Illumination Processing Recognition of Face Images Based on Improved Retinex Algorithm

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Abstract—In order to change the defects of the similar traditional Retinex algorithm that it is easy to appear the "Halo" phenomenon in the illumination image acquisition process, we proposed a study on the face images recognition under the illumination condition based on the improved Retinex Algorithm, which is based on the Retinex Theory Algorithm defects and analyzes the brightness, contrast rate of the face images as well as the design of the illumination background in the improved Retinex, and draw the conclusion that this algorithm can overcome the Halo phenomenon to a certain extent when occurs the illumination mutation. In order to verify the effectiveness of the algorithm, we did a simulation to the face images in the Yale B face database finally and studied the comparison test of similar algorithms in different images. The result shows that the improved Retinex algorithm can be a good solution to the Halo problem, reduce the time complexity and can be applied to the face recognition under the condition of strong illumination changes, the recognition rate of which is higher, and the illumination robustness is stronger.

Index Terms—Recognition Rate, Retinex Algorithm, Face Image, Feature Extraction

I. INTRODUCTION

The face recognition research involving image processing, pattern recognition, machine vision, computer graphics, human intelligence, cognitive science and other related disciplines, because of its technical difficulty and complex factors, it can provide a good specific object of study for these disciplines, which is helpful to build the basic experimental platform for these disciplines to try new theories and methods. The in-depth study and final settlement of face recognition can promote these disciplines to be mature and developed [1-3]. At the same time, the face recognition is a research hot point in the field of pattern recognition and image processing and is one of the key technologies of biometric identification, which refers to the identity verification technology that uses the physiological characteristics or behavioral characteristics that belong to human or can be used to identify the identity of a person. Compared with the traditional identity verification technology, the outstanding advantages of biometric identification technology are the biometric characteristics can fundamentally eliminate forgery and theft, and it belongs to human beings and have a higher reliability, security and availability [4-7]. As a typical biometric identification technology, face recognition is favored by people for its high natural characteristic and the acceptability etc. And it has broad applications in the fields of national public security, judicial field, financial security, and human-computer interaction: (a) In terms of public security and identity verification, we can use the biometric identification technology, in particular, the face recognition technology to assist the monitoring of terrorists and criminals, especially after the events of 911, it has become a common sense of the Governments to strengthen the identity verification and identification of personals; (b) In the field of information security, with the development of computer network technology and e-commerce, the information security issues become increasingly prominent, so it has broad application prospects in achieving the computer logon rights, control and the identity verification in the electrical household transactions and other information security aspects by using the face recognition technology [8-10].

The face recognition designed to give computers the ability to distinguish the identity through faces. In the face recognition system, the initial presentation of a face is an image, but under the influences of factors such as illumination, age and expression changes, there are great differences in the images of the same face which provide challenges to the study of the face identification [11-13]. However, since most people face images are acquired under non-ideal conditions (such as illumination is variable, posts are variable, expressions are variable, etc.), especially when the illumination varies greatly, the image will be underexposed and appears the luminance unevenness which result in considerable differences between collected face images and personal appearances and it can seriously affect the subsequent face recognition. Therefore, the illumination is still a key issue in the study of face recognition technology [14].

With respect to other aspects of face recognition, the illumination problem has not obtained the researchers' attention. After the FERET test found the impact of illumination on the face recognition results, scholars started the problem and put forward a number of illumination processing algorithms. The classic illumination processing algorithms at present are: linear transformation, non-linear transformation, histogram equalization, histogram specification and so on, all of these algorithms are simple and easy to implement, but they are all based on the gray-scale transformation image.
enhancement algorithm that means when the illumination changes greatly, the effects of the enhancement processing will not be very satisfactory or can not effectively improve the image quality. In 1977, Edwin Land was first to propose a color theory called Retinex, and some scholars introduced it into the face image enhancement processing which has opened up a new path to solve the problems of illumination change [15]. There has been many types of enhancement algorithms based on the Retinex theory, currently the relatively more common ones are Single-Scale Retinex (SSR), Multi-Scale Retinex (MSR) and Multi-Scale Retinex Color Recovery (MSRCR) and other algorithms, all of these Retinex algorithms have improved robustness and recognition rate of the face recognition to different extents. However, the Retinex theory assumes that the incident illumination component of the image pixels are the same, i.e., the illumination changes is smooth, while actually the incident illumination component still have slight differences, so the classic Retinex method can occur the “Halo” phenomenon in the strong chiaroscuro, which affects the subsequent image processing.

