerged as one of the biggest challenges. This is due to differences between face images created by illuminations which are always bigger than the inter-person that usually be used for identities' recognition. No doubt, the use of illumination technique for face recognition is much more popular with a greater number of users in various applications in these days. It is able to make applications that come with face recognition as a non-intrusive biometric feature becoming executable and utilizable. There are tremendous efforts put in developing the illumination and face recognition by which numerous methods had already been introduced. However, further considerations are required such as the deficiencies in comprehending the sub-spaces in illuminations pictures, intractability in face modelling as well as the tedious mechanisms of face surface reflections as far as face recognition and illumination concerned. In this study, few illuminations have been analyzed in order to construct the taxonomy. This covers the background and previous studies in illumination techniques as well the image-based face recognition over illumination. Data was obtained from the year of 1996 through 2014 out of books, journals as well as electronic sources that would share more on the advantageous and disadvantageous, the current technique's performance as well as future plan.**

***Index Terms*—Taxonomy; Face Recognition; Strategies; Filters; Illumination.**

I. INTRODUCTION

Vital challenge in the real time applications is on the face recognition through different illumination. Despite of numerous illuminations filtering techniques are in place, the concepts are said to be archaic and the critical analysis of performance of illumination filtering techniques are not covered [1],[2]. Based on the current face recognition techniques that come with a group function to normalize the illumination help to facilitate the critical challenge in the face recognition system [3-6].

II. ILLUMINATION NORMALIZATION FACE RECOGNITION

In general, the illumination variation techniques could be classified into three main categories which are

- Illumination normalization
- Illumination modelling
- Illumination invariant feature extraction.

The illustration of Taxonomy of illumination's filtering could be seen as described in Figure 1.

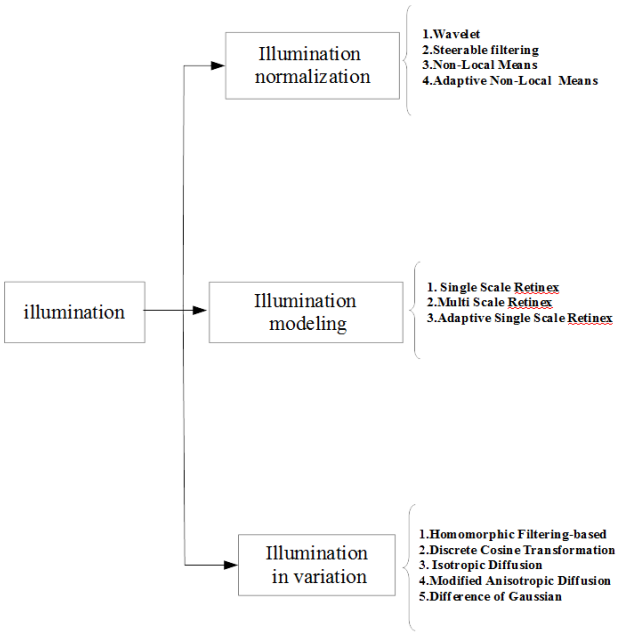


Figure 1: Taxonomy of Filtering based illumination face recognition

A. *Illumination Normalization*

The first category refers to the normalized face images under illumination variation. The typical algorithms for this category are Wavelet, Steerable filtering, Non-local Means based as well as adoptive Non-local means.

B. *Wavelet-based (WA)*

Du and Ward were the first to introduce the Wavelet-based normalization (WA) technique [5]. In this technique, the wavelet transformation which will become discrete on the image is used and followed by the processing of the obtained subands. The histogram equalization will be used based on the estimated transformation's coefficient to focus on the detailed coefficient's matrices [5]. We could redesign the normalized image through the inversely wavelet transformation when once the sub-bands manipulated.

$$f(x) = \sum_k a_{o,k}\,\phi_{o,k}(x) + \sum_i \sum_k d_{j,k}\psi_{j,k}(x) \qquad (1)$$

where ϕ j,k and ψ wj,k are scaling functionalities and wavelet functionalities at scale j, respectively. Whereas Aj,k, and D j,k are scaling and wavelet coefficients respectively.

