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An Improved Homomorphic Filtering Algorithm for Face Image Preprocessing

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Abstract. Homomorphic filtering has a good illumination preprocessing effect on face images under complex illumination conditions such as weak illumination, side illumination and drastic illumination changes. However, too many parameters need to be set artificially in the filtering process, and the pre-processed face features are not clear. In view of the above disadvantages, Firstly, this paper proposes an exponential homomorphic filtering image enhancement algorithm with only one parameter. In order to highlight the face details after illumination pre-processed, this paper improves the traditional canny operator: adding 45° and 135° gradient directions of the edge template, and then using the improved canny operator to extract the edge of the face image after the improved homomorphic filtering, so as to get a more complete face edge image. Finally, this paper weighted fused the edge image and the face image after illumination pre-processed, and a new approach of homomorphic filtering for illumination pre-processed is proposed. Simulation results show that the details of face images pre-processed by this method are clear and the overall contrast is moderate. Compared with the traditional algorithm, the accuracy of face recognition is improved by almost 2% in the extended Yale B face database, which proves that the proposed method is effective.

Keywords: complex illumination, face recognition, exponential homomorphic filtering, canny operator, weighted fused

1 Introduction

In recent years, with the rapid development of computer technology, pattern recognition and other technologies, face recognition has been more and more popular in life. The face recognition technology try to identity human information according to the face features. Now, face recognition under normal lighting conditions has reached a high accuracy, but complex lighting has always affected the collection of face images, so more and more experts have done a lot of innovation in this area recently.

At present, the methods of face image illumination pre-processing can be divided into three categories: face modeling, illumination normalization and illumination invariant feature extraction. Face modeling includes: 3D imaging model [1], subspace method [2], spherical harmonic function method [3] and illumination cone method [4]. This kind of method can effectively reduce the influence of illumination on face image, but there are many problem such as longer time spending, more workload, and the algorithm complexity, illumination normalization includes histogram equalization [5], gamma transformation [6] and so on. This kind of method has the advantage of low complexity, but easily neglected problems of

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detail image, illumination invariant feature extraction includes: 2D Gabor Transform [7], Retinex Theory [8], Quotient Image Method [9], Homomorphic Filtering [10], etc. Compared with the above two methods, the third method can completely retain the illumination invariant features of human faces.

Homomorphic filtering algorithm is simple, which can effectively remove the high-frequency components of the illumination, keep the low-frequency components of face feature. Not only enhance the details in face image, but also the face image is of better visual effects. so it is widely used in the field of face recognition under complex illumination conditions. However, when enhancing face images, there are many traditional homomorphic filtering parameters, and the adjustment of the parameters is very subjective, which increases unnecessary workload and can not get the best preprocessing effect

In recent years, many scholars have improved homomorphic filtering. For example, cheng et al. [11] proposed a method of low illumination image enhancement based on homomorphic filtering and image fusion. In this method, combined multiple images with different exposures, so as to determine the appropriate parameter values for filtering, but the improved algorithm has complex arithmetic and the time of operation takes too long; M. M. Hadhoud et al. [12] proposed enhancement technique of using adaptive filters. In this method, adaptive high-pass (HP) and low-pass (LP) filters are combined in homomorphic. So that get an adaptive enhancement filter. However, the processed images generally have the problem of fuzzy details. Fan et al. [13], in order to recognize human faces under different illumination conditions, proposed an illumination normalization method based on homomorphic filtering, and the key part of the method is Gaussian Difference (DoG) filter. Although this method retains face details, it has bad result of details on side illumination. In 2014, Hossein Shahamat [14] used homomorphic filtering to enhance face images in the spatial domain. He proposed a simple homomorphic filter kernel. The application of this method is to reduced the calculation time in the preprocessing part, and the disadvantage was that generalization ability is poor.

1.1 Goal and Purposes

According to the characteristics that the transfer function profile of homomorphic filtering is similar to the trend of exponential function, this paper proposes a single parameter homomorphic filtering algorithm. Before the improvement, the traditional method have three parameters that need to be set manually, however the improved algorithm has only one parameter, which greatly reduces the complexity of the algorithm, also the improved algorithm can get clear image enhancement effect. In addition, in order to strengthen the edge features of the pre-processed face image, this paper improves the canny edge detection operator, adding 45° gradient directions and 135° gradient directions, then using the improved operator to detect the edge of the pre-processed face image, thus preserving the contour information of the face more completely. Finally, fused the edge image and the pre-processed face image into a final output image.

In this paper, a simulation experiment is test on the extended yale B face database, and the results show that the face image by the improved method has obvious features, fine contrast, high brightness, picture quality is clear, clean-cut. In the final comparison of face recognition experiments, the accuracy rate of face recognition is increased by almost 2% by use the improved method.

The first section is the introduction, the second section is the homomorphic filtering principle, and the third section is the improvement of illumination preprocessing part. This section includes three parts: the first part is the design of single parameter exponential homomorphic filter, the second part introduces canny operator and improves it, the third part is the weighted fusion of edge image and illumination pre-processed image, the fourth section is the simulation experiment, and the fifth section is the conclusion.

2 Principle of Homomorphic Filterin

An image can be divided into incident component and reflection component. In the process of image gathering, noise and image are often combined by multiplication, which is commonly used brightness imaging model [15]. The expression is:

$$f(x, y) = i(x, y) \cdot r(x, y) \tag{1}$$

Where $i(x, y)$ in equation (1) represents the incident component; $r(x, y)$ is the reflection component; $f(x, y)$ represents the generated image.

The incident component determines the dynamic range of the whole image, which belongs to the low-frequency part of the slow change. The reflection component reflects the edge information of the image, represents the details of the image, and belongs to the high-frequency part.