To this end, to against the above problems, we propose a face recognition method under the condition of illumination changes based on the improved Retinex algorithm, and analyze and verify its performance through specific tests. This thesis mainly makes development and innovation work from the following areas:

It analyzes the traditional Retinex theory algorithm finds a defect that when the illumination changes greatly, the “Halo” phenomenon will occur; It analyzes the identification of the improved Retinex algorithm in face recognition. Through the analysis of the brightness nonlinear enhancement of the face image, the brightness nonlinear enhancement of the face image contrast ratio and the illumination background design of the face image, we can know that the traditional image recognition is difficult to overcome the "Halo" and shadow so the face image is difficult to complete presented. While the improved Retinex algorithm’s bilateral filtering is an anisotropic filter - it can take advantage the spatial proximity and gray value similarity of the current and neighborhood pixels at the same time and it can also take into account the sudden changes in illumination in the image and can overcome the “Halo” phenomenon to a certain extent. Compared to the same class algorithms, the improved Retinex algorithm can make the details in the face image dark area to be identified more clearly, and the gray dynamic range of the image is compressed which and can guarantee that in different levels of illumination, the image can get a good enhancement effect to make the face image seem to be more harmonious and natural, which means it plays a good smoothing effect and its robustness is stronger;

In order to test the effectiveness of the algorithm proposed in this thesis in the face image, we adopt the images in the Yale B face database to do the simulation and randomly select 5 groups of images for testing. In all the image processing algorithms, the algorithm in this thesis not only has the fastest processing speed, the minimum time consumption, but also meets the real time and online requirements in face recognition. It can also eliminate the impact of the illumination well to prevent the phenomenon of "Halo" to make the face image to be more complete, more natural and more clearer presented, which effectively solves the illumination normalization problem of face images and eliminates the impact of illumination on face recognition algorithm, all of these improve the illumination robustness of the face recognition system and the face recognition ratio.

II. RETINEX THEORY

A. Retinex Algorithm

According to Retinex Theory, a figure can be regarded as the product of the radiation image and the reflection image, whose mathematical expression is as follows:

\[ I(x, y) = L(x, y) \times R(x, y) \] (1)

In which, \( I(x, y) \) represents the collected signal of the original image; \( R(x, y) \) represents the reflection components of the target object carrying the details of the image, \( L(x, y) \) is the illumination components of the ambient illumination, and they meets \( L(x, y) = I(x, y) \times F(x, y) \).

In order to separate the illumination and reflection components, we can take the logarithm of both sides of (1) to recover the original appearance of the object, that is:

\[ \log I(x, y) = \log L(x, y) + \log R(x, y) \] (2)

According to Retinex Theory, \( R(x, y) \) and \( L(x, y) \) are corresponding to the high and low frequency parts of the image respectively, therefore to the single-scale Retinex...
(SSR) algorithm, the output result $R(x,y)$ of the Retinex Algorithm of the $I_0$, color component is as follows:

$$R(x,y) = \lg[I(x,y)/L(x,y)] = \lg I(x,y) - \lg[F(x,y)*I(x,y)]$$

(3)

where, $i=1,2,3,*$ represents the convolution operation, $F(x,y)$ represents the Gaussian Surround Function, which is used to estimate the brightness of the image after convolving with the original image, that is

$$F(x,y) = K \cdot e^{-c^2 + y^2/\sigma^2}$$

(4)

where, $\sigma$ represents the scale parameter of the Gaussian Surround Function, $K$ is a constant, which is determined by the Normalized Function, that is:

$$\int F(x,y)dx\,dy = 1$$

(5)

When $\sigma$ is relatively smaller, it can enhance the detail in the dark region of the image and has the good dynamic compression but the color distortion is severe, conversely, the color constancy is better. In order to gain the balance between these two, we introduce the Muti-Scale Retinex Algorithm (MSR), which is the weighted sum of several Single-Scale Retinex Algorithm (SSR) s. The mathematical description is as follows:

$$R(x,y) = \sum_{i=1}^{n} w_i \{ \lg I(x,y) - \lg[F(x,y)*I(x,y)] \}$$

(6)

where $n$ represents the number of the surrounding scale, and it usually selects 3 scales of high, middle and low; $w_i$ represents the weight coefficient.

B. The Defects of the Retinex Algorithm

Analyze the performance of the classic Retinex Algorithm by adopting the Yale B face database, in which according to the differences of the irradiation direction of the illumination sources (azimuth and elevation) the faces are divided into five subsets: S1(0~12°), S2(13~25°), S3(26~50°), S4(51~77°), S5(above 78°). The original images are shown in figure 2 and the results after the enhance processing by SSR Algorithm, MSR Algorithm and MSRCR Algorithm are shown in figure 3.