C. Adoptive Non-Local Mean

Struc and Pave˘si˘c [5] introduced Adaptive Non-Local Means based normalization which is known as ANL. Functionality of luminance is measured by employing the algorithm for Adaptive Non-Local Means de-noising and then reflectance number is calculated in this technique. The Adaptive Non-Local Means filter with a mixture of Wavelet is just like the NLM filtering. However, the smoothening parameter is adapted locally which could be expressed as:

$$\sigma^2 = \min(d(R_i, R_j)) \forall \neq i and R = \mu - \Psi(\mu) \quad (2)$$

where volume R is the input for a distance measured by subtracting the original noisy volume u and the low pass filtered volume $\psi(\mu)$.

By removing the low frequency input with minimal operator applied, experiments showed that a minimal distance which is approximately similar to s2 is required in this case [12],[18]. However, the database in search that comes along with unique patches will give a minimal overestimation over the noise variance in this case. Thus, the parameter h2 will be established by the adaptive filtering which is similar to the minimal distance calculation as in equation 2.

D. Illumination Modelling

In second category, the image construction under different illumination conditions will need to consider the assumptions of certain surface reflectance properties [6]. The illumination variation could be very well modelled with the typical algorithms for second category such as SSR, MSR, and ASR [7].

E. Single Scale Retinex (SSR)

With many similarities to photometric normalization techniques, the algorithm for Single Scale Retinex or SSR was introduced [7],[17]. Retinex theory is considered as SSR parent since it is derived from this theory [8]. The local contradiction will be improved when the SSR scale is low and this indirectly makes the robust compression range becomes better. This is due to the variations of the images' ratio of compressed robust scales [9],[10]. The SSR form could be defined as (3)

$$R(x,y) = logI(x,y) - log(F(x.y) * I(x,y)) \quad (3)$$

where image intensity is represented by I (x, y), operation of convolution is illustrated by '*' in the formula. Retinex output is shown by R(x, y) and Gaussian functionality is displayed as F(x, y).

$$F(x,y) = K \bullet e\text{-}(x2+y2), integral(integral(F(x,y), dx, dy = 1 \quad (4)$$

F. Multi Scale Retinex (MSR)

The Multi Scale Retinex or MSR is an extended algorithm from the SSR [11]. One of the assumptions in retinex theory is that, the perception of color is solely relying on the neural structure of human vision system [12],[13]. This in turn has introduced the retinex model for lightness computation. The utilization of retinex theory which is derived from the human visual system helps to improve the images contrast that comes with complex lightings [12],[14]. The Land's theory was applied after the first SSR was introduced and created based on the retinex theory [13] followed by MSR [15-17].

G. Adaptive Single Scale Retinex (ASR)

As suggested by the researches, the algorithm for Adaptive Single Scale Retinex or ASR has become the latest add-on to the retinex techniques [18]. The integration of various images from the SSR output to the weight linked to each SSR scale has been the aim of ASR with the weight computed from the image input content adaptively [19],[25]. In the beginning, transformation of red, blue and green is used to retrieve the component of luminance Y as to input the image color. This is possible by applying the functional equation as shown below:

$$Y(x,y) = 0.299 \cdot R(x,y) + 0.587.G(x,y) + 0.114 \cdot B(x,y) \quad (5)$$

where R(x, y), B(x, y) and G(x, y) reflect the values of red, blue and green pixels located in (x, y). Then, the suggested AMSR technique will process the Y luminance image to yield the improved image of luminance Y^{AMSR}.

H. Illumination Invariant Feature Extraction

The aim of the third category is to find the potential representation of illumination variant in face images under the different illumination conditions. The typical algorithms used in the third category are DCT, ISOTRPIC DIFFUSION, MAS and DoG.

I. Discrete Cosine Transformation (DCT)

Discrete Cosine Transformation (DCT) is widely used in different studies on face recognition at the stage of features extraction [23]. The illumination invariance could be obtained through this technique by establishing the amount of DCT coefficients that corresponds from low frequencies to zero [22]. A comprehensive local appearance-based or appearance-based manner which does not account for the spatial information uses DCT features while carrying out the classifications. Nowadays, there are many studies have been conducted [24],[26] focusing on the way to reduce the impact of illumination variation and effect of pose variation.

J. Isotropic Diffusion-Based Normalization

Isotropic diffusion-based normalization technique or IS in short is employing isotropic smoothing of image in calculating functionality of the luminance. This technique reflects the simplified r-variant of the anisotropic diffusion-based normalization technique [14]. The algorithm for anisotropic diffusion (AD) is famous with its illumination invariant removal's feature on the face image. However, conduction functionality and measure of discontinuity impacts on anisotropic diffusion functions of algorithm [22]. Usually, the discontinuity measurement is picked from the in-homogeneity or space gradient in the conventional algorithm of the anisotropic diffusion [20].

