

Image Enhancement Algorithm for Low Illumination LCD Screen

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Abstract

The image with LCD screen taken by camera is easy to be affected by the illumination or the display problem of the screen itself. The image quality is low and it is difficult to distinguish the information in the screen. When using the traditional Retinex algorithm for image enhancement, there will be halo phenomenon due to uneven illumination. In order to solve this problem, this paper proposes to use homomorphic filtering to correct the illumination, and then use Retinex algorithm to enhance the image after the illumination correction, which can avoid the halo phenomenon. The experimental results show that this method can effectively improve the visual effect of low illumination LCD screen image, which is better than the traditional retinex algorithm.

Keywords

LCD Screen; Retinex Algorithm; Homomorphic Filtering; Image Enhancement.

1. Introduction

The existing natural scene text recognition system has better recognition effect for high-quality images with higher imaging quality and better visual effect. However, when some information to be recognized exists in the LCD screen, it is necessary to take pictures of the screen and identify the scene, because the screen will produce strong reflection phenomenon, especially in the case of low illumination, The visual effect of the image is poor, the image contrast is low, the recognition of the text area is low, and it is difficult to distinguish from the background area. Therefore, it is necessary to enhance the low illumination screen image. The common methods of image enhancement are global histogram equalization, wavelet transform, curvelet transform and Retinex algorithm. Among them, Retinex theory [2-5] is a commonly used image enhancement method based on spatial domain, which has many advantages, such as improving image contrast, improving image color constancy, enhancing image details and so on. Since the 1970s, single scale Retinex [6-7] (single scale Retinex, SSR) algorithm has been gradually formed Multi scale Retinex [8] (multi-scale Retinex, MSR) algorithm, multi-scale Retinex with color restoration (msrcr) algorithm, which can take into account both color fidelity and image details, but these methods generally have the disadvantage of halo artifacts at the edge of the image pixel changes dramatically, and all of them are accompanied by color distortion. Therefore, a large number of Retinex improved algorithms continue to appear. Retinex algorithm based on variational framework [10] improves the problem of artifact and color distortion existing in the original variational method, but the time cost of this method is large, and the threshold needs to be determined artificially, so it can not be adaptive. Meylan et al. Proposed the method of adaptive filtering [11] to estimate the illumination, which has a good effect on the elimination of the halo, but the algorithm needs to calculate point by point, and the time complexity of the algorithm is high.

In this paper, Retinex algorithm is combined with homomorphic filtering, and homomorphic filtering is used to correct the illumination of the original image, so that the illumination tends to be smooth, so as to ensure that Retinex algorithm can effectively enhance the image and eliminate the halo phenomenon at the same time.

2. Retinex theory

Retinex is an image enhancement algorithm based on theoretical constancy proposed by Edwin. H. Land in 1963. Retinex is a word composed of two words. They are retina and cortex, namely retina and cortex. In essence, Retinex is an image enhancement algorithm that simulates the human brain visual processing system.

The basic principle of Retinex algorithm is that an image can be decomposed into two different images, reflection image $r(x, y)$ and brightness image $L(x, y)$. The incident light enters the human eye through the reflected light, which is the image seen by human beings. The final image can be expressed as:

$$S(x, y) = R(x, y) \cdot L(x, y) \quad (1)$$

Through a variety of ways to estimate the brightness image, and finally remove the brightness image to get the enhanced image.

Over the years, researchers have developed Retinex algorithm by imitating the human visual system, from single scale Retinex algorithm to multi-scale weighted average Retinex algorithm, and then to multi-scale Retinex algorithm for color restoration.

