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The Research of Histogram Enhancement Technique Based on Matlab Software

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Abstract: Histogram enhancement technique has been widely applied as a typical pattern in digital image processing. The paper is based on Matlab software, through the two ways of histogram equalization and histogram specification technologies to deal with the darker images, using two methods of partial equilibrium and mapping histogram to transform the original histograms, thereby enhanced the image information. The results show that these two kinds of techniques both can significantly improve the image quality and enhance the image feature. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Image processing, Matlab, Histogram equalization, Histogram specification, Image enhancement.

1. Introduction

Image enhancement technology [1, 2] is one common ways of digital image processing, it has been widely used in aviation, medical, military etc. Through the enhancements of some characteristic information, making the unshaped images more legible, or expanding the features between different objects, thus, ameliorates the image quality and satisfies the need of human visual or some special analysis. The image enhancement technology includes histogram transform, image smoothing, image sharpening etc. [3].

A histogram is a statistical function between the gray scale and the gray frequency, which reflects the occurrent times or frequency of different gray-scale levels in one image. The histogram shown as a two-dimensional image in visual [4], the value of the abscissa reflects all the gray-scale levels, and the ordinate shows the occurrent times or frequency of the whole gray-scale levels.

The histogram enhancement technique is a common way of image enhancement technology. This paper mainly studies the histogram enhancement, with the method of obtaining and transforming the histogram distribution structures as to enlarge the image feature information, improve the image quality and achieve the purpose of image enhancement.

2. Principle of Image Enhancement Technology

Using some special methods to transform the image information of original manuscript, emphasizing or bating some peculiar features to match the human visual, are the principles of image enhancement technology. During the processing of image enhancement, without considering the differences in quality between the original and the processed images, the processed images are not necessarily same with the originals. As formula (1) shows: assuming that the gray value of original image in coordinate (x, y) is f(x, y), the post-processed value is g(x, y) so the processing of image enhancement can be expressed as:

$$g(x,y)=T[f(x,y)], \quad (1)$$

where sign T denotes the different techniques of the processing methods. At the present time, the image enhancement technology is divided into two mainly categories: spatial domain enhancement technology [5] and frequency domain enhancement technology [6].

2.1. Spatial Domain Enhancement Technology

Spatial domain enhancement technology which belongs to the direct image enhancement technology is one of transformation methods based on image pixel space. It consists of gray level transformation, histogram transformation, noise elimination smoothing and edge enhancement sharpening.

2.2. Frequency Domain Enhancement Technology

Frequency domain enhancement technology is a way to covert images from original space to other space by a peculiar form. Processing the image in virtue of the unique characters in other space then converting them back to the original space to display finally. In the frequency domain, image information is organized according to the frequency which is based on the theory of Fourier transform [7, 8].

Two-dimensional continuous Fourier transform:

$$F(u,v)=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(x,y)e^{-j2\pi(ux+vy)}dxdy, \quad (2)$$

Two-dimensional inverse continuous Fourier transform:

$$F(u,v)=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(x,y)e^{j2\pi(ux+vy)}dxdy, \quad (3)$$

Two-dimensional discrete Fourier transform:

$$F(m,n)=\frac{1}{N}\sum_{i=0}^{N-1}\sum_{k=0}^{N-1} f(i,k)e^{-j2\pi(m\frac{i}{N}*n\frac{k}{N})}, \quad (4)$$

Two-dimensional inverse discrete Fourier transform:

$$F(m,n)=\frac{1}{N}\sum_{i=0}^{N-1}\sum_{k=0}^{N-1} f(i,k)e^{j2\pi(m\frac{i}{N}*n\frac{k}{N})}, \quad (5)$$

3. Histogram Equalization and Histogram Specification

The histogram of digital image processing mainly refers to the gray-histogram, the mathematical expression is:

$$P(r_k)=n_k/n \quad \text{k=0,1,…L-1}, \quad (6)$$

In equation (6), sign “n” denotes the total numbers of the pixels, sign “r_k” denotes the corresponding gray level of “k”, sign “n_k” denotes the occurrent times or frequency of “r_k” , sign “$p(r_k)$” denotes the probability of “r_k”.