A Equation (1) takes logarithms on both sides, that is:

$$\ln \mathrm{f}(x, y) = i(x, y) + r(x, y). \quad \textbf{(2)}$$

The two-sided fourier transform of the Equation (2) is:

$$F(u, v) = I(u, v) + R(u, v). \quad \textbf{(3)}$$

Equation 3 bilateral multiplication frequency function $H(u, v)$ get:

$$H(u, v)F(u, v) = H(u, v)I(u, v) + H(u, v)R(u, v). \quad \textbf{(4)}$$

In Equation (4), $H(u, v)$ is a homomorphic filter transfer function, which effect on illumination component and reflection component in frequency domain respectively. Equation (4) take inverse fourier transform:

$$h_f(x, y) = h_i(x, y) + h_r(x, y). \quad \textbf{(5)}$$

Take logarithm on both sides of Equation (5) to get:

$$f(x, y) = e^{h_f(x, y)} = e^{h_i(x, y)} e^{h_r(x, y)}. \quad \textbf{(6)}$$

From the above, we can see that the essence of homomorphic filtering is: the image is transformed into logarithmic domain by logarithmic transformation, the multiplicative noise is transformed into additive noise, then transformed into frequency domain by fourier transformation, and the noise is eliminated by linear filtering $H(u, v)$, and finally the homomorphic filtered image is get inverse transformation. The specific flow chart is shown in Fig. 1.

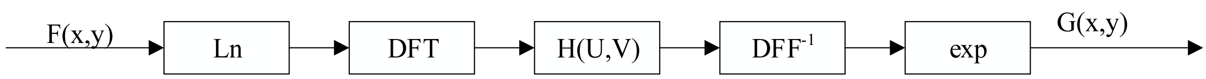


Fig. 1. Flow chart of homomorphic filtering

For images under the complex illumination, the gray values change dramatically, while the contrast of the area of interest in the image is fuzzy, such as the contour of a face appears blurred in the shadow, which will not only lose important features for recognizing a face, but also lose the human face details. The incident component changes slowly in space, corresponding to the low frequency part in the image frequency domain, and the reflected component in the photo changes sharply at the facial feature, corresponding to the high frequency part in the image frequency domain [16]. Therefore, by designing a filter function that has different effects on the high and low frequencies, we can reduce the low frequencies, enhance the high frequencies, compress the dynamic range of the image, and enhance the overall contrast of the image.

Fig. 2 shows the effect after homomorphic filtering (where the parameters selected is $\gamma_H = 5.7$, $\gamma_L = 0.2$, $c = 2$, $D_0 = 10$).

It can be seen from Fig. 2 that the quality of the original face image is poor, and the details are severely lost. After the homomorphic filtering process, the face features can be clearly recognized, the brightness of the image is enhanced, and the effect of maintaining the details is good, the image comparison vivid.

The parameters in homomorphic filtering are γ_H, γ_L, c, and D_0. Among them, the only parameters that play an important role in removing the shadows in the image are γ_H and γ_L, The following Fig. 3 to Fig. 4 are face enhancement effect pictures when the values of γ_H and γ_L are not appropriate.

Before After

Fig. 2. Pictures before and after homomorphic filtering

Fig. 3. below is a picture of inappropriate γ_L value:

Before After

Fig. 3. The values of γ_L are not appropriate

From Fig. 3 the after face image the overall brightness of the is low, because the homomorphic filtering use inappropriate parameter values, and the features of the face are also blurred, which is not helpful to subsequent face feature extraction.

Fig. 4 below is a picture of inappropriate γ_H value:

Before After

Fig. 4. The values of γ_H are not appropriate

Although the overall brightness of the face image value is increased with inappropriate parameter, if observe the processed face image carefully, such as where the face detail feature distribution is dense, there will be some "checkerboard" patterns appear at the boundary of light and dark. These "checkerboard" gray-white pixel will obscure the important recognition features of the face and blur the contour boundaries of the face, leading to distortion of the face image after lighting pre-processing.

Therefore, the value plays a vital role in removing the influence of shadow on the face. Relying on prior knowledge to select the parameters of homomorphic filtering will increase some unnecessary workload, so this article is to reduce the number of homomorphic filtering parameters, and setting the paramete based subjectivity, a single-parameter exponential homomorphic filtering algorithm is proposed.

3 Improved Homomorphic Filtering

3.1 Design of Single-Parameter Exponential Homomorphic Filtering

The shadows of different illumination will occlude the face. Homomorphic filtering can effectively eliminate these shadows when processing the face image, that is, brighten the dark area and darken the overexposed area to make the face features are easier to show. Although the effect of homomorphic filtering on image enhancement is better, there are some obvious disadvantages, such as: (1) There are many parameters that need to be debugged, only relying on prior knowledge for debugging, it is not suitable for processing a large number of pictures, (2) Can not meet the needs of real-time performance under special circumstances. (3) During the manual adjustment of parameters, the set parameters are subjective, not scientific and objective, so that it will cause errors. According to exponential function is similar with homomorphic filter profile, therefore, this article proposed a single-parameter exponential homomorphic filtering algorithm.

The homomorphic filter $H(u, v)$ is designed as a high-pass filter to filter out low-frequency incident components, thereby retaining and high-frequency reflection components [17]. The profile function of the homomorphic filter $H(u, v)$ is shown in Fig. 5:

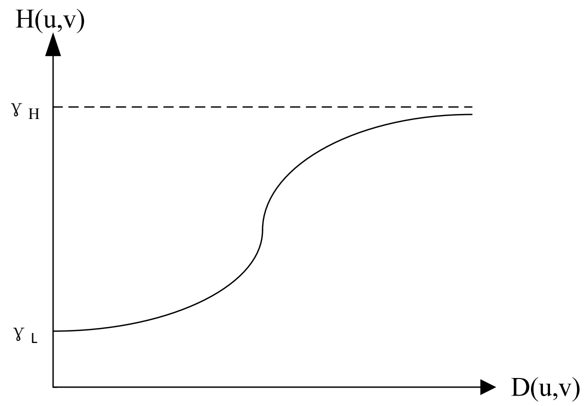


Fig. 5. Sectional view of homomorphic filter

The homomorphic filter $H(u, v)$ usually takes the following form:

$$H(u,v) = (\gamma_H - \gamma_L)\left[1 - e^{\left[\frac{D^2(u,v)}{D_0^2}\right]}\right] + \gamma_L. \tag{7}$$

