Image Enhancement Based on Histogram Equalization

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Abstract: Image enhancement is an important technology in the process of image processing. It can improve the image effect, enhance the overall brightness and clarity of the image. Histogram equalization is a very effective image enhancement technology. On the basis of probability theory, it uses gray point calculation to transform histogram. This paper mainly studies the basic theory of histogram equalization for image processing. At the same time, the image is experimentally analyzed by matlab. The results show that histogram equalization can improve the image effect and enhance the contrast of the image.

1. Introduction

Image is an important way for people to obtain external information. With the development of technology, a variety of cameras have come on the scene. The resolution and exposure time of cameras have been improved greatly. However, in different working environments, the images acquired by cameras always have various problems, which can not meet people's requirements very well. Therefore, we need to process, analyze and transform the acquired image [1]. General image processing technologies include image compression, image enhancement, image reconstruction and so on. Image enhancement is a very important application in image processing technology. It can improve the visual effect of the image, enhance the contrast and brightness of the image, highlight some information in the image, and meet the requirements of analysis.

Airspace method and frequency domain method are two commonly used methods for improving image quality. Airspace method mainly deals with the pixel value of a point in the image directly to achieve the effect; Frequency domain method mainly uses Fourier transform to transform the image into frequency domain, and then uses inverse transform to get the final result. By comparing and analyzing the two methods, we can find that airspace method is simple and effective, and it is a common processing method. Histogram equalization is a kind of spatial method. It uses the different contrast of image histogram to process, increases the local brightness of the image, and does not affect the contrast of the whole image while increasing the local contrast [2].

2. Spatial domain image enhancement

2.1. grayscale enhancement

Gray level transformation is an important technology of image enhancement in airspace method. It can expand the display width of the image and enhance the contrast of the whole image, and make the
whole image clearer. Gray transformation improves every pixel of the image by point operation, and analyses and adjusts the pixel value of the output point by the gray level of the input pixel. Gray-level transformation does not change the spatial relationship of the image itself, but uses some gray-level transformation method to adjust the pixel of the image[3]. It is an operation of transforming from one pixel to another.

2.1.1. Linear grayscale enhancement

Linear grayscale enhancement is a kind of gray transformation enhancement. It transforms every pixel of an image according to a certain gray transformation relationship. If the camera is under-exposed or over-exposed, the gray level of the whole image will be limited to a very small gray level range. At this time, the collected image will be blurred. It is possible to use a linear function to transform each pixel in the image linearly, which can effectively improve the quality of the image[4]. If the gray scale range before an image transformation is \([a, b]\), and you want the gray scale range after the transformation to be expanded or compressed to \([c, d]\), the gray scale linear transformation function expression is:

\[
h(x, y) = \frac{d-c}{b-a}(f(x, y) - a) + c
\]  

(1)

2.1.2. Piecewise linear gray enhancement

Piecewise linear gray enhancement does not transform all the pixels of the image equally, but expands the gray level of the pixels needed and compresses the unnecessary pixels. If the gray scale range of the input image is 0~M level, the gray scale range of the enhanced image is 0~N level, and the interval \([a, b]\), \([c, d]\) are respectively a gray level interval of the source image and the enhanced image. Then the piecewise linear transformation function is:

\[
h(x, y) = \begin{cases} 
\frac{c}{a}f(x, y) & 0 \leq f(x, y) < a \\
\frac{d-c}{b-a}[f(x, y) - a] + c & a \leq f(x, y) \leq b \\
\frac{N-d}{M-b}[f(x, y) - b] + d & b < f(x, y) \leq M
\end{cases}
\]  

(2)

2.1.3. Nonlinear gray enhancement

When the nonlinearity function is used to map the image grayscale, the nonlinear grayscale enhancement of the image can be realized[5]. Commonly used nonlinear gray enhancement methods are logarithmic function nonlinear transformation and exponential function nonlinear transformation.

When doing a logarithmic nonlinear transformation on an image, the transformation function is:

\[
h(x, y) = a + \frac{\ln[f(x, y) + 1]}{b \ln c}
\]  

(3)

When performing an exponential function nonlinear transformation on an image, the transformation function is:

\[
h(x, y) = e^{c[f(x, y) - a]} - 1
\]  

(4)

By adjusting \(a, b, c\), you can adjust the position and shape of the curve. With this transformation, the low gray scale range of the input image can be expanded, and the high gray scale range is compressed to make the image distribution uniform[6].