The histogram can be defined as another form: assuming that a continuous image which defined by Function D(x, y), Let “A” means the first contour surrounded area, “A_1” means the second contour surrounded area, when the values of corresponding gray-level comes from “D_1” to “D_2”, the histogram can be described as Fig. 1.

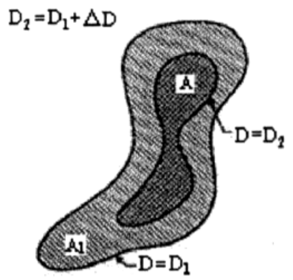

Fig. 1. Image grayscale contour surrounded area.

$$H(D)=\lim_{\Delta D\to 0}\frac{A(D)-A(D+\Delta D)}{\Delta D}=-\frac{d}{dD}A(D), \quad (7)$$

For the discrete function, ΔD=1 consequently

$$H(D)=A(D)-A(D+1), \quad (8)$$

From the functions above, histogram can reflect the characteristics of the probability and statistics. With the converting of probability function, the structure of gray scale can be changed, so will enhance the requisite image feature. At present, the common histogram transform technique is divided into two mainly categories: histogram equalization and histogram specification.

3.1. Histogram Equalization

Histogram equalization is a way of converting the structure of original histogram to the equilibrium ones with the gray-level transformation function. Thus, the dynamic range of the gray-scale values will increase, and the image becomes clear.

Histogram equalization transform function as shown in Fig. 2, assume sign “r” and “s” denote the value of gray-scale level which have been normalized respectively. When r=s=0 it stands for black, while r=s=1 means white. The gray transform function shown as:

$$S = T(R), \tag{9}$$

It satisfies the following two conditions:
1) $0 \le r \le 1$, T(r) is monotone increasing;
2) $0 \le r \le 1$, $0 \le T(r) \le 1$.

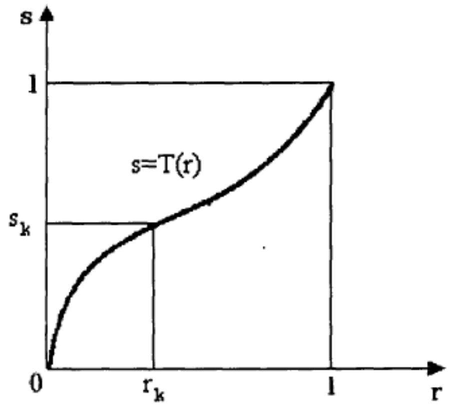

Fig. 2. Histogram equalization transform function.

Get the histogram equalization transform function from formula (6), namely the image gray cumulative distribution function s_k:

$$s_k = T(r_k) = \sum_{j=0}^{k} p_r(r_j) = \sum_{j=0}^{k} \frac{n_j}{n}, \tag{10}$$

3.2. Histogram Specification

Histogram specification is a way to transform the local histogram to the ones desired, via a gray mapping function Gnew=F (Gold), which can change the partial shape of original histogram by accentuating some special range information selectively.

The histogram specification constitutive of three steps:

1) Histogram specification of original histogram:

$$t_k = EH_s(s_i) = \sum_{i=0}^{k} p_s(s_i) \quad k=0,1,\ldots, M-1, \tag{11}$$

2) Ascertain the histogram while equalized:

$$v_i = EH_u(s_j) = \sum_{j=0}^{k} p_u(u_j) \quad j=0,1,\ldots, N-1, \tag{12}$$

3) Project the original space into the new equalized ones, so as to achieve the purpose of image enhancement.

4. Image Enhancement Using Matlab Software

This paper adopts the Matlab software to enhance the image information [9, 10] by using histogram transform technique. Convert the original color image (as Fig. 3 shows) into the gray one (as Fig.4 shows) firstly in order to facilitate the processing. Fig. 5 is the original 256 gray-scale histogram of Fig. 4.

Fig. 3. Original color image [11].

Fig. 4. Gray image.