In general, $\gamma_H > 1$, $\gamma_L < 1$, control the range of the filter, c is a constant, D_0 is the cut-off frequency domain, the choose of cut-off frequency is decide to different filters (the Gaussian transfer function is selected in this article), $D(u, v)$ is the distance from the center of the image. In general, the value of the parameter plays a major role in the preprocessing of the image illumination. In each filtering process, although it is possible to select a more appropriate parameter each time through repeated tests, but this method is subjective, and sometimes the best pre-processing result cannot be get. Through the homomorphic filtering profile of Fig. 5, we can get that $D(u, v)$ is the distance the pixel point of the input image and the pixel center point, the filter curve presents an S-shape, and the exponential function is similar to it the trend. The general exponential function expression is:

$$y = \frac{\alpha}{1 + \beta e^{\gamma x}}. \tag{8}$$

When $\alpha = 1$, $\beta = 1$, $\lambda = 1$, the curve of the exponential function is shown in Fig. 6:

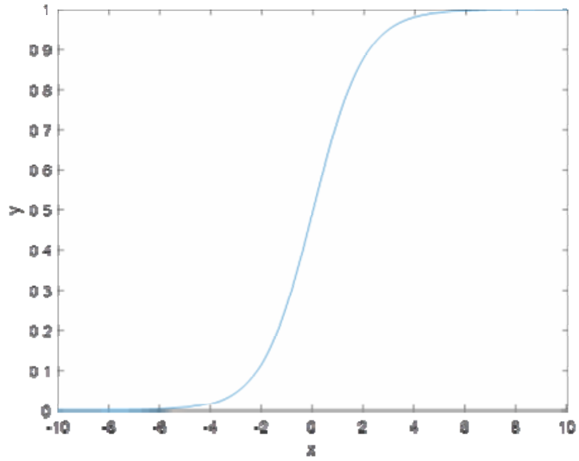


Fig. 6. exponential function

According to Fig. 6, under the above values, the change trend of this exponential function is similar to the curve in Fig. 5. Therefore, this paper proposes a single-parameter exponential homomorphic filter transfer function, as shown in Equation (9):

$$H(u,v) = \frac{1}{1+\exp^{-k\frac{D_0}{D(u,v)}}}. \quad \textbf{(9)}$$

There is only one parameter k in equation (9), where the value range of k is [0.5-1], in this paper, the value of k is 0.5, and $D(u,v)$ is the distance between pixel point (u,v) and the central pixel $D(u,v)$, the $D(u,v)$ is calculated in the same way as before the improvement. The improved homomorphic filtering no longer needs to consider how to take the values of γ_H and γ_L It only needs to transform the parameter k to determine the specific homomorphic filtering function and achieve a satisfactory preprocessing result. In order to illustrate the single-parameter exponential transfer function is reasonable, this paper gives its three-dimensional space coordinate map, as shown in Fig. 7:

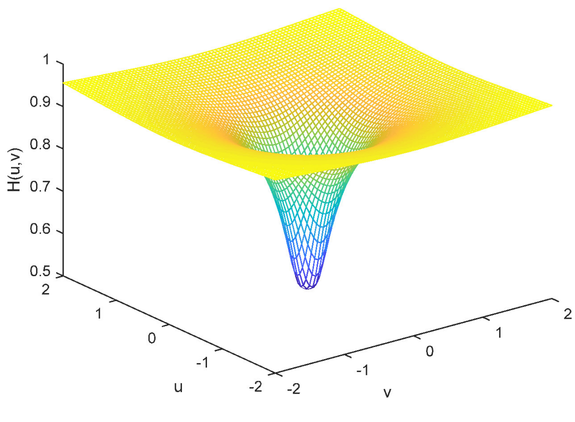


Fig. 7. Three-dimensional diagram of transfer function

It can be seen from Fig. 7 that the change trend of the slope of the outer tangent line of the three-dimensional curve meets to the S-type transfer function of the homomorphic filtering. At the lowest frequency, the improved transfer function retains a low-frequency gain of 0.5, which helps stretch the contrast of the image. In the transition phase from low frequency to intermediate frequency, the slope becomes larger, which can retain part of the intermediate frequency information, while in the transition phase from intermediate frequency to high frequency, the slope changes slowly, which can make the face image filtering uniform and the transition smooth.

Literature [18] also proposed an exponential function as shown in equation (10) to replace the traditional homomorphic filtering.

$$H(u,v) = \frac{1}{1 + D(u,v)^{-t}}. \quad \textbf{(10)}$$

The transfer function also only needs to set one parameter t, and its three-dimensional surface diagram is shown in Fig. 8:

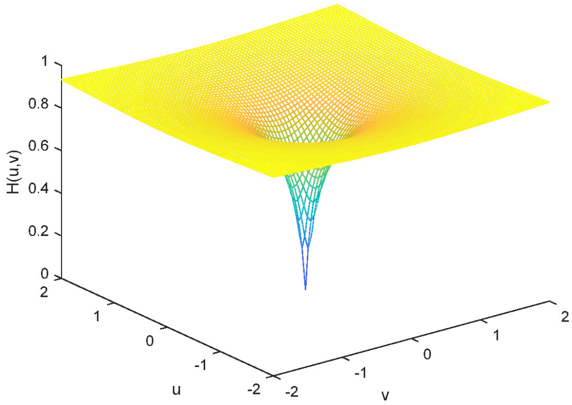


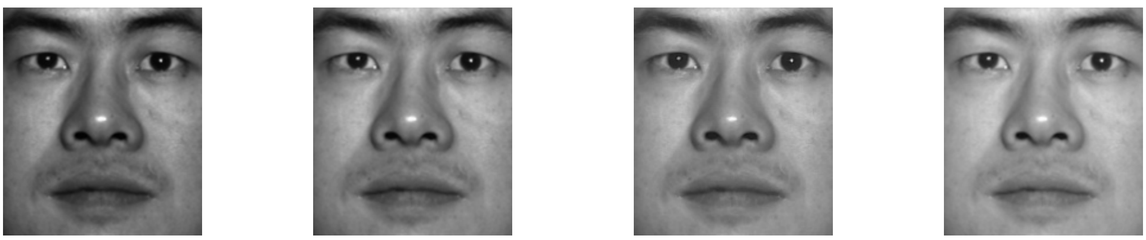
Fig. 8. Three-dimensional diagram of transfer function

It can be seen from the three-dimensional graph of Fig. 8 that this method has a gain of 0 at the lowest frequency, which reduces the low-frequency information and compresses the contrast of the image. The slope of the transition region from mid-frequency to high-frequency in Fig. 8 changes drastically, which will affect the filtering process of the image, resulting in discontinuous transition of the output face image in different brightness regions.

