Image Processing Based on Histogram Equalization Optimization

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Abstract: Histogram equalization is a method to enhance image contrast by stretching the range of pixel intensity distribution. Using the traditional histogram equalization method, the image texture will appear fuzzy or even unclear, especially for the image with strong light or dark light, the effect is not ideal. This paper introduces a method to optimize the traditional histogram equalization, and compares the optimization effect through experiments. Then, the image under special environment is collected, and the optimization method is verified by experiments. From the analysis of experimental results, the optimization method in this paper is more suitable for stereo matching of images, and it is also beneficial to the later research.

1. Introduction

Image is an important means for us to obtain information. About 80% information around us is obtained by visual perception [1]. As an important branch of computer vision, image processing technology can improve the clarity and contrast of images, and is widely used in many fields such as aviation.

As a promising subject, image enhancement technology has been paid more and more attention by many countries, and has made great achievements in many fields, such as aerospace technology, biomedical technology, industry, literature and art, etc [2]. There are two image contrast enhancement methods, namely: direct contrast enhancement method and indirect contrast enhancement method. Histogram stretching and histogram equalization are common indirect contrast enhancement methods. Histogram equalization is to use the cumulative function to adjust the gray value to achieve contrast enhancement. In recent years, a lot of literatures have paid great attention to the research and improvement of histogram equalization [3, 4].

This paper focuses on histogram equalization and its optimization, and makes a comparative analysis through experiments.

2. Histogram and Processing

Histogram is a graphic expression of the intensity distribution of pixels in an image. It counts the number of pixels in each intensity value. Histogram displays image data in the form of a distribution curve with dark left and bright right, instead of displaying the original image data [5]. the basis of spatial domain processing technology, histogram can enhance the image. The histogram of the image is a reflection of the relationship between the frequency of the gray level pixels and the gray level in an image.

Suppose the gray level of an image is [0, L-1], then the histogram of the image is a discrete function, as shown in formula (1).

$$h(r_k) = n_k \tag{1}$$

Where r_k is the k-level gray value, n_k is the number of pixels with gray level r_k in the image:

we use the total number of image pixels divided by each component of the image to normalize the histogram. Assuming that P is the dimension of row of the image and Q is the dimension of the column, then normalize it as shown in formula (2).

$$p(r_k) = n_k/PQ \tag{2}$$

Where k = 0,1,…,L-1. $p(r_k)$ is an estimate of the probability of occurrence of the gray level r_k in the image. The sum of all components of normalized histogram is 1.

3. Histogram Equalization and its Improvement

3.1. Histogram Equalization

The central idea of histogram equalization is to stretch the histogram of gray image nonlinearly and redistribute the value of image pixels, so that the more concentrated part of gray histogram can be transformed into a more uniform distribution in the whole gray range. In this way, the dynamic range of pixel gray value is increased, so as to enhance the overall contrast of the image [6]. The essence of histogram equalization is to turn the histogram into a histogram with "uniform" distribution.

The variable R is used to represent the gray level of the image to be processed, and the value range of R is [0, L-1], and R = 0 is black, and R = L-1 is white, then the gray mapping function is shown in formula (3).

$$s = T(r)，0 \le r \le L\text{-}1 \tag{3}$$

For each gray level r value of the input image, an output gray value s is generated. The condition that the gray mapping function T (r) satisfies is that T (r) is a monotone increasing function in the interval 0 ≤ R ≤ L-1, and when 0 ≤ r ≤ L-1, 0 ≤ T (r) ≤ L-1. T (r) is a strictly monotone increasing function on the interval 0 ≤ r ≤ L-1, so as to ensure that the reflection projection is also single valued, that is, the mapping in both directions is one to one; when 0 ≤ r ≤ L-1, 0 ≤ T (r) ≤ L-1. T (r) is a strictly monotone increasing function in order to ensure that the range of output gray level is the same as that of input gray level.

3.2. Improvement of Histogram Equalization

The main steps include:

1) An image with a pixel range of [0-255] is used

2) Process the image histogram

3) A mapping function curve is obtained by adding and summing the values of each pixel in histogram, and the curve is normalized

4) A pixel block of the image is processed, and the central pixel of the block is mapped through the mapping curve

5) Traverse the whole image so that each pixel is mapped

4. Experiment and Analysis of Percentage of Mismatched Pixels

4.1. Introduction of Error Percentage Calculation

In this paper, opencv + C + + is used to realize image equalization and image optimization. The experimental disparity map is analyzed and compared with the standard disparity map in Middlebury image library, and then the calculation accuracy of each algorithm is analyzed and determined. The common criteria are the running time of the algorithm and the percentage of mismatched pixels [7, 8].