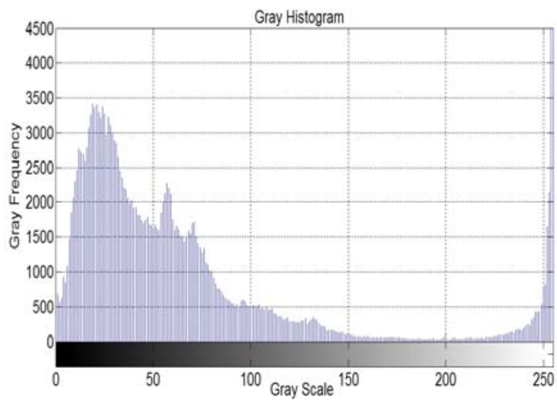

Fig. 5. Original 256 gray-scale histogram.

4.1. Histogram Equalization Using Matlab Software

As Fig. 5 shows that, the values of gray-level mainly concentrated in between [0, 120].

In order to enhance the image information better, [0, 120] was chose to equalization so as to get a clear sharpening image feature in the modified image. The post-correction 120 gray-level image and the post-equalization 120 gray-level image are showed as Fig .6 and Fig.7 respectively.

Fig. 8 shows the post-correction 120 gray-scale histogram of Fig. 6. And Fig. 9 shows the post-equalization 120 gray-scale histogram of Fig. 7.

Fig. 6. Post-correction 120 gray-scale image.

Fig. 7. Post-equalization 120 gray-scale image.

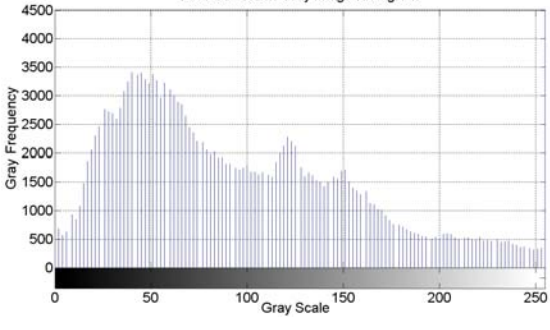

Fig. 8. Post-correction 120 gray-scale histogram.

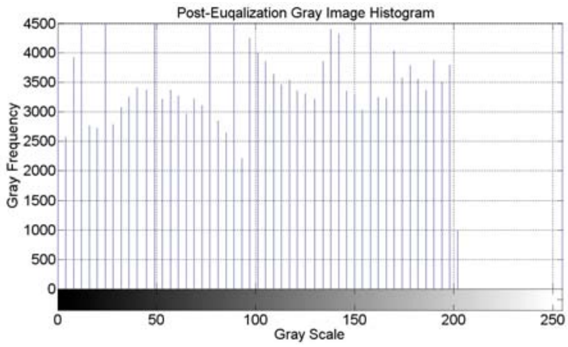

Fig. 9. Post-equalization 120 gray-scale histogram

4.2. Histogram Specification Using Matlab Software

Histogram specification can enhance the whole visual effects of the image. Fig. 5 shows that the values of gray-level mainly concentrated in between [0, 120], if it can be converted to the desired histogram nearly like Fig. 9, so will get the enhancement of image information.

5. Experimental Results and Analysis

5.1. Analysis of Histogram Equalization

As Fig. 6 shows, the post-correction 120 gray-scale image has been significantly improved in darker details and increased the dynamic range than the original one. After equalization, the image quality has improved further, the brightness distributed equilibrium and the tone become gentler. There are more details can be distinguished in visual in the center of the sunflowers. As Fig. 9 shows, the values of gray-level which concentrated in [0, 120], become a balanced distribution comparatively. The experimental results which are consistent with the image displayed, achieved the aim of image enhancement.

5.2 Analysis of Histogram Specification

Fig. 10 is the post-specification 256 gray-scale image which has more ranks and details expression than the post-equalization one as showed in Fig.7.

Only corrected the values of [0, 120] gray scale during the process of histogram equalization, thus lost the brightness image information in the original image. But in process of histogram specification, the whole image information has been reserved. All the mountains and trees which caused of backlighting are visible, due to expending the dynamic range with the whole gray scales. After post-equalization, the details of image feature enhanced, the brightness becomes uniform and the tone has a gentler appearance.