2. Histogram enhancement

The histogram of the image is to analyze the gray scale range of image and understand the distribution of the gray level. From the distribution of the gray level, we can see many features of the image. Therefore, image enhancement can be achieved by changing the histogram characteristics of the image, modifying the histogram of the image, improving the different gray levels and enhancing the contrast.
of the image[7]. Histogram equalization and histogram specification are the two most commonly used methods.

Before performing histogram related operations, we must know what the histogram looks like, that is, histogram statistics. Mathematically, the image histogram is actually a function of the statistical properties of the gray values of the image and the gray value of the image. It counts the number or probability of occurrence of each gray level in an image. Graphically speaking, it is a two-dimensional map, with the abscissa indicating the gray level of each pixel; the ordinate indicates the number of pixels or probability of the corresponding gray level[8].

3. Color component extraction in color images

Image captured by camera in MATLAB is an X×Y×3 array. Each data in the array is the color information components corresponding to the color image in a specific spatial position. By combining these three components, a color image can be obtained.

In MATLAB, read a color image, its data type is unit8, that is, 8-bit unsigned integer data. The image stored in this way is called 8-bit image, which can save data space very well. The imread command in MATLAB is to store the image into an 8-bit matrix. If the read image is a color image, it will store the data into an 8-bit RGB matrix. For example, if the pixels of the color image read are 800×1248, then the matrix stored in MATLAB is 800×1248×3, and each channel value of the color image is between 0 and 255. The images saved by MATLAB are all uint8 data types, but the double type is used in matrix operation. This method can ensure the accuracy very well. In matrix operation, uint8 type arrays can operate with each other, and the result is still uint8 type[9].

![Figure 1. Grayscale and color component histograms extracted from the original color image](image)

In MATLAB, the histogram components of color information can be obtained by the following procedure:

\[
\begin{align*}
R1 &= \text{RGB}(:,1); \\
G2 &= \text{RGB}(:,2); \\
B3 &= \text{RGB}(:,3);
\end{align*}
\]

The histogram of the obtained color components is shown in Fig. 1. It can be seen from the figure that the dynamic range of the original image histogram is limited to a small range. The degree of aggregation is high and the gray value of the area is low. The contrast of the original image is not high and the brightness is low, some important information in the image can’t show up.

4. Image histogram equalization processing

Histogram of image is based on probability theory and gray level calculation. The image is enhanced by modifying a specific histogram. Therefore, the quality of image enhancement depends on the performance of the histogram we use[10].
In Matlab, the instruction that can equalize the histogram of the color components of a color image is histeq. The specific line is as follows:

\[
\begin{align*}
    r &= \text{histeq}(R_1); \\
    g &= \text{histeq}(G_2); \\
    b &= \text{histeq}(B_3);
\end{align*}
\]

Figure 2. Grayscale and color component histograms extracted from the image after equalization

The histogram obtained by equalizing the color components of the image is shown in Fig. 5. From the histogram shown in the figure, it can be observed that the display width of the image is significantly widened, and the gray value of the region is significantly enhanced. The three images are synthesized using the cat command in Matlab. The synthesized color image is shown in Figure 5. Compared with the original image (Fig. 3) and linear change in pixel (Fig. 4), the contrast of the image after equalization is improved, and the brightness of the image is obviously enhanced.

Figure 3. original image

Figure 4. Linear change in pixels

Figure 5. Image equalization

Compare the three pictures mentioned above, the original image is changed linearly, the pixels of
the image are increased, the overall brightness of the image is enhanced, and the image becomes clear gradually, but the information points of the image are not highlighted. The image is equalized to highlight the local information of the image and improve the overall contrast of the image. As shown in Figure 5, the equalized image can reflect the required information.

5. Conclusion
Image enhancement is an indispensable video processing method. Histogram equalization is the most commonly used method of image enhancement. It can improve the quality of image very well. This paper mainly discusses the principle of histogram equalization, and carries out image enhancement experiments through MATLAB experiments. The results show that the histogram equalization method has a good processing effect. It will increase the contrast of the image and highlight the elements of the image.

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