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Image Enhancement based on Human Visual Model

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Abstract

This paper mainly study traditional histogram image enhancement method. Aiming at the lack of image enhancement, a method based on human visual model was proposed, and the experimental results show that this algorithm has better performance than is a traditional histogram equalization method, which provided a good direction studying image enhancement algorithm.

Keywords: *image enhancement, human visual model, histogram*

1. Introduction

Image is widely used in medical, industrial detection, space science, geomorphology, military and other fields. Image processing includes image collection, image storage, image analysis and processing, transmission and display of the image. In these modules, image analysis and processing is the most core part of the whole process. This paper mainly study of the method of image enhancement, dedicated to the discovery of more, useful hidden information inside the image.

2. Based on the Principle of the Histogram Enhancement

In traditional image enhancement methods, the most commonly used method is the histogram enhancement. The histogram, is refers to all gray levels in a digital image with different gray levels in the relationship between the probability of the graphics. Its 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. A specific instance of histogram equalization is as follow.

The actual process of histogram enhancement is that the distribution gray scale of image is relative to the probability of the pixel of gray level. In other words, the distance between a gray scale and the next gray scale is proportional to the number of pixels on gray scale.

Histogram stretch the distance between the adjacent gray scales to, so as to make the parts in the image become more clear and visible. But when simple histogram equalization processing, it has not be considered where a gray scale is located in the gray level range. For the two adjacent gray scales, the distance stretched between them is determined by only the probability that former gray scale appear in the image. Research shows that the human eye has different ability in observing different gray scale. For example, if gray scale darker or lighter, the human ability to distinguish between adjacent gray scales is low. However, in the middle position of gray scale, the human ability of

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this distinction is relatively strong. The curve established based on the factors called human visual model (HVM). Aiming at this feature, we proposed the following improvement scheme.

Figure 1. The Original Image (left) and the Image after Histogram Equalization (right)

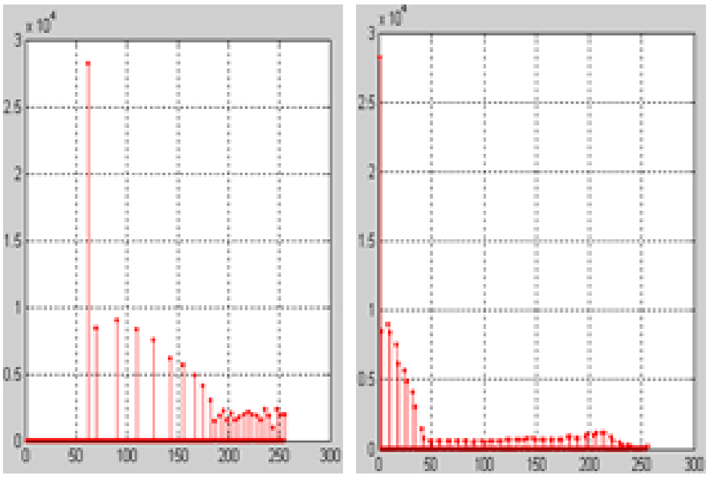

Figure 2. The Corresponding Histogram Equalization of Original Image and the After Images

3. Image Enhancement based on HVM

Human visual model (HVM) is a widely attention in recent years. When considering the image enhancement, on one hand we should begin from the image itself; On the other hand, we also consider some outside factors, such as the observer's eye. In image enhancement based on HVM, it is mainly related to the analysis human eye to distinguish gray ability. We introduce the visible deviation (JND), and the optimal critical deviation (OND) two concepts. The establishment of the JND is aimed to reveal the perception of the law of human eye under the background of different visual; OND is put forward in order to take full advantage of the characteristics of visual perception, optimizing the allocation of leading the dynamic range of gray levels, then make the image get the best visual effects, while retaining the original image in more details.

3.1. What is JND

JND is Just Noticeable Difference; it is used in image compression coding design and evaluation by Jayant earlier. JND and image enhancement have close relations, and it reflects the minimum brightness deviation the human eye can distinguish in a particular context, which is the minimum threshold that detail information can be effectively distinguish. Studies have shown that JND is associated with the brightness of the background and spatial frequency, that is, the human eye visual threshold effect and spatial frequency masking effect.