![Figure 2. Original images with different illumination conditions](image)

According to the results of Figure 2, for the image in the illumination of 50° or less, after various Retinex algorithms processing, good treatment effects can be obtained; but for images of more than 50°, there were significant shadows. This is mainly due to the reason that the Retinex algorithm assumes that the change of illumination in space is relatively smooth, which does not match with the actual situation, so when the illumination change is large, it will produce a "Halo" phenomenon.

C. Improved Retinex Algorithm

The Global Nonlinear Enhancement of the Face Images Brightness

There is correlation between the RGB channel, so if directly enhanced the input image, the enhanced image will occur color distortion [12]. Therefore we should transfer the color space of the input image first of all, that is to say transfer the input image from RGB space to HSV space, which can save 2/3 of the amount of calculation, and then enhance the luminance component of the image only. Because the classic Retinex algorithm uses a log function to adjust, but the log function has no center to adjust so the adaptive ability is very bad while the center of the varies with the changes of the average value of the image so the adaptive regulation is strong, therefore this thesis adopts the S-shape tangent hyperbolic function in literature [7] to process the brightness of the image.

Local Nonlinear Enhancement of Face Images Contrast Ratio

After doing the global nonlinear enhancement to the face image, the whole image becomes suitable to see. In order to make the details of the face image more clear and rich and do the local nonlinear enhancement to the contrast rate of the image at the same time, the local enhancement details can be obtained by the calculation in Formula (9) Non-linear Transform, i.e.

$$V_{out}(x,y) = [V_{in}(x,y) - F(x,y)*V_{in}(x,y)]$$

(7)

To get more details, the value of the scale parameter $\sigma$ of the Gaussian function $F(x,y)$ in Formula (7) should be small. The value range of this experiment is 2.2, $\gamma$ is the nonlinear adjustment coefficient, whose value range is [0, 1]. The larger $\gamma$ is, the greater the contrast enhancement and the more obvious the sharpening effect will be; the smaller $\gamma$ is, the greater the gray dynamic range compression and the more clear the details in the dark region of the image [13].

Figure 4 (a) shows the original face image and histogram effect; Figure 4 (b) shows the image and the histogram effect after the logarithmic transformation enhancement processing by Formula (6); Figure 4 (c)
shows the image and the histogram effect after the processing by the enhancement algorithm proposed in this thesis. Through the comparison of the processing effects by different enhancement algorithms in Figure 4, we can find that after logarithmic transformation enhanced, the grayscale of the image gained the expansion, but the overall is overly bright, which will result in the loss of face image minutiae. While after enhanced by the nonlinear enhancement algorithm proposed in this thesis, the details of dark areas of the face image are more clear and the gray dynamic range of the image is compressed which can prove that under different levels of illumination, image can get to the good enhancement effect and better robustness.

![Image of original image and histogram](attachment:image1.png)

(a) The original image and the histogram

![Image of enhanced histogram](attachment:image2.png)
(b) The image and the histogram after the enhance of the change comparison

![Image of enhanced histogram](attachment:image3.png)
(c) The image and the histogram after the enhance of the algorithm proposed in this thesis

Figure 4. The comparison results of images enhance algorithms

Figure 5. The origin image and the image by Bilateral filter

**D. Illumination Evaluation of Face Images Backgrounds**

"Halo" phenomenon occurs mainly in the edge region with intense gray-scale changes, whose main cause is that we adopt the isotropic low-pass filter to estimate the illumination, while isotropic low-pass filtering operator does not take into account the situation of the changes of image grayscale when smoothes the image, so when the edges of the image occurs the illumination mutation, it is difficult to accurately obtain the background illumination of the region this point is in, therefore the "Halo" phenomenon occurs.

In order to reduce the "Halo" and shadows, to find a suitable low-pass filtering operator is very important, and the low-pass filtering operator should have a good edge retention characteristic which means the illumination component estimated by the using of the low-pass filtering operator can reflect the overall structure of the image. The Bilateral filter is an anisotropic filter, while taking advantage of the space and gray value of similarity of the current point and the neighborhood pixel at the same time, it is preferably considered to the illumination mutation case in the image which can overcome the Halo phenomenon to some extent, so this thesis adopts the Bilateral filter instead of Gaussian Function in classic Retinex Algorithm to estimate the illumination of the input image.