2.1. Single scale Retinex algorithm.

The single scale Retinex (SSR) method was proposed by Jobson

According to the formula (1), it is concluded that:

$$r(x, y) = \log R(x, y) = \frac{\log S(x, y)}{\log R(x, y)} \quad (2)$$

$$r(x, y) = \log S(x, y) - \log[F(x, y) * S(x, y)] \quad (3)$$

Where $R(x, y)$ is the output image, $s(x, y)$ is the original image, and $f(x, y)$ is the center surround image

$$F(x, y) = \lambda e^{\frac{-(x^2+y^2)}{c^2}} \quad (4)$$

C is the Gaussian scale, λ is a scale whose value satisfies the following conditions:

$$\iint F(x, y) dx dy = 1 \quad (5)$$

The smaller the setting is, the smaller the radius of the Gaussian template is, and the greater the influence of the surrounding pixels on a specific pixel is, the more obvious the contrast of the enhanced image is, but at the same time, the color distortion of the image is also increasing. In practical applications, it is difficult to find a balance point to make the enhanced image meet the requirements of contrast and color fidelity at the same time. Based on this problem, Jobson and others proposed a multi-scale Retinex algorithm.

2.2. Multi scale Retinex algorithm.

Multiscale Retinex (MSR) is an improved algorithm based on SSR. It is the result of weighted average of SSR on different scales according to the requirements.

The principle of MSR algorithm is as follows:

$$R_{MSR}(x, y) = \sum_k^K W_k \{ \log S(x, y) - \log[F_k(x, y) * S(x, y)] \} \quad (6)$$

Where k is the number of Gaussian surround functions and W is the weight of the k th scale. When $k = 1$, it degenerates into SSR. Generally, in order to ensure that the algorithm has the advantages of high, medium and low scales at the same time, the value of K is usually 3, and $W_1 = W_2 = W_3 = 1/3$.

Compared with SSR algorithm, MSR has a better effect in dealing with the balance of color fidelity and contrast, but there is still color distortion, which is mainly because the ratio of R, G, B channel components of the image processed by the algorithm has changed. Therefore, Jobson and others proposed a multi-scale Retinex algorithm for color restoration.

2.3. Multi scale Retinex algorithm for color restoration.

The multi-scale Retinex with color restoration (msrcr) algorithm is based on the MSR algorithm, adding color adjustment factor to restore the component ratio of R, G and B channels of the enhanced image to the original image ratio, so as to achieve the effect of color fidelity

$$R_{MSRCR}(x, y) = \alpha(x, y) \cdot R_{MSR}(x, y) \quad (7)$$

Among them, $\alpha(x, y)$ is the color adjustment factor, which is expressed as follows:

$$\alpha(x, y) = \log \left(\beta \frac{I(x, y)}{\sum_{n=1}^N I(x, y)} \right) \quad (8)$$

Where $I(x, y)$ represents the original image, β Represents the adjustment parameters, and N represents the number of bands to divide the image into.



a. original image



b. multi scale Retinex enhanced image

Figure 1. Retinex algorithm halo phenomenon

3. Image enhancement algorithm based on Retinex theory and homomorphic filtering

3.1. Halo phenomenon of Retinex algorithm.

Using Retinex algorithm for image visual enhancement can achieve good results, but due to the limitation of the principle of this algorithm, they all assume that the light is low frequency, that is, the light changes slowly, but the actual situation is not so. At the edge where the brightness varies greatly, the illumination changes are not smooth. At this time, the halo phenomenon will appear in the area with large brightness difference. Halo can also be understood as the place where the light changes violently, which is enhanced as a detail [12]. The deeper explanation of the halo phenomenon is that the spatial filtering gives different weights to the current pixel according to the position of the surrounding pixels when calculating the illumination, and does not fully consider the significance of the pixel brightness itself. This directly leads to the mutual

influence between the high and low value pixels on both sides of the edge when estimating the illumination of the high contrast edge region of the image: the illumination of the high value pixels is affected by the adjacent low value pixels, resulting in the low estimated illumination; The illuminance of low value pixels is affected by adjacent high value pixels, resulting in higher estimated illuminance. This will result in the distortion of illumination estimation in this area, and the so-called "halo artifact" will appear. As shown in Figure 1, figure (a) is a low-quality image with serious uneven illumination, and figure (b) is the result of enhancement by using multi-scale Retinex algorithm. Compared with the original image, the visual effect of the image is enhanced, and some details of the object in the image can be displayed. However, there is an obvious halo phenomenon at the boundary of the text in the image, which is obviously not what we want to see.