Existing visual research results show that the minimum brightness difference ΔI human eye can feel is associated with the background of the observable object, that is to say that visual is sensitive to the brightness changes with the background nonlinear. In the high brightness background, on the whole, the human eye sensitivity to the brightness difference is smaller than low intensity area. When the actual image is displayed, different gray scale of pixels is used to show light and shade. The study shows that approximately proportional relationship exits in the brightness and gray levels. In this paper, the image referred has 256 gray scales.

Most of the images contain complex and uneven background. Experiments show that, a non-uniform background will raise the visual threshold of the human eye. In other words, the deviation degree of the human eye to gray scale drops. This is known as the masking effect of non-uniform background.

3.2. The Establishment of JND

Although "visual threshold effect" and "spatial frequency masking effect “has been found, there is no the establishment of a unified, accurate about the mathematical model of the human eye vision, as the visual mechanism is more complicated, and the visual effect is related to visual psychology. This makes a certain deviation between JND value derived from the existing theory and practical application. More practical way is to determine the value of the JND by many people grouping experiments. The images provided by the TEXAS University at Austin institute of image database DMOS is obtained through this method.

For a single stimulus with a gray scale in fixed space frequency and brightness background, determination of JND is relatively easy. But in the actual image, in the same image area, there are usually multiple gray scale distribution, which compose multiple stimulate bodies, whose spatial frequency of local background, which brought difficulties for measuring JND. It is found in the actual test that visual threshold effect in optimizing the allocation of leading the dynamic range of gray levels play a leading role. in order to make the JND is more general, our main consideration under the background of the same, different gray scale JND change rule, as shown in Figure 3.

3.3. The Establishment of OND

OND is Optimal Noticeable Difference; its building method is similar to the JND. The result of the experiment is gradually increasing deviation based on the deviation of JND satisfied; OND is obtained when the human eye has a certain comfort conditions. The test results are shown in Figure 4.

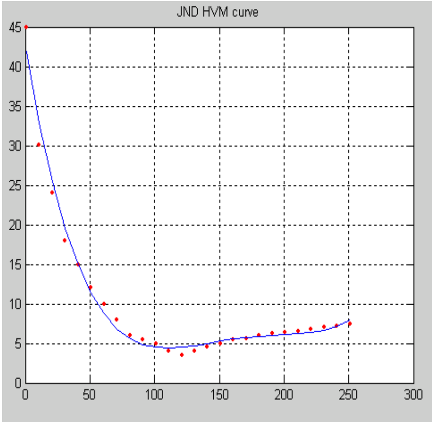

Figure 3. Relation Curve between JND and the Background Luminance

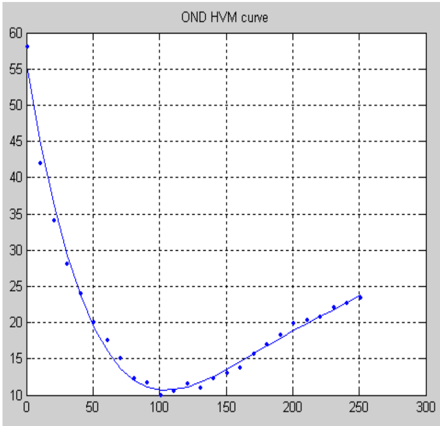

Figure 4. Relation Curve between OND and the Background Luminance

4. Result Evaluation

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 an 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.