The formula for calculating the percentage of mismatched pixels is shown in formula (4).

$$B = \frac{1}{N}\sum_{(x,\ y)}(|d_c(x,y) - d_T(x,y)|) > \varphi \tag{4}$$

Where N is the number of pixels in the whole image, φ is disparity tolerance. The error percentage reflects the proportion of the number of pixels whose error between the disparity value calculated by the algorithm and the disparity value in the standard parallax map is greater than a certain threshold value in the pixels of the whole image. The threshold should not be too large, otherwise the data obtained will lack credibility [9].

4.2. Error Percentage Before and after Image Processing

Through the optimization of the image processing, the comparison of the test time difference diagram is obtained, and the processing result of the image error percentage is obtained, as shown in Table 1.

Table 1. Image error percentage

image	error percentage %
Original image	21.055
optimized image	17.284

Through experimental analysis, the error percentage after image optimization processing is significantly lower than the original error percentage, but the image optimization time complexity is high, and the running time is relatively long.

5. Verification of Optimization Scheme under Different Illumination Conditions

This section mainly aims at processing and optimizing the image in the case of dark and strong light, so as to judge the experimental effect under different lighting conditions before and after optimization.

5.1. Comparison of Optimization Results in Dark Light

As shown in Figure 6.1, figure a shows the original image and its histogram, figure B shows histogram equalization and its histogram, figure C shows histogram equalization optimization and its histogram, figure D shows partial screenshots of equalization results, and figure e shows partial screenshots of equalization optimization results.

Figure a Original image and its histogram

Figure b Histogram equalization and its histogram

Figure c Histogram equalization optimization and its histogram

Figure d Partial screenshot of equalization results

Figure e Partial screenshots of balanced optimization results

Figure 1. Comparison of processing results in dark light

5.2. Comparison of Optimization Results under Light Conditions

As shown in Figure 6.2, figure a is the original image, figure B is the histogram equalization image, figure C is the histogram equalization optimization image, figure D is the local effect display of image B, and figure e is the local effect display of image C

Figure a original image

Figure b histogram equalization image

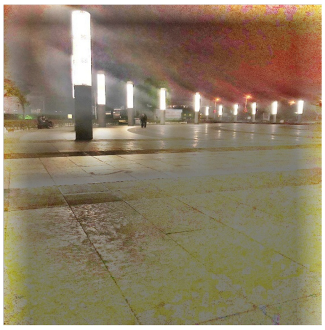

Figure c histogram equalization optimization image

Figure d the local effect display of image B

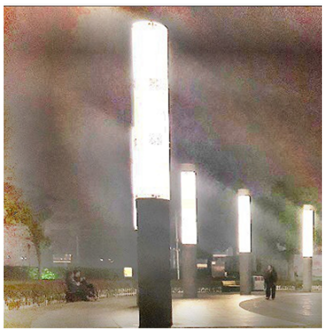

Figure e the local effect display of image C

Figure 2. Comparison of processing results in strong light

From the above results, in the case of dark light, after histogram equalization, some parts of the image texture is not clear or even blurred, but the optimized image texture is clear and visible. In the case of strong light, the object photo is seriously distorted. After equalization optimization, the basic feature information of the original image is maintained, so the image distortion is reduced when the image is balanced and backlight, and the texture is clearer.

6. Conclusion

From the above experimental results, we can know that the histogram effect of image equalization is more uniform than that after optimization, but some texture after image equalization is obviously fuzzy or even invisible. In contrast, the optimized image has the enhancement effect, although the equalization is not obvious, but the visual effect is acceptable. The most important thing is that the optimized image can maintain the original image texture clarity, which is beneficial for image matching. The clearer the texture is, the better the matching effect will be, and the 3D information of the object will be more accurate.

In the follow-up research, this method will be used in the 3D reconstruction of the object to realize the 3D reconstruction of the object [10]. Image optimization has an important impact in many fields. For example, high-quality image optimization is beneficial to the accurate positioning of UAV; clear image is more conducive to the accurate positioning and navigation of robot.

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