3.2. Homomorphic filtering algorithm.

Homomorphic filtering [13] is a method to compress the image brightness range and enhance the image contrast in the frequency domain, which is based on the image imaging model. The basic idea of homomorphic filtering: in order to separate the signals of additive combination, the linear filtering method is often used, while the non additive signal combination often uses the homomorphic filtering technology to transform the nonlinear problem into the linear problem, that is, to do some mathematical operation on the nonlinear (multiplicative or convolutional) mixed signals and transform them into the additive one. Then, the linear filtering method is used to process the image. Finally, the inverse transform operation is performed to restore the processed image. The treatment process is as follows

A graph $f(x, y)$ can be expressed as the product of illumination component $I(x, y)$ and reflection component $R(x, y)$

$$f(x, y) = i(x, y) * r(x, y) \quad (9)$$

Among them, the illuminance component $I(x, y)$ is mainly determined by the illumination conditions, and the frequency spectrum is mainly concentrated in the low frequency region; The reflection component $R(x, y)$ mainly reflects the details of the object in the image, and the spectrum is mainly concentrated in the high frequency region. When processing the uneven illumination image, homomorphic filtering algorithm is used to process the image, suppress the low-frequency components and enhance the high-frequency components, reduce the influence of illumination on the image, compress the brightness range of the image, and enhance the details of the image.

Because this property is multiplicative, $I(x, y)$ and $R(x, y)$ can not be controlled directly by Fourier transform. Therefore, we can take logarithm of $F(x, y)$ first

$$\ln f(x, y) = \ln i(x, y) + \ln r(x, y) \quad (10)$$

The Fourier transform is used to obtain:

$$F(u, v) = I(u, v) + R(u, v) \quad (11)$$

By using homomorphic filter $H(U, V)$, equation (11) is processed

$$F(u, v)H(u, v) = R(u, v)H(u, v) + I(u, v)H(u, v) \quad (12)$$

The inverse Fourier transform is used to return the operation to the spatial domain

$$h_f(x, y) = h_i(x, y) + h_r(x, y) \quad (13)$$

Finally, logarithm is taken on both sides of equation (13), that is, the image after homomorphic filtering is obtained

$$g(x, y) = e^{h_f(x, y)} = e^{h_i(x, y)} e^{h_r(x, y)} \quad (14)$$

Where $g(x, y)$ represents the enhanced image, represents the illumination component of the enhanced image, and represents the reflection component of the enhanced image.

3.3. Homomorphic filtering algorithm.

The main reason for Retinex algorithm to produce halo is that the algorithm assumes that the illumination change of the image is gentle, so when processing the uneven illumination image, the estimation of the illumination will produce deviation, leading to halo phenomenon. Through the characteristics of homomorphic filtering algorithm, the low-frequency part of the image, that is, the illumination component, is filtered to achieve the suppression of the strong illumination part, so as to achieve the requirements of gentle illumination. Homomorphic filtering can enhance the details of the image and relatively ignore the fidelity of the color in the image, while Retinex algorithm can achieve the color recovery of the image well. Therefore, the combination of the two can theoretically achieve the image details enhancement while retaining the original color of the image and avoid the halo phenomenon.

The key to the effect of homomorphic filtering lies in the selection of homomorphic filter transfer function. Different filter transfer functions will have different effects on the low-frequency and high-frequency components of Fourier transform. In general, the illumination level determines the dynamic range of the pixel gray in the image, and the contrast reflects the reflection characteristics of some detail information in the image. After homomorphic filtering, the dynamic range of the pixel gray or the contrast of the image will be enhanced.