In order to prove the effectiveness of the improved method in this paper, this paper selects face images taken under low light, medium light and high light conditions for verification. The results are shown in Fig. 9 to Fig. 11.

(a) Original image (b) Homomorphic filtering (c) Literature method (d) This paper method

Fig. 9. Comparison of results before and after homomorphic filtering of face images in low light



(a) Original image (b) Homomorphic filtering (c) Literature method (d) This paper method

Fig. 10. Comparison of results before and after homomorphic filtering of face images in medium light

(a) Original image (b) Homomorphic filtering (c) Literature method (d) This paper method

Fig. 11. Comparison of results before and after homomorphic filtering of face images under high light

Fig. 9 is low-light conditions, Fig. 10 is medium-light conditions, Fig. 11 is high-light conditions, Fig. (a) is the original image, Fig. (b) is the result of traditional homomorphic filtering, Fig. (c) is the result of the method in [18], Fig. (d) It is the result of the improved method of this paper.

From the above processed image, it can be seen that under low light conditions, Fig. (b) has improved the uneven light distribution and unclear face contour to a certain extent, but the best face image has not yet been got. The contrast of many shadow areas has not improved, some features of the face are still not clear enough, and the adjustment of the filter parameters only through prior knowledge, so it is difficult to find a most suitable parameter value, resulting in unsatisfactory preprocessing effects. The method proposed in literature [18] improves the contrast of the image better, the shadow area in the face image is reduced, and various features are clearer. The face image pre-processed by the improved method proposed in this paper has good contrast, the dark areas are well eliminated, and various detailed features of the face can be extracted.

Under medium light conditions, because the various features of the face image are very clear, the three methods all slightly enhance the original image, and the effect is valid. But the improved method in this paper enhances more detailed features.

Under high light conditions, due to the light intensity, the facial features are blurred. The traditional homomorphic filtering over-enhanced the original image, concealing most of the facial features. The method in [18] improves the contrast of the image to a certain extent and stretches the dynamic range of the image, but the light and dark transition area of the image is not continuous enough. In terms of contrast, dynamic range and transition area, the paper proposed the method performs better.

If simply judge the preprocessing effect of Fig. 9 to Fig. 11 by human eyes, it cannot draw conclusions objectively. Therefore, calculating the average gray value of the processed image can reflect the processing result to a certain extent. For an 8-bit binary gray value image, the gray value range is [0-255]. If the pre-processed face image, if most of its gray pixel values can be distributed in [64-192], then it proves that the various features of the face are well preserved. Therefore, this article counts the average values of face grayscale all images in Fig. 9 to Fig. 11, and the results are shown in Table 1.

Table 1. Parameters under different lighting conditions and comparison of gray values before and after transformation

	Original image	Homomorphic filtering	Literature [18] method	Method of this paper
Low light	52	76	107	120
Medium light	105	122	133	147
High light	187	100	166	148

It can be seen from Table 1 that under different lighting conditions, although the average gray value of the image after the three methods, it all can be maintained in the range of 64-192, the image obtained after the improve method of this paper, the gray value can be very close to the intermediate gray value of 128, so that the facial features can be displayed to the greatest extent.

From Fig. 9 to Fig. 11 and Table 1 above, it can be seen that the single-parameter exponential function homomorphic filtering reduces the number of adjustable parameters on the one hand, low-complexity of the algorithm and cut down the volume of unnecessary work on the other hand, under different illuminations conditions, the face image pre-processed by this paper has a moderate contrast, a positive compression effect on low-frequency information and a good stretching effect on high-frequency information, the transition area is continuous, and the characteristic of the edge detail is evident. In order to enhance the edge contour of the face, this paper improves the canny operator, uses the improved canny operator to detect the edge of the pre-processed face image, and merge the edge image and the processed face image. Then get the final output result.

3.2 Canny Edge Detection Operator and The Improvement

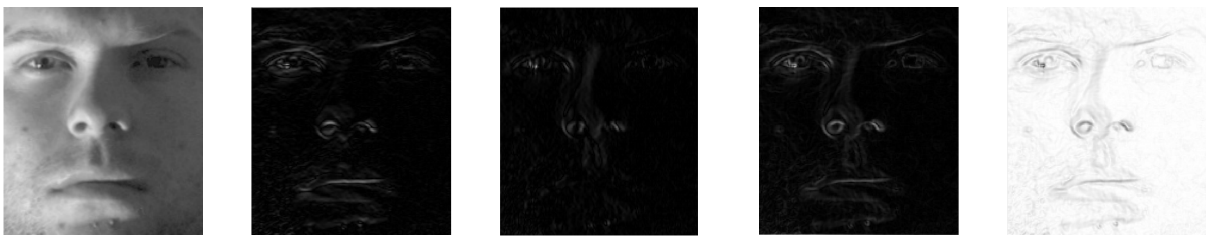
The Canny edge detection operator is a multi-level detection algorithm, proposed by John F. Canny, and three criteria for edge detection are also proposed [19]: (1) The accuracy of detecting the edge of the image is high. There is basically no false edge; (2) The edge point is positioned correctly. Close to the real edge; (3) Single edge point response. This means that where there is only a single edge point, the detector should not find out multiple pixel edges.

