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Digital Image Enhancement Method based on Image Complexity

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Abstract

In this paper, aiming at the shortcomings of the traditional histogram enhancement method and defect, a kind of image enhancement algorithm is put forward based on digital image complexity. Experimental results show that this method has advantages compared with traditional image enhancement algorithms, mainly reflected in the results obtained by using the improved image enhancement algorithms, the corresponding SNR and MSSIM index are higher than the original. In the paper, SNR and MSSIM index is proved best combination, which are high reflects that the similarity of after-image and the reference image and the image is more suitable to the human eye.

Keywords: *Image enhancement, Digital image, Complexity*

1. Introduction

With the coming of information age, information is getting more and more important. At present, information, energy and materials is considered the three pillars of human society. As an important information carrier, Image plays an irreplaceable role in people's life. Image is widely applied in medical, industrial detection, space science, geomorphology, military and other fields. In all these fields, there are some common parts: image acquisition, image storage, image analysis and processing, which is the important part, image transmission and display. In image acquisition process, because of the influence of many unavoidable interference factors and the limitation of CCD and other hardware itself, some noise appears in captured images, which have obviously influence on the analysis of the image later. It is important to remove the effects of the noise and save useful information in the image as much as possible.

2. The Traditional Digital Image Enhancement Method Based On Histogram

We will introduce traditional histogram enhancement method.

2.1. Traditional Histogram Enhancement Principle

In traditional image enhancement methods, the most commonly used method is the histogram enhancement. Histogram, is refers to all gray levels in a digital image with different gray levels in the relationship between the probability of graphics, whose mathematical expression is as follows

$$P_r(r_k) = \frac{n_k}{n} \qquad 0 \le r_k \le 1 \tag{1}$$

r_k represents the discrete gray levels, n_k represents the number of pixels in the gray, n is the total number of pixels.specific instances of histogram equalization is as follow

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Figure1. The Original Image (Left) and the Image After Histogram Equalization (Right)

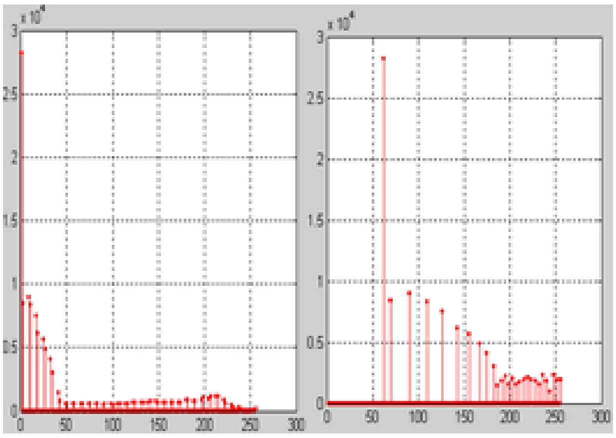

Figure2. The Corresponding Histogram Equalization of Original Image and the After Images

The process of histogram equalization is described as follow: Grayscale distribution in the image is according to the probability of the pixel of gray level in the image. The advantage of histogram enhancement algorithm is that if two adjacent grayscale occupies more pixels, it is easy to be separated by histogram equalization, which makes the distance to stretch between the adjacent grayscale and makes parts of the image become more clear and visible. As shown in figure 1,the part of the folds of the clothes in his right arm cannot be identified in the original image, after histogram equalization, image characters in clothes fold is clearly displayed.

2.2. Analysis of Traditional Digital Image Enhancement Method

There are the following shortcomings of histogram equalization:

1. After histogram equalization, obvious distortions happen in the image, which is caused by the grayscale merging as grayscale squeezed if the number of the pixel in that gray level.

2. In the process of histogram equalization, only the pixels number of gray level is considered regardless of whether the pixel of image content overall display. As digital image is a kind of comprehensive information expression, when a person looks over an image and try to obtain the required information, he might be interested in one or a few areas in the image,but not the other areas.In this case, if only the number of pixels of different gray level or the frequency of gray levels are considered in the process of

histogram equalization, some areas will display not clear.In this paper, 256 grayscale is adopted.

3. The Image Enhancement Algorithm Based On Digital Image Complexity

Aiming at the shortcoming of histogram equalization, if you can consider the content of the original image, in other word, in the process of histogram enhancement, we can deal with the image according to the content of the image, we can overcome the above shortcomings. Based on this assumption, we put forward the image enhancement algorithm based on digital image complexity.

3.1. The Complexity of the Image Array

For a generalized set, assuming that the total number of the individual N is known, and the number of individual n ,sign value for which is x, is a function of x, so n/N is a function of x. If

$$u(x_i) = -\log(n_i / N) \tag{2}$$

We get the average of another function:

$$\bar{u}(x) = \frac{1}{N}.\sum_{i=1}^{k} u(x_i) \tag{3}$$

If denoting N times of the special average as C, we can get

$$C = \sum_{i=1}^{k} u(x_i) = -\sum_{i=1}^{k} [\log(n_i / N)] \tag{4}$$

It is general calculation formula of internal state complexity. In the formula, k denotes the number of different symbol values in the general set; ni denotes the number of individuals each symbol value occupies, N is the number of individual.