Fig. 11 shows the post-specification 256 gray-scale histogram of Fig. 10.

Fig. 10. Post-specification 256 gray-scale image.

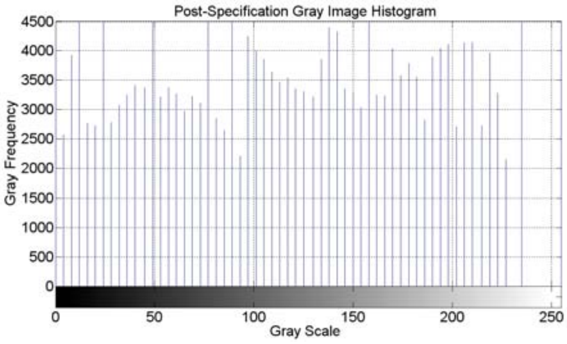

Fig. 11. Post-specification 256 gray-scale histogram.

The post-equalization 256 gray-scale image displays as Fig. 12, which preserves the whole detail information of the original image in theory. And Fig.13 shows the post-equalization 256 gray-scale histogram of Fig.12.

Fig. 12. Post-equalization 256 gray-scale image.

As Fig. 11 shows, post-specification 256 gray-scale histogram which using [0, 120] levels equalization mapping space to transform during the process of histogram specification, has the same distribution structure with the post-equalization one in values of [0，190] gray scale which compared with the Fig. 9. Fig.11 preserves the [120, 255] levels brightness tone information in original image is the reason for the differences between the two histograms in [190, 255] gray scale. So we can see all the details of image without losing the data of the distant hills and trees that are invisible in original manuscript. After histogram specification the image features distinct, and achieve the aim of image enhancement.

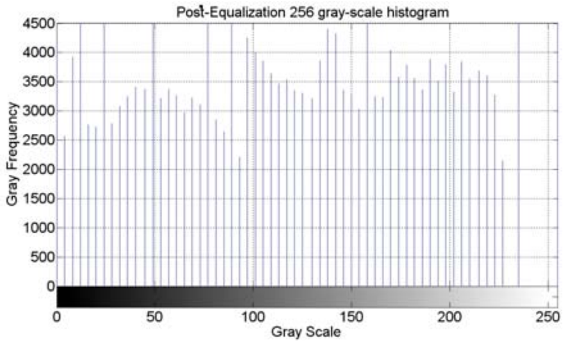

Fig. 13. Post-equalization 256 gray-scale histogram.

Fig. 12 shows the post-equalization 256 gray-scale image. It seems slightly darker overall the whole tone in Fig. 10 by contrast with the Fig. 12, but they have the same expression in visual effect. Comparing with Fig. 11 and Fig. 13, the two histograms display the nearly identical gray frequency distribution, differences only between [180, 220] levels in which a lower numerical data in brightness proportion of Fig. 10. The reason is that, neglecting the [120, 255] levels brightness tone information in original image and using [0, 120] levels equalization mapping space to transform during the process of histogram specification. By comparing the two methods, we can see that, selects [0,120] levels gray scale data to dispose in this paper can save more computational space, and the experimental process is entirely reasonable and feasible.

6. Conclusions

This paper is based on Matlab software, adopt two kinds of ways: histogram equalization and histogram specification technologies to enhance the image information. In histogram equalization process, with the separation treatment of the gray levels which are concentrated in darker part of the image on purpose, image quality has been improved significantly and accorded with human visual. During the process of histogram specification, project the original histogram into the mapping one through the global transformation of the histogram, and display the whole image information which is rich in details and brightness of the original manuscript, achieve the aim of image enhancement.

To sum up, the coalescent two kinds of techniques can improve the image quality and enhance the image feature significantly. The experimental results and methods in this paper can provide the reference for the further study in related research too. And also can provide the reference for the mechanical information technology education of The Open University of China, especially for the teaching and practice of Radio and Television Universities in the future.

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