The edge detection algorithm of Canny operator has been widely used because of its high detection accuracy [19]. Until this day, Canny algorithm is still an excellent edge detection algorithm. Expect some special circumstances, that Canny is not suitable, it is difficult to find a better edge detection algorithm like Canny operator. Therefore, this paper applies Canny as the algorithm for face edge feature extraction.

The steps of Canny algorithm are roughly estimated divided into five steps [20]:

1. Use a Gaussian filter to smooth the image and filter the noise.
2. Calculate the gradient intensity and direction of each pixel in the image.
3. Apply non-maximum suppression to eliminate false responses.
4. Apply double-threshold detection to determine true and potential edges.
5. By reduce the alone weak edges, edge detection is finally completed.

Use traditional Canny operator to detect pre-processed face image, the results shown in Fig. 12 to Fig. 14.



(a) Pre-processed (b) Vertical edge (c) Horizontal edge (d) mix two directions (e) inversion

Fig. 12. Edge detection of canny operator on preprocessing results under low light

(a) Pre-processed (b) Vertical edge (c) Horizontal edge (d) mix two directions (e) inversion

Fig. 13. Edge detection of canny operator on preprocessing results under medium light

(a) Pre-processed (b) Vertical edge (c) Horizontal edge (d) mix two directions (e) inversion

Fig. 14. Edge detection of canny operator on preprocessing results under high light

It can be seen from Fig. 12 to Fig.14 that although the traditional canny operator can detect part of the edge of the face image, there will still be discontinuous and incomplete edge features of the face, and even "false detection", the reason is that detecting some non-feature areas of the face, it's cause difficulties to face feature extraction, so this article improves the Canny operator from the direction of the newly added edge gradient template.

The four gradient templates are convolved with the image respectively, and the gradient amplitudes G0, G45, G90, and G135 in the four directions are Equation (11):

$$\begin{cases} G_0 = (p_{31} + 2p_{32} + p_{33}) - (p_{11} + 2p_{12} + p_{13}) \\ G_{45} = (p_{32} + 2p_{33} + p_{33}) - (p_{12} + 2p_{11} + p_{21}) \\ G_{90} = (p_{13} + 2p_{23} + p_{33}) - (p_{11} + 2p_{21} + p_{31}) \\ G_{135} = (p_{12} + 2p_{13} + p_{33}) - (p_{21} + 2p_{31} + p_{32}) \end{cases} . \tag{11}$$

The gradient and gradient direction of the target point can be get by Equation (12) and Equation (13):

$$G = \sqrt{G_0^2 + G_{45}^2 + G_{90}^2 + G_{135}^2} . \tag{12}$$

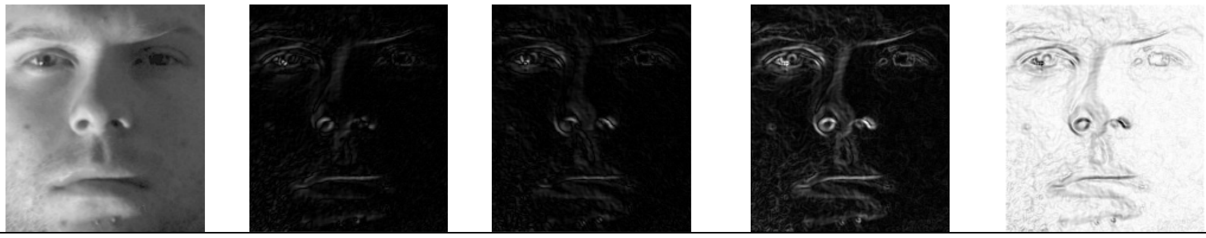
$$\theta = \arctan\left(\frac{G_{90}}{G_0}\right). \tag{13}$$

The traditional edge detection operator can use Equation (14), and Equation (15) is the newly added edge detection operator:

$$0^\circ \text{ gradient } G_0 = \begin{pmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{pmatrix}.\ 90^\circ \text{ gradient } G_{90} = \begin{pmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{pmatrix}. \tag{14}$$

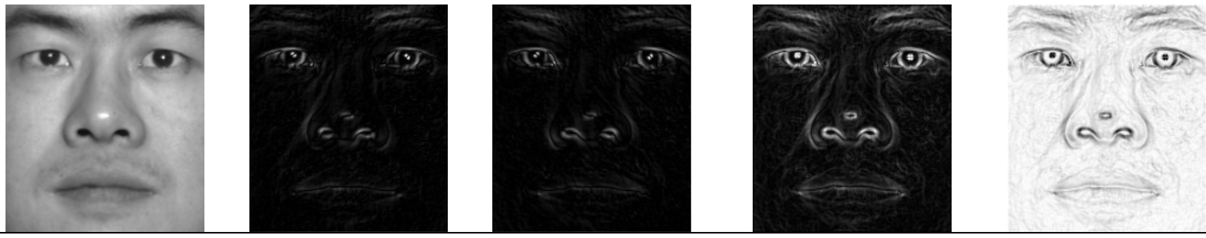
$$45^\circ \text{ gradient } G_{45} = \begin{pmatrix} -2 & -1 & 0 \\ -1 & 0 & 1 \\ 0 & 1 & 2 \end{pmatrix}.\ 135^\circ \text{ gradient } G_{135} = \begin{pmatrix} 0 & 1 & 2 \\ -1 & 0 & 1 \\ -2 & -1 & 0 \end{pmatrix}. \tag{15}$$

The improved canny operator is used to edge detection on the face image after illumination preprocessing, and the results obtained are shown in Fig. 15 to Fig. 17:



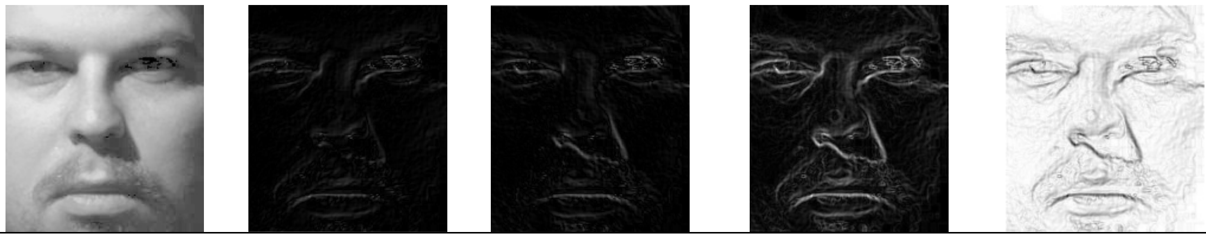
(a) Pre-processed (b) 45° edge (c) 135° edge (d) mix four directions (e) inversion