A new physical quantity was introduced, which is complexity.

Digital image complexity is the amount of information contained in digital image. Thus, we consider that the measure of image "information content" must be objective. Digital image is the concept of "complexity" was put forward in this background. Considering the formula

$$C = \sum_{i=1}^{k} u(x_i) = -\sum_{i=1}^{k} [\log(n_i / N)] \tag{5}$$

We introduce internal state complexity concept used to represent a broad set into the field of image processing. Specific parameters in the formula are defined as follows: for a gray scale image for the k digital image, the image of the smallest unit number for N (pixels), for a gray scale i, n_i said the probability on the gray level.

3.2. Image Complexity and Entropy

"Complexity" is used to measure the amount of "information" of a given image. If you want to quantify the size of the "complexity”, another concept, which is "Entropy", is needed. Entropy denotes any kind of energy distribution in the space of uniformity. The more uniform energy distribution, the greater the entropy.

In information theory, entropy is defined as follows:

$$H = -\sum_{i=1}^{k} p_i \log_2(p_i) \tag{6}$$

Formula p_i is the probability of occurrence of the signal x_i, k is a total of different signals. p_i is the probability of calculating. If the value of p_i is zero, the value of $p_i \log p_i$ is zero, which is also the result of limit processing in mathematics.

Consider the use of a binary 0 and 1 encoding a piece of information which contains n symbols. The probability of symbol *Fn* in the whole message is assumed P_n, then the number of bits required for sign symbol *Fn*, which is the entropy of *Fn* is:

$$H_n = -P_n \log_2 (P_n) \tag{7}$$

The entropy of the piece of information is:

$$H = \sum_{i=1}^{k} H_i \tag{8}$$

Entropy is a measure of the affirmative of the random variable (system), if a random variable x has n kinds of possible states, and each state probability are equal, x maximum certain degree or its maximum entropy is:

$$H_{\max}(x) = \log_2 (n) \tag{9}$$

3.3. Digital Image Enhancement Method Based On Image Complexity

Partitioned histogram enhanced principle is to properly partitioned an image first, calculate the complexity of each sub-block C_{ij} and the expression of corresponding histogram $n_{ij}(r)$. The next is to find the maximum of all the complexity C_{max}. The whole image histogram expression is obtained according to the following formula:

$$N(r) = \frac{C_{i,j}}{C_{\max}} n_{i,j}(r) \tag{10}$$

Finally the above formula is used image histogram stretching. Histogram equalization processing is dealed with respectively for each sub-block. The result may be an image in the "block effect", the direct reason of which is that boundaries is not continuous between blocks. This is the so-called "ringing". Solution is to appropriate the border part, such as: take on either side of the border as the boundary of the average value; or the image fusion technology can reduce or even eliminate "ringing" brought about by the adverse effect. In the concrete experiment, this paper adopted the wavelet fusion technology. From the perspective of the result of experiment, this method is feasible.

Compared with traditional histogram enhancement algorithm, the concrete implementation process of image enhancement algorithm based on complexity is calculating each subblock gray scale distribution, and put each child the gray scale distribution of weighted on the complexity of the sub-block, take the results as a whole image gray scale distribution, giving the whole image of gray level stretch model first. In this way, at the same time to enhance the whole image, the content of the different regions of the image considered, it is more reasonable compared with the traditional histogram stretching.

4. Result

Different individuals observe the same target inevitably with different subjective factors, including the angle of the viewer, focus, and even personal aesthetic standards, psychological factors, *etc.*. Digital image quality evaluation should not rely on competent feelings but should follow uniform and objective evaluation criteria. The following contents describe digital image quality evaluation, and use it to measure the improved algorithm.

Digital image quality evaluation methods can be divided into three categories according to the need for a reference image [14]~[15].The first kind of image quality evaluation methods needs reference images, the second doesn't ,and the last one is between above-mentioned two.

The most common is the first method. It put the original image as a reference image, and strike a parameter marked some kind of link between the original image and the images to be assessed. The traditional parameters are: Mean Square Error (MSE) and Signal to Noise Ratio (SNR). The relationship between the post-processing image and the reference image can be shown by these parameters, thus indirectly measure the effectiveness of enhancement methods. These parameters realization is relatively simple, and its physical sense, also relatively obvious. However these parameters' shortcomings are obvious.

Firstly, when SNR and MSE are calculated, reference image is needed. However, it is difficult or impossible to obtain a reference image in most cases.

Secondly, when use MSE as a measure of parameters, the results often is inconsistent with human visual system (HVS)[16]~[20]. This problem has not been unified, objectively solved.

To solve this problem, the following discussions are around parameter MSSIM.

4.1. Traditional Digital Image Quality Evaluation Parameters

Common parameter MSE (the Mean Squared Error) is calculated by the formula as follow.

$$MSE = \frac{\sum_{n=1}^{FrameSize} (I_n - P_n)^2}{FrameSize} \tag{11}$$

I_n refers to the gray value of the n-th pixels of the original image , P_n refers to the gray value of the n-th pixels of the reference image, and FrameSize is the size of the image.