K. Difference of Gaussian (DoG)

DoG normalization or in short DoG is a normalization technique which is using variation of Gaussians filter for normalized image producing [2]. Basically, a band-pass filtering to the inputted image is used which then will create a normalized version. Before applying the filter, gamma correction or log transformation should be applied on the

image otherwise desired outcome will not be achieved [7],[15-17].

Outcome of an illumination component i(x, y) and r(x, y) as reflectance component is illustrated as f(x, y) in this model which represents pixel values of image which could be seen as in the equation (6) below:

$$f(x,y) = \mathrm{i}(\mathrm{x},\mathrm{y})\,\mathrm{r}(\mathrm{x},\mathrm{y}) \tag{6}$$

The logarithm transformed on Equation (13) is applied on two independent components to separate them and facilitate process of separation which could then be transformed into Equation (7):

$$z(x,y) = \inf(x,y) = Ini(x,y) + Inr(x,y) \tag{7}$$

z(x,y) as result of filter function h process on convolution of the two functionalities which is shown as "*". This could be derived based on the convolution theory as:

$$s(x,y) = h * z(x,y) = h * Ini(x,y) + Inr(x,y) \tag{8}$$

$$s(\mu,\mathrm{v}) = \mathrm{H}(\mu,\mathrm{v})\,\mathrm{Z}(\mu,\mathrm{v}) = H(\mu,\mathrm{v})Fi(\mu,\mathrm{v}) + H(\mu,\mathrm{v})Fr(\mu,\mathrm{v}) \tag{9}$$

where S(u,v), H(u,v), Z(u,v), Fi(u,v), and Fr(u,v) are individual Fourier transforms of s(x,y), h(x,y), z(x,y), lni(x,y), and lnr(x,y). By inversing the Fourier transform, the s(x, y) can be computed as expressed in Equation (10):

$$\begin{aligned} s(x,y) &= \Im^{-1}\{s(\mu,\mathrm{v})\} \\ &= \Im^{-1}\{\mathrm{H}(\mu,\mathrm{v})\}\,\mathrm{Fi}(\mu,\mathrm{v})\} + \Im^{-1}\{\mathrm{H}(\mu,\mathrm{v})Fr(\mu,\mathrm{v})\} \end{aligned} \tag{10}$$

where $\Im^{-1}$ is the inverse Fourier transform operator. Set:

$$i(x,y) = \Im^{-1}\{\mathrm{H}(\mu,\mathrm{v})\}\,\mathrm{Fi}(\mu,\mathrm{v})\} \tag{11}$$

and

$$\mathrm{r}(x,y) = \Im^{-1}\{\mathrm{H}(\mu,\mathrm{v})\}\,\mathrm{Fr}(\mu,\mathrm{v})\} \tag{12}$$

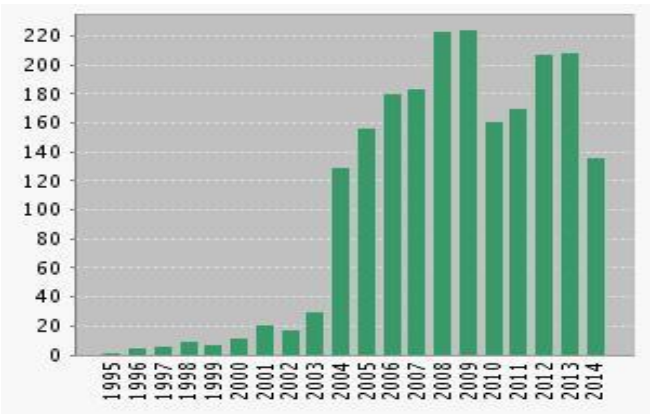
Thus, the Equation (8) can be simplified and expressed as:

$$\mathrm{S}(x,y) = \mathrm{H}(\mu,\mathrm{v}) + \mathrm{r}(\mu,\mathrm{v})\} \tag{13}$$