Fig. 15. The edge detection of the improved canny operator on the preprocessing result under low light



(a) Pre-processed (b) 45° edge (c) 135° edge (d) mix four directions (e) inversion

Fig. 16. The edge detection of the improved canny operator on the preprocessing result under medium light



(a) Pre-processed (b) 45° edge (c) 135° edge (d) mix four directions (e) inversion

Fig. 17. The edge detection of the improved canny operator on the preprocessing result under high light

It can be know from Fig. 15 to Fig. 17 that, compared with before the improvement, due to the addition of two new detection gradient directions, the improved canny operator can detect face edges with more directions, and the features are more distinct. The outline is clearer and brighter, and the edges of important features are more continuous and complete. Next, in order to better highlight the face features, this paper weighted fusion of the edge image and the face image after illumination preprocessing, so that achieve a better image enhancement effect.

3.3 Weighted Fusion of Images

Face images under complex illumination conditions are processed by single-parameter exponential homomorphic filtering, the image is enhanced to a certain extent, the overall contrast is better, the low-frequency part of the image is compressed, and the high-frequency part is stretched. However, some details of the picture are still not clear enough, and the improved canny edge operator can extract the contours of the facial details. Taking this into consideration, this article fuse the image after pre-processing with the edge feature image. The purpose of images fused is achieve of highlighting the details of the face. The specific step is as follows:

Let c be the final output image, and a be the face image pre-processed by single-parameter exponential homomorphic filtering. Use the improved canny operator to detect image a to get image b, equation 16 below shows this process:

$$c = \lambda_1 a + \lambda_2 a. \quad \textbf{(16)}$$

λ_1 is the weight of the image after illumination preprocessing, λ_2 is the weight of the edge image, where $\lambda_1 + \lambda_2 = 1$;

When weighted image fusion, if the edge image b is directly weighted and fused with the pre-processed image a, it will affect the overall gray value of the image a. Because the overall background of the edge image b is black, the outline part it is white, in other words, the gray value of the background area is smaller, and the gray value of the contour area is larger. So in this paper, the pixel value of the image b is reversed, and the edge image -b the background area is white, and the contour area is black, which is the background the gray value of the area is larger, and the gray value of the contour area is smaller. Before weighted fusion, this article first detect the average gray value of image a. If the average gray value is less than 128, the image a and image-b are weighted and fused to get image-c, the reason for this is that make the gray average value of the weighted closer to 128. Otherwise, image a and image b are directly weighted and merged to get image c. When determining the weighting coefficients λ_1 and λ_2, if the value of λ_1 is too high, the contour details are not clear enough. If the value of λ_2 is too large, the image will be distorted and the feature cannot be extracted. After repeated experiments, in order get the best preprocessing effect, the best parameter value is that $\lambda_1 = 0.85, \lambda_2 = 0.15$.

3.4 Summary of This Paper Algorithm

The method steps in this paper are as follows:

(1) Use single parameter exponential homomorphic filtering to pre-process the face image under complex illumination conditions to get image a,

(2) Use the improved canny operator to extract the edge of image a to get image b, and then reverse image b to get image -b,

(3) Determine whether the average gray value of image a is less than 128. If it is, then weighted fusion with image-b to get image-c, otherwise, weighted fusion with image b to get image c,

(4) Make some simple adjustments to image c.

The algorithm flow is shown in Fig. 18:

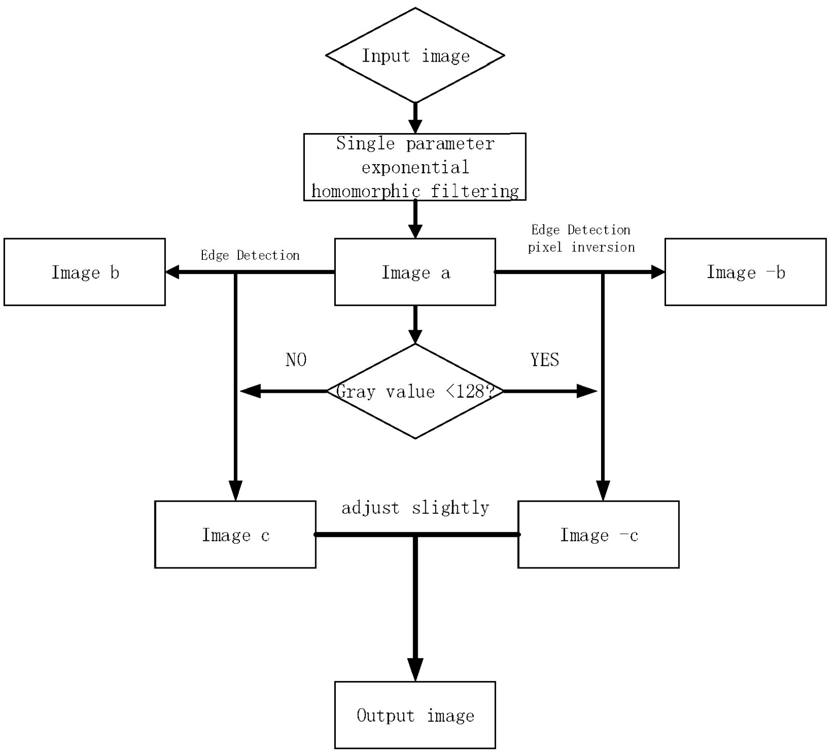


Fig. 18. The algorithm flow chart of this paper

4 Simulation Experiment

The simulation experiment platform is windows10 system, 64-bit, memory 8G, graphics card version is NVDIA GTX 1060, compiler is PyCharm 4.0.1, interpreter is python 3.5.2 version, and the main modules involved are opence-python, and Tensorflow, etc..