The brightness estimation of bilateral filtering the image is as follows:

\[
\hat{l}(x, y) = k^{-1}(x) \sum_{(m,n) \in W} d(x, y, m, n)\lambda(x, y, m, n)f(x, y, m, n) \tag{8}
\]

where \( W \) is the size of the window.

\[
k(x) = \sum_{(m,n) \in W} d(x, y, m, n)\lambda(x, y, m, n) \tag{9}
\]

Based on the Weber’s law, calculate the luminance difference between the points in the neighborhood with the present point in the \( W \times W \) Window neighborhood of each image, then calculate and comprise according to the luminance difference. The specific formula is as follows:

\[
\lambda(x, y, m, n) = \begin{cases} 
    e^{-\frac{1}{2}\left((f(x, y)m)^2 + (f(x, y)n)^2\right)} & \text{if } \|f(x, y) - f(x, y, m, n)\| < K \times f(x, y) \\
    e^{-\frac{1}{2}\|f(x, y) - f(x, y, m, n)\|^2} & \text{otherwise}
\end{cases} \tag{11}
\]

where \( f(x, y, m, n) \) is the pixel value in the circle centered as the present point \((x, y)\), \( K \) is the threshold; \( \sigma_r \) is the scale for the difference of the brightness.

We can observe from the experiments that the illumination part can be estimated totally if using the SSR Algorithm to estimate the image illumination, but the image will appear to be unnatural, therefore, we add a weight value in the process of eliminating the illumination estimation, the form is as follows:

\[
g(x, y) = \log(f(x, y)) - \alpha \log(\hat{l}(x, y)) \tag{12}
\]

where \( g(x, y) \) is the output result, \( f(x, y) \) is the original image, \( \hat{l}(x, y) \) is the illumination estimation image.
The results of the original face image after bilateral filterer shown in Figure 5. We can see from Figure 5 that after the filtering the face image looks more natural and harmony and the filtering plays a very good smoothing effect.

Process of Face Recognition Based On the Improved Retinex Algorithm

1. Transfer the original color image to the HSV space, and do the global nonlinear enhancement to the face image, then locally enhanced image contrast rate.
2. Adopt the Bilateral filter instead of Gaussian Function used in the classic Retinex algorithm to estimate the filtering, and eliminate the "Halo".
3. According to step (2), estimate the illumination component, then adopt the Retinex algorithm to eliminate the adverse effects of illumination on the image.
4. Adopt the support vector machine to build relevant face recognition classifier and do the face recognition to get the face recognition results.

III. EXPERIMENTAL RESULTS

A. Comparison of the Quality of Face Images

In order to test the effectiveness of the algorithm proposed in this thesis in face image, we adopt the images in the Yale B face database to do the simulation, and randomly select 5 groups of images for testing. Some Yale B face images are shown as figure 6.

Figure 6. Some images of Yale B face data

In order to make the algorithm proposed in this thesis more convincing, we adopt the histogram equalization algorithm and SSR algorithm to do the comparative experiments and take the image information entropy, brightness and contrast ratio to be the objective evaluation standard.

a. The information entropy is used to measure the richness of the image information. The calculation formula is as follows:

\[ E = - \sum_{x=1}^{m} \sum_{y=1}^{n} p(x, y) \log p(x, y) \]  \hspace{1cm} (13)

In which, \( p(x, y) \) represents the grayscale proportion of pixel \((x, y)\), \( m \) and \( n \) represent the wide and height of the image respectively.

b. The specific calculation formula of the brightness is as follows:

\[ \text{Def} = \sum_{x=0}^{m-1} \sum_{y=0}^{n-1} g(x, y) \]  \hspace{1cm} (14)

In which, \( g(x, y) \) represents the gradient value of the pixel \((x, y)\).

c. The formula of the contrast rate is as follows:

\[
con = \frac{1}{mn} \sum_{x=0}^{m-1} \sum_{y=0}^{n-1} I(x, y) - \frac{1}{mn} \sum_{x=0}^{m-1} \sum_{y=0}^{n-1} I(x, y)
\]  \hspace{1cm} (15)

Since the image enhancement algorithm using the HSV space, therefore the evaluation indicator is calculated by using the luminance image of the HSV space. Figure 7 to 9 represent the entropy of the information, brightness, and contrast results before and after enhancement of the 5 groups of image.

According the contrast of the image information entropy after various enhancement algorithms in Figure 7, in all the 5 groups of images, the information entropy enhanced by the histogram equalization algorithm is lower than the information entropy of the original image, the information entropy enhanced by the classic algorithm is basically the same as the one in the original image and the information entropies enhanced by the algorithm proposed in this thesis are high than the ones in the original images.

![Figure 7. The comparison results of the image entropy](image)

According the contrast of the image brightness after various enhancement algorithms in Figure 8, in all the 5 groups of images, the image brightness enhanced by the histogram equalization algorithm is equal to the brightness of the original image, but the histogram equalization algorithm adopts a unified treatment without considering the characteristics of different images. To the classic SSR algorithm, the image brightness enhanced by the algorithm proposed in this thesis has been greatly improved.