The traditional homomorphic filtering algorithm can enhance the image details in the dark area of the image, while retaining the image details in the bright area. Because of the influence of shooting equipment, angle and illumination, the frequency of many details of the image itself is reduced, which can not form obvious contrast with the background information, and at the same time, the contrast is reduced. Therefore, the low frequency component also contains a lot of image details, so it is not easy to select a cut-off frequency [14] to process the whole image. In this paper, high and low cut-off frequencies, expressed as D_H and D_L , are selected to enhance the high frequency part higher than the high cut-off frequency D_H , weaken the low frequency part lower than the low cut-off frequency D_L , and enhance the qualified part at the same time, so that the processed image retains most of the image details and reduces the impact of noise. The improved homomorphic filtering function is expressed as follows:

$$H(U, V) = \frac{\gamma_H}{1 + c \left\{ \frac{D_H}{D(U, V)} \right\}^2} - \frac{\gamma_L}{1 + c \left\{ \frac{D(U, V)}{D_L} \right\}^2} + \gamma_L \quad (15)$$

Among them, γ_H and γ_L represents the increase multiple of high frequency component and the decrease multiple of low frequency component, D_H and D_L represent the cut-off frequency of high frequency and low frequency respectively, $D(U, V)$ represents the distance from the point (U, V) to the filter center, and C is a constant, which is used to control the shape of the filter.

After the homomorphic filtering algorithm is improved, the traditional Retinex algorithm is improved to keep the edge information of the image better. Gauss function is used as its surround function, and the Gauss function in MSR algorithm is replaced by bilateral filter function [15]. Compared with Gaussian filter, bilateral filter has one more Gauss variance, so far away pixels near the edge will not affect the pixel values on the edge, which can better maintain the edge information of the image, It can make the edge of the processed image more smooth and continuous, and solve the halo problem of the image to a certain extent. The bilateral filtering template is expressed as:

$$W(i, j, k, l) = d(i, j, k, l) * r(i, j, k, l) \quad (16)$$

Where $d(I, J, K, l)$ is the distance template coefficient

$$d(i, j, k, l) = \exp\left(-\frac{(i-k)^2 + (j-l)^2}{2\sigma_d^2}\right) \quad (17)$$

$R(I, J, K, l)$ is the range template coefficient

$$r(i, j, k, l) = \exp\left(\frac{\|f(i, j) - f(k, l)\|^2}{2\sigma_f^2}\right) \quad (18)$$

Where, (k, l) is the central coordinate of the template window, (I, J) is the coordinate of other coefficients of the template window, and the function f (x, y) represents the pixel value of the image at the point (x, y).

3.4. Simulation experiment.

This section will use different traditional methods to enhance the screen image, and compare with the subjective visual effect and objective evaluation index with this method, and comprehensively evaluate the usability and superiority of this method.