This paper selects some samples from the Extended Yale B face database for comparative experiments. The database contains 10 people and a total of 9 poses. Each pose collects facial images under 64 kinds of illumination environments. The total number of samples is 5760, which can be used as a face recognition test database under complex illumination. The selected samples include face images under different illuminations such as side light, forward light, back light, and top light. Some of the experimental results are shown in Fig. 19.

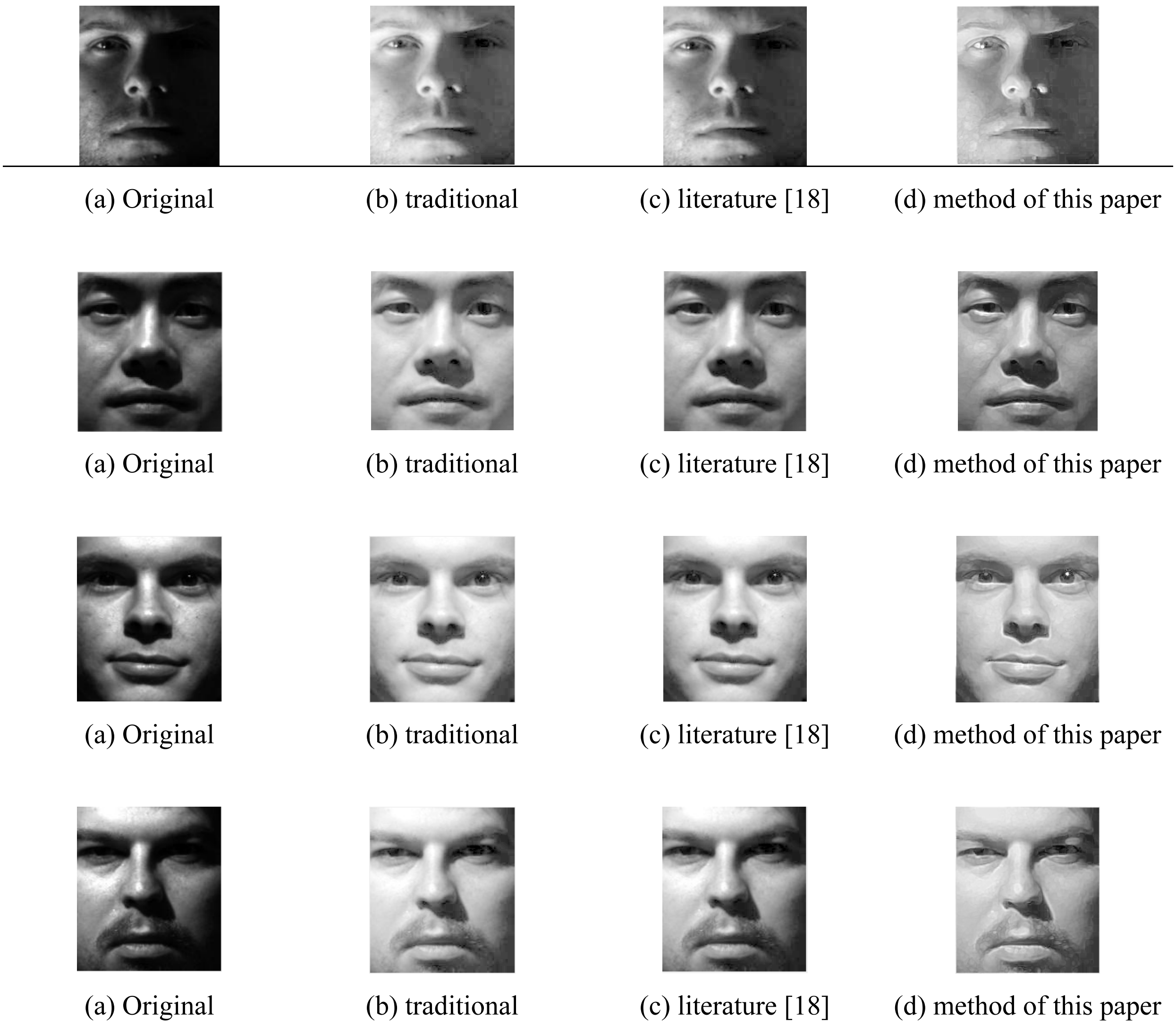


Fig. 19. Simulation results of partial face samples

In Fig. 19, category (a) is a face image under complex illumination conditions, category (b) is a face image processed by traditional homomorphic filtering, and category (c) is the processing result from the literature [18], (d) category is the result of the improved method proposed in this paper. Category b images have a certain enhancement effect, which makes most of the features of the face recognizable. However, due to improper parameter settings, some areas may be over-enhanced and facial features are masked. Category c images have moderate enhancement effects, but some of the face features are still blurry, the transition area is not continuous enough, and the category d image has better contrast and dynamic range, and the boundary is clear, which is beneficial to the subsequent facial feature extraction and recognition.

In order to more objectively evaluate the experimental effects of various algorithms, this paper will use average gradient, information entropy, contrast, gray histogram as evaluation indicators. The average gradient can sensitively reflect the image contrast of details, and the more information include of the image, and the clearer the image; if the information entropy value is large, it's representative the more information the image contains; the contrast clarity assessment method for face images [21]; for gray histogram, if the gray value centralized in 64-128, most of face information can be distinguished by the human eye.

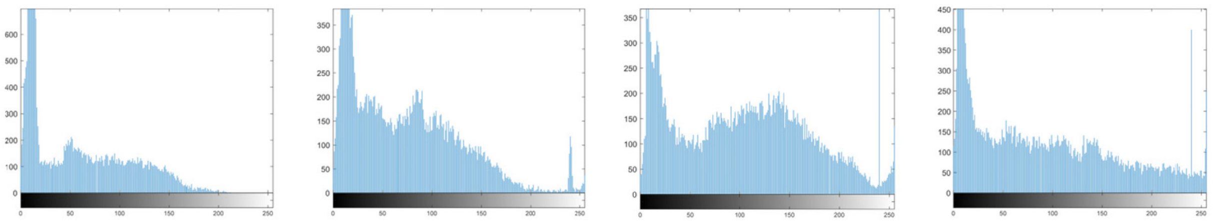
Table 2 is the evaluation index results from the second group of images in Fig. 19, a is the original image, b is traditional homomorphic filtering, c is the method proposed in literature [18], and d is the method proposed in this paper.