Another common parameter is SNR (Signal to Noise Ratio), which is calculated as follow:

$$SNR = 10 * 1n(p_s / p_n) \text{(db)} \tag{12}$$

SNR of two-dimensional digital image can be calculated by the formula as follow:

$$SNR = 10 * 1n(\frac{255^2}{MSE}) \text{(db)} \tag{13}$$

These parameters are relatively simple calculations up, which is relatively clear physical meaning. But they and the human visual effect is often not consistent. Because they do not consider that the effect of different errors on the human eye system is different. In addition we use a combination of brightness, contrast and image quality evaluation parameters structural characteristics ---- MSSIM , which is Mean Structural Similarity. Then we give the definition and use of its specific instance.

4.2. MSSIM(Mean Structural Similarity)

First let's introduce following a few basic concepts.

Mean brightness and standard deviation:

$$\mu_x = \frac{1}{N}\sum_{i=1}^{N} x_i \tag{14}$$

$$\sigma_x = (\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \mu_x)^2)^{1/2} \tag{15}$$

Structural Similarity:

$$SSIM(x,y)=[l(x,y)]^{\alpha}[c(x,y)]^{\beta}[s(x,y)]^{\gamma} \tag{16}$$

Above formula:

$$l(x,y)=\frac{2\mu_x\mu_y+C_1}{\mu_x^2+\mu_y^2+C_1} \tag{17}$$

$$c(x,y)=\frac{2\sigma_x\sigma_y+C_2}{\sigma_x^2+\sigma_y^2+C_2} \tag{18}$$

$$s(x,y)=\frac{\sigma_{xy}+C_3}{\sigma_x\sigma_y+C_3} \tag{19}$$

$$\delta_{xy}=\frac{1}{N-1}\sum_{i=1}^{N}(x_i-\mu_x)(y_i-\mu_y) \tag{20}$$

Let $\alpha=\beta=\gamma=1$ $C_2=2C_3$, we can get:

$$SSIM(x,\ y)\ =\ \frac{(2\mu_x\mu_y\ +\ C_1)\ (2\sigma_{xy}\ +\ C_2)}{(\mu_x^2\ +\ \mu_y^2\ +\ C_1)\ (\sigma_x^2\ +\ \sigma_y^2\ +\ C_2)} \tag{21}$$

We calculate SSIM's average:

$$MSSIM(x,\ y)\ =\ \frac{1}{M}\sum_{j=1}^{M}SSIM(x,\ y) \tag{22}$$

By Equation 7 to Equation 12, we can see that factors associated with MSSIM mainly in three aspects: the brightness similarity of the two images (defined by Equation 8), contrast similarity (defined by Equation 9) and structural similarity (by equation 10 is defined). α,β,γ represent weight that two image brightness similarity, contrast similarity, and structural similarity affects to the human eye system.

4.3. Image Enhancement Result and Quality Evaluation

As mentioned above, the image enhancement algorithm based on digital image complexity applied in the specific examples shown as follow. Figure 3 is the original image, figure 4 is the image after histogram stretching, figure 5 is the image after streching based on the complexity.

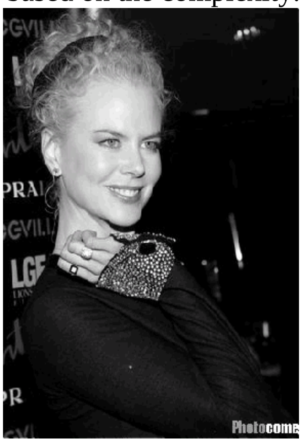

Figure3. Original Image (Left)

Figure4. The Image After Histogram Stretching (Middle)

Figure5. The Image After Streching Based on the Complexity (Right)

Table 1. SNR and MSSIM of Three Images

Image / Param	Figure3	Figure4	Figure5
SNR	100	8.618	13.3140
MSSIM	1	0.2876	0.3990

By the actual image quality evaluation and the corresponding numerical value, we can see: complexity histogram stretching algorithm based on image to get the final result of figure 5, the results obtained by using histogram stretching algorithm directly is figure 4. By Table 1 shows that the corresponding SNR and MSSIM in figure 5 is higher than the corresponding SNR and MSSIM in figure 4. This means that the image enhancement algorithm based on image complexity is better than traditional histogram enhancement algorithm.

The algorithm itself still exist the following disadvantages: 1) it has failed to fully consider the gray scale limit problem. For gray image, there are 256 gray levels in total. In this way, the gray level of conflicts still exists. In this case, the ways to solve this contradiction is the limit of maximum tensile distance. In other word, for the gray level stretch distance is too big and beyond the threshold, limits its tensile distance. In this way, we can resolve this contradiction. 2) The algorithm itself is only considering local content, without considering the overall image information. In practice, an image needs to be considered as a whole. This is because the image itself is a whole; and any part does not represent all the information.

5. Conclusion

In this paper, the digital image of the traditional histogram enhancement method is studied, aiming at its disadvantages, proposes the image enhancement algorithm based on image complexity, the experimental results show that although there are still lack of the algorithm, but its performance is superior to the traditional histogram. The image enhancement algorithm based on digital image complexity is still a bold and good attempt.

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