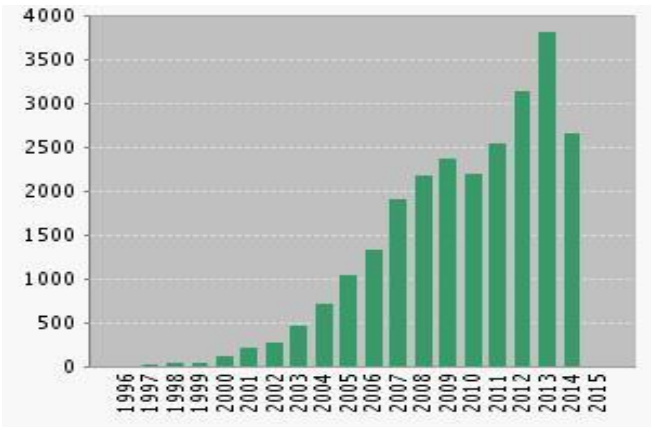
Enhanced image is represented by g(x,y) after filtering. Logarithm of F(x,y), g(x,y) is displayed as z(x,y) can be produced by applying illumination normalization process.

III. CURRENT TRENDS

Figure 2 displays the publication and citation trend of filtering illumination technique from 1995 till present, as measured by web of science. The constant trend of illumination versus the drastically hiking trend of face recognition.



(a)



(b)

Figure 2: (a) Published Items in Each Year and (b) Citations in Each Year

IV. DISCUSSION

The pros and cons of illumination filters could be seen as shown in Table 1. Different filtering techniques were compared in terms of their performance and accuracy as described in Table 1. The SSR proven helps to reduce the illumination differences and protects the discrimination of the inter-class significantly. A better execution is obtained by applying the MSR technique compare to SSR technique by considering edge reinforcement and dynamic range compression. However, the edge and color distortions are some of the defects that could still be seen. The reflectance components of the face images could be removed through the Homomorphic filtering technique. The expectation to integrate both advantages of dimension reduction as well as maximizing the class separations by feature image creation has influenced the development of DCT technique. Decomposition of estimated and detailed coefficients is employed in image analysis of wavelet-based. These coefficients interact with low and high frequency components of image.

The modification of algorithm for Modified Anisotropic is based on the radiologists' feedback on the improvement required for the medical details of the liver ultrasound images. The modifications were carried out particularly by utilizing templates which are used to measure derivative, diffusion, and Laplacian and are large in size. Finally, the modification is end up with the increase of resolution on the ultrasound image details by embedding the regularization. Using modified execution of homomorphic filtering by having Differences of Gaussian (DoG) as main part reduces the differences in Gaussian of illumination and applying histogram equalizations improves contrasts.

Table 1
Disadvantage with drawback of illumination filters in face recognition

Flirter	Advantages	Disadvantage
SSR	The scale of a SSR expands, its shading unwavering quality elements im-demonstrate.	Incorporates radiance ancient rarities. SSRs have diverse element range pressure qualities as per the scale. The SSR does not run great tonal execution.
MSR	Works effectively with images that are grayscale.	In order to enhance color of images, histogram equalization is used. This might cause color scale change and observing imbalance in image colors can be result of this.
ASR	Restores the image quicker while holding the execution of practically identical entrancing.	Expanded fundamentally. Feeble results between pixels that contain little varieties.
DCT	This filter maintains low, mid and high frequencies of coefficients while decreasing image space dimensions.	DCT does not have sufficient energy recurrence limitation in light of the fact that by and large they are over the distributed time.
WA	No training image is needed for this technique. However, they cannot dispose of gave shadows totally a role as they need versatility in protecting the discontinuities adequately.	This cannot be executed as there are more develop and speedier algorithms for wavelet change.
ISOTROPIC	Can safeguard edges of image and can decrease noise in the meantime	It is uncaring to introduction and symmetric, bringing about blurred edges.
ADAPTIVE NON-LOCAONL	Applying this filtering in order to enhance data might be used for segmentation, Relaxometry or Tractography based applications.	This method does not lessen the trouble of the algorithm altogether while just diminishing somewhat the exactness of filtering.
DOG	No light source information or 3D shape data is needed in this filtering as well as great number of training samples. As a result, this filter is suitable for training of single image per person.	Based on surface: using spatial information 2Connecting of edges: an excessive amount of segmentation Based on image: just has a low-level characteristic

V. CONCLUSION

Comprehensive illumination variations methods are employed in pattern recognition and computer vision by researchers in order to tackle facing challenges. There are various techniques observed would be able to tolerate and/or compensate with the variations caused by illumination variation in image. However, gaining the illumination in face recognition still remains a serious challenge. This requires a continuous and tremendous efforts as well as attention to put on it.

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