Table 2. Evaluation results

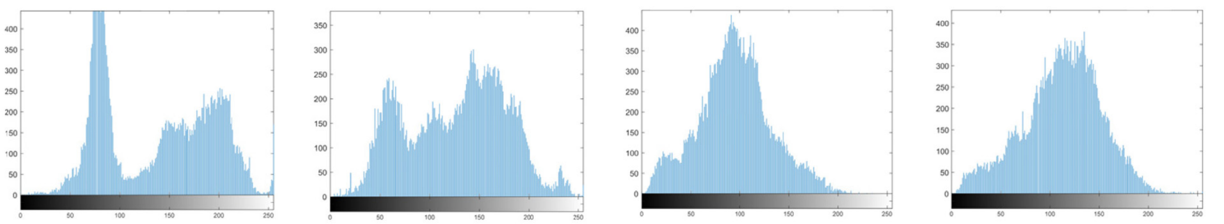
	entropy	gradient	contrast
a	3.3655	1.0257	0.6520
b	3.7216	2.3210	0.6801
c	3.8113	2.6201	0.6834
d	4.4975	3.5219	0.7562

It can be seen from Table 2, entropy, average gradient value and contrast detected from improved algorithm in this paper, the value of it is larger than b、c, which shows that the improved algorithm has the best image enhancement effect. On the other hand, in order to further prove that after the improved method got better result of face image, the most pixel of gray value the face image after preprocessing can be distributed in the range of 64-192, this paper counts the four groups average gray histogram in Fig. 19, including original image and final output image.

It can be seen from Fig. 20 that the gray value of the original image is randomly distributed in the range of 0-255. After the preprocessing of the improved homomorphic filtering method proposed in this paper, the gray value of the face image can mostly be distributed in the range of 64-192, various detailed features of the face image in the gray-scale interval can be extracted to the greatest possible.



(a) Original image (b) Original image (c) Original image (d) Original image



(e) output image (b) output image (g) output image (h) output image

Fig. 20. Input and output image gray histogram

In order to verify that the improved preprocessing method proposed in this paper can improve the accuracy of face recognition, the following four comparative experiments were carried out on the Extended Yale B face database in this paper. Here, this experiment uses Vgg16 to build a network framework for training and classification. And select the same number of samples for everyone.

Plan a: Select face samples in the database, then extract features, finally train and classify.

Plan b: Use traditional homomorphic filtering to perform illumination processing on the samples in the database, then extract features, finally train and classify.

Plan c: Use the improved homomorphic filtering method proposed in literature [18] to process the selected samples in the database, then extract features, finally train and classify.

Plan d: Use the single parameter exponential homomorphic filtering and edge detection image weighted fusion method proposed in this paper to perform illumination processing on the selected samples in the database, then extract the features, finally train and classify.

In addition, this experiment selects 100 samples for each person in the database, and gets a total of 1000 samples as the test set, and compares the recognition accuracy of each plan under different training samples. The results are shown in Table 3 and Fig. 21.

Table 3. Recognition accuracy rate under different schemes

Training samples	500	1000	1500	2000	2500	3000	3500	4000	4500	5000
Plan a	0.393	0.418	0.426	0.449	0.462	0.47	0.491	0.517	0.52	0.523
Plan b	0.557	0.638	0.702	0.743	0.789	0.823	0.856	0.881	0.89	0.892
Plan c	0.506	0.604	0.711	0.752	0.814	0.836	0.875	0.882	0.897	0.901
Plan d	0.539	0.632	0.688	0.7	0.768	0.813	0.852	0.89	0.907	0.913

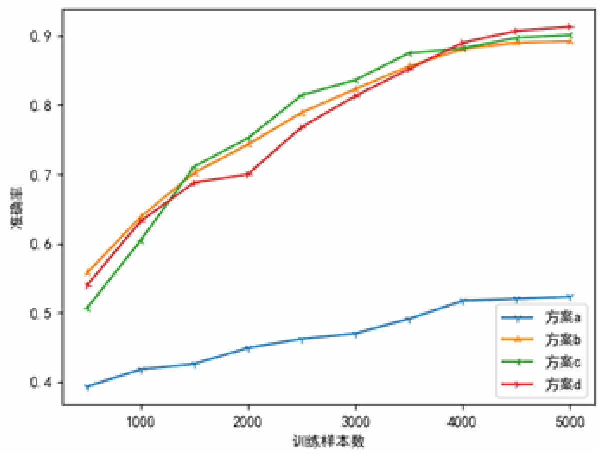


Fig. 21. Comparison curve of recognition accuracy under different plans

Table 3 and Fig. 21 show the accuracy of face recognition got by using different preprocessing methods when the number of training samples is different. It can be seen from Fig. 21 that the recognition rate of the face image after the illumination preprocessing in this paper is higher than the image recognition accuracy of the other three methods. From this, it can be concluded that the illumination preprocessing can improve the accuracy of face recognition. At the same time, the method in this paper shows high stability under different illumination angles, and both reach a high recognition rate, it can retain more facial details when preprocessing the image. It can effectively suppress the impact of light on face recognition and improve the rate of face recognition.

5 Conclusion

The improved homomorphic filtering proposed in this paper solves the problem of traditional homomorphic filtering with many parameters and difficulty in finding appropriate values. The edge image is introduced into the improved homomorphic filtering, so that the contrast of the output image is improved The value can be distributed in the normal brightness range, the transition area of the face is continuous, and various face features are clear, which facilitates the extraction of face features, so as to achieve a higher accuracy of face recognition.

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