The image enhancement effect with different methods is shown in Figure 2 below

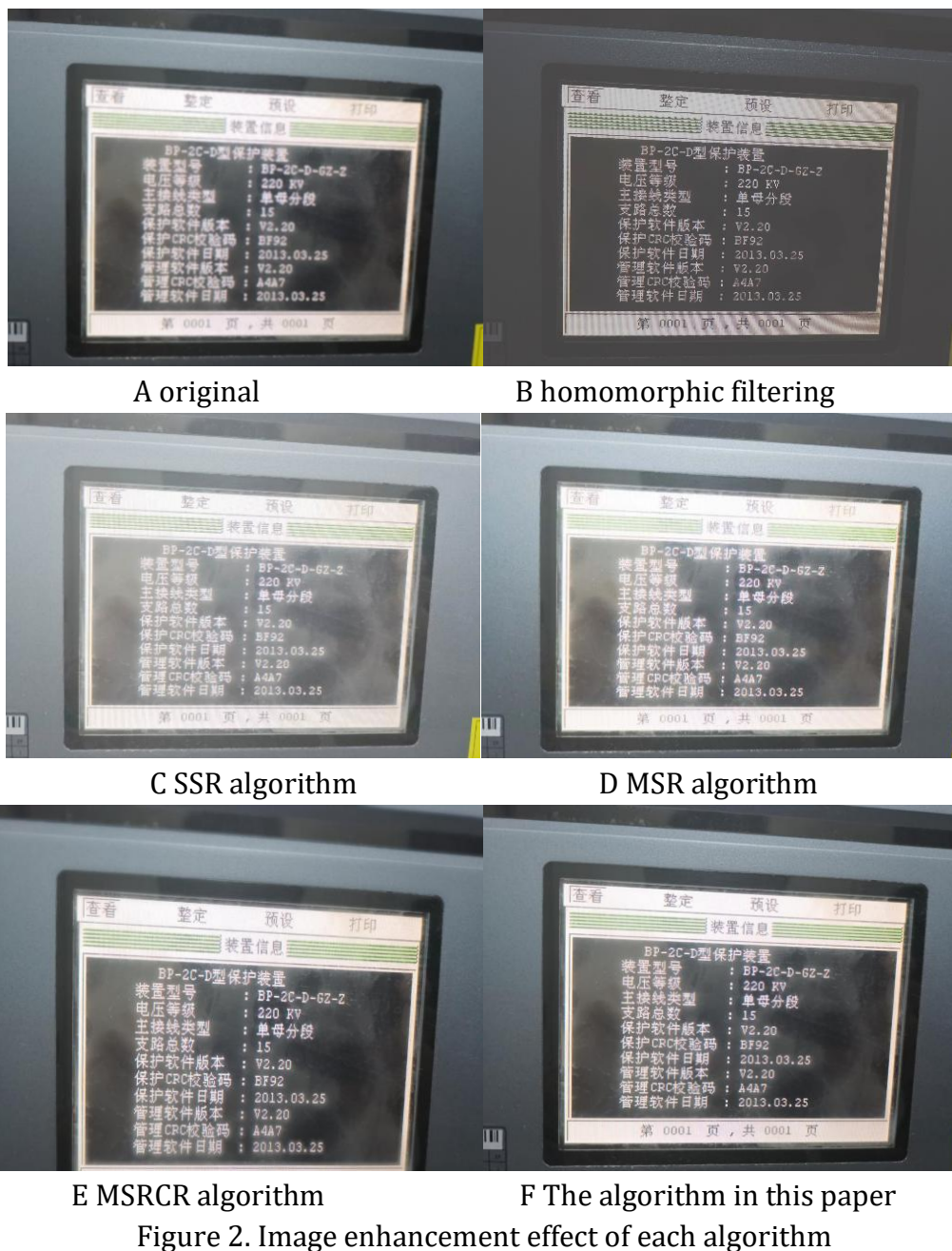


Figure 2. Image enhancement effect of each algorithm

It can be seen from Figure 2 that the original image is affected by the limitations of the shooting equipment and illumination, the font is fuzzy, and the discrimination between the original

image and the background is low, so it is difficult to recognize. After the homomorphic filtering algorithm processing, although the definition is improved, the image brightness loss is serious, and the color distortion. In Fig. 2, C, D and f show that the brightness of the image processed by various Retinex algorithms is improved. However, one common problem is that there is some white light on the edge of the text, that is, the halo phenomenon mentioned above, which leads to the image still blurring. The visual effect of this algorithm is more satisfactory. It can restore the color of the object more realistically, at the same time, retain more image details, make the image clearer and improve the character recognition.

For the objective verification, the objective evaluation indexes selected in this paper are entropy, contrast and brightness, in which entropy can reflect the richness of information in the image, contrast is reflected by the standard deviation of the image, both of which can reflect the details of the screen image, and the enhanced image should be increased. The brightness is reflected by the average gray level of the image. Because the captured screen image often shows insufficient illumination, the brightness of the enhanced image should also be increased. The calculation formula of the three objective evaluation indexes is as follows:

(1) Entropy

$$H[B(x, y)] = -\sum_{i=1}^{256} P_i \cdot \log(P_i) \quad (19)$$

(2) Brightness

$$B = \frac{1}{MN} \sum_{x=1}^M \sum_{y=1}^N S(x, y) \quad (20)$$

(3) Contrast

$$\sigma = \sqrt{\frac{1}{MN} \sum_{i=1}^M \sum_{j=1}^N (S_{i,j} - B)^2} \quad (21)$$

In the above three formulas, s represents the gray image, m and N represent the width and height of the gray image respectively, and P represents the probability of a certain brightness value.

The comprehensive comparison of each index of the image shown in Figure 2 is shown in Table 1.