![Figure 8. The comparison results of the images luminance](image)

We can see from the contrast of the contrast ratios after various enhancement algorithms in Figure 9 that the contrast ratio of the image processed by the classic SSR algorithm has declined compared to the original image, while the algorithm proposed in this thesis and the histogram equalization algorithm both effectively improve the contrast ratio of the image.
In this paper, we adopt the histogram equalization algorithm, the SSR algorithm and the algorithm proposed in this thesis to preprocess the face image illumination. The face classifier, and measure the performance of the various illumination processing algorithms by using the face recognition rate, in which the experimental image data is also from the Yale B face database. As we focus mainly on the illumination changes, so we select only the face images which have the illumination changes on the positive side in the image database. According to the illumination source direction and the angle between the axes of the camera, we divide the face image into five sub-sets. The experiment result is shown as figure 10.

To sum up, among the three image quality evaluation indicators, the results of the algorithm proposed in this thesis is superior than the comparative algorithms, which means that the classic Retinex algorithm improved in this thesis can effectively preprocess the illumination to the face image to prevent the illumination “Halo” phenomenon, and significantly improve the image quality of the face region.

B. Time Consumption Comparison for Algorithms

In the platform of CPU 2.8 GHz, Memory 2 GB and the operating system is Windows XP, using VC + + programming to realize various algorithms to get the average time consumption information of the three kinds of image enhancement algorithms. The results are as shown in Table 1 below.

<table>
<thead>
<tr>
<th>Algothm</th>
<th>The time consumption</th>
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<tbody>
<tr>
<td>Histogram Equalization</td>
<td>28.64</td>
<td></td>
</tr>
<tr>
<td>SSR Algorithm</td>
<td>36.78</td>
<td></td>
</tr>
<tr>
<td>Algorithm proposed in this thesis</td>
<td>17.46</td>
<td></td>
</tr>
</tbody>
</table>

We can see from Table 1 that in all the image processing algorithms, for face recognition, the histogram equalization algorithm consumes time of 28.64, illumination lower than the SSR algorithm; while the SSR algorithm has the longest time-consuming, reaching 36.78. So it is easy to see that if use the SSR algorithm for face recognition, the time-consuming is the worst; the algorithm proposed in this thesis has the advantages of the fastest processing speed, the minimum time-consuming of 17.46 which is significantly better than the histogram equalization algorithm and the "SSR algorithm" and meets real-time and online requirements for face recognition.

C. Comparison for the Face Recognition

In order to detect the influence of the face image after illumination pretreatment on the subsequent face recognition effect, we adopt the histogram equalization algorithm, the SSR algorithm and the algorithm proposed in this thesis to preprocess the face image illumination firstly, then use the support vector machine to establish the face classifier, and measure the performance of the various illumination processing algorithms by using the face recognition rate, in which the experimental image data is also from the Yale B face database. As we focus

We can see from the results of the experimental contrast in Figure 10, different preparation methods have great influence on the face recognition rate. For all the five sub-set, the recognition rate without using the pre-processing algorithm and the histogram equalization algorithm is low, which indicates that the traditional preprocessing algorithm can not be a good way to eliminate the adverse effects of the illumination on the face recognition. The SSR algorithm can only get a high rate of face recognition in the subset 1 and 2, in which the recognition rate can reach 80%-98%, while the face recognition rates of the remaining subsets are very low. This is because the face images in the subset 1 and 2 are affected little by illumination, so the recognition results is the best; while SSR algorithm can not effectively eliminate the greater impact of illumination change, therefore the recognition rates of the subsets 3 to 5 are lower, but the algorithm proposed in this thesis can well eliminate the influence of illumination to prevent the phenomenon of the "Halo", and effectively improve face recognition rate.

IV. CONCLUSION

Since the classic Retinex algorithm is based on the gentle illumination change in the scene, so when the illumination change is relatively strong, it will be easy to appear the "Halo" phenomenon, therefore, we proposes a face recognition method under the condition of illumination changes based on the improved the Retinex algorithm. The experimental results show that the improved Retinex algorithm reduces the time complexity and the image enhancement effect is better than the similar algorithms, and it can be a better solution to the "Halo" issue, which results a corresponding increase in face recognition rate and achieves a satisfactory treatment results. The face recognition is a challenging subject in which the illumination, pose and expression are the very difficult problem that the current technology can not fully solve. Therefore, the illumination studied in this thesis still have a lot of work needs further studying, for example the time processing speed of illumination face recognition algorithm, the parameter selection, data and so on, which are also the direction of the future study.
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