Table 1. Comprehensive comparison of image enhancement indexes of each method

	Original picture	Homomorphic filtering	SSR	MSR	MSRCR	The algorithm in this paper
Entropy	5.0634	5.8654	5.3249	5.4863	5.8365	6.5739
Brightness	61.3589	40.2365	95.6314	170.6344	169.3564	146.3566
Contrast ratio	14.5546	25.6419	14.3168	14.5234	14.8569	40.5279

It can be seen that compared with the original image, there is no obvious change in the entropy and contrast of the image enhanced by traditional SSR algorithm, MSR algorithm or msr cr algorithm. This is because of the limitation of Retinex algorithm's principle, it is unable to retain more image details and effectively improve the image contrast, However, the brightness of the image changes greatly, which makes the image appear white and halo. However, the entropy and contrast of the image processed by homomorphic filtering algorithm are relatively high, which indicates that the image enhanced by homomorphic filtering has more details, but the brightness drops too much, which will lead to the color distortion of the image. The algorithm in this paper has obvious enhancement in the three indicators, can retain more image details, and the brightness is more moderate, can avoid halo or color distortion phenomenon.

4. Conclusion

Aiming at the problems of low boundary discrimination between characters and background, loss of details, high noise, over exposure and so on, this paper proposes an image enhancement

algorithm based on Retinex theory and homomorphic filtering. The experimental results fully demonstrate the feasibility of the algorithm from two aspects of subjective visual effect and objective indicators, and combine with a variety of algorithms for comparative analysis, the experimental results fully reflect the high visibility and obvious details of this method. It is helpful for character location, character segmentation and text recognition of LCD screen image

References

- [1] Fang Ming, Li HONGNA, Lei Lihong, et al. Overview of low illumination video image enhancement algorithms [j]. Journal of Changchun University of Technology (NATURAL SCIENCE EDITION), 2016,39 (03): 56-64+69.
- [2] Wu Di, Zhu Qingsong. The latest research progress of image defogging [j]. Journal of automation, 2015,41 (02): 221-239.
- [3] Feng Wei, Wu Guiming, zhaodaxing, et al. Multiple image fusion Retinex for weak light image enhancement [j]. Optical precision engineering, 2020,28 (03): 736-744.
- [4] LISANI J L,MOREL J M,PETRO A B,et al. Analyzing center/surround retinex[J]. Information Sciences,2020,512.
- [5] TAOZHANG, WENLI DU, HAOWANG, et al. A Stronger Adaptive Local Dimming Method with Details Preservation. 2020, 10(5).
- [6] Tian Qing, Wang Lei, wangyinchu, et al. Research on vehicle detection algorithm based on Retinex [j]. Industrial control computer, 2019,32 (12): 1-3+6.
- [7] LI Ying. Research on image enhancement algorithm based on Retinex theory [D]. Northwest University, 2014:1-7.
- [8] Feng Ju Qiang, Yang Weihu, Zhang Xing. Adaptive multi-scale Retinex algorithm based on HSV color space [j]. Journal of Xinxiang University, 2020,37 (03): 36-40.
- [9] Zhang Wenjuan. Research on image defogging enhancement algorithm combining Retinex and dark channel [D]. Xi'an University of petroleum, 2019.
- [10] Sima Ziling. Research on image enhancement algorithm based on variational framework [D]. Chongqing University of Posts and telecommunications, 2019.
- [11] Zhang Chuanmin. Research and implementation of low quality image adaptive enhancement algorithm [d]. Beijing Jiaotong University, 2019.
- [12] Bai Jiahong. Research on Retinex image enhancement algorithm based on block fusion [d]. Liaoning University of engineering and technology, 2016.
- [13] Cheng Xin. Research on image enhancement algorithm based on homomorphic filtering [D]. Xi'an University of Posts and telecommunications, 2016.
- [14] Feng Xianghui. An improved homomorphic filtering image enhancement algorithm [j]. Journal of Chongqing University of post and Telecommunications (NATURAL SCIENCE EDITION), 2020,32 (01): 138-145.
- [15] Wang Yifan, Yin Chuanli, Huang Yiming, et al. Image defogging based on bilateral filtering [j]. Journal of Chinese image graphics, 2014,19 (03): 386-392.