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

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:

$$SNR = 10 * 1n(p_s / p_n)(\text{db}) \quad (3)$$

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

$$SNR = 10 * 1n(\frac{255^2}{MSE})(\text{db}) \quad (4)$$

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:

$$\mu_x = \frac{1}{N}\sum_{i=1}^{N} x_i \quad (5)$$

$$\sigma_x = (\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \mu_x)^2)^{1/2} \quad (6)$$

Structural Similarity:

$$SSIM(x,y) = [l(x,y)]^{\alpha}[c(x,y)]^{\beta}[s(x,y)]^{\gamma} \quad (7)$$

Above formula:

$$l(x,y) = \frac{2\mu_x\mu_y + C_1}{\mu_x^2 + \mu_y^2 + C_1} \quad (8)$$

$$c(x,y)=\frac{2\sigma_x\sigma_y+C_2}{\sigma_x^2+\sigma_y^2+C_2} \tag{9}$$

$$s(x,y)=\frac{\sigma_{xy}+C_3}{\sigma_x\sigma_y+C_3} \tag{10}$$

$$\delta_{xy}=\frac{1}{N-1}\sum_{i=1}^{N}(x_i-\mu_x)(y_i-\mu_y) \tag{11}$$

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

$$SSIM(x,y)=\frac{(2\mu_x\mu_y+C_1)(2\sigma_{xy}+C_2)}{(\mu_x^2+\mu_y^2+C_1)(\sigma_x^2+\sigma_y^2+C_2)} \tag{12}$$

We calculate SSIM's average:

$$MSSIM(x,y)=\frac{1}{M}\sum_{j=1}^{M}SSIM(x,y) \tag{13}$$

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

The proposed image enhancement method based on image OND is used, the enhanced results are given as follows, and the corresponding MSSIM and SNR values for the results are calculated.

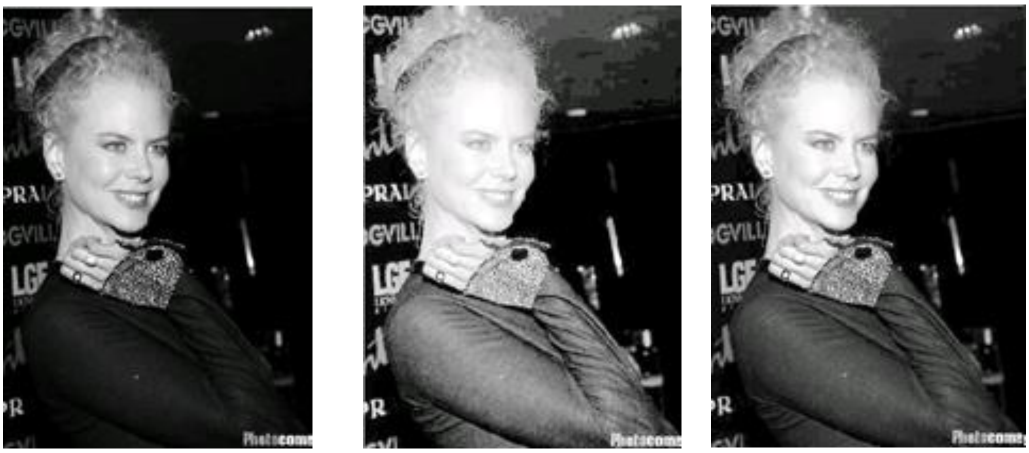

Figure 5. Original Image (Left), Histogram Equalization Image (Middle) and OND Enhancement Image (Right)

Figure 5 is the the results in use of the algorithm to enhance of the original figure, and the right image is based on OND enhancement algorithm. From the result we can see, after histogram equalization, fold clothes of the original image is displayed, but the whole image has too much exposure phenomenon. And after OND enhancement, the image information displayed, also the image brightness is moderate for the human eye to watch.

Then we give the SNR and MSSIM of the images as follow in Tablet 1.From the data obtained in the tablet, we can get the conclusion that OND enhancement method is better than histogram equalization method, as the SNR and MSSIM of it's image is more than the histogram equalization image.

Tablet 1. SNR and MSSIM of Three Images

Image / Param	Fig.(5)	Fig.(6)	Fig.(7)
SNR	100	8.618	15.3140
MSSIM	1	0.2876	0.3510

5. Conclusion

The establishment of JND reveals the law of HVS perception of gray image. This provides a quantitative basis to determine whether the information is enhanced effectively, and provides a beneficial exploration path for the further improvement of image enhancement algorithm. To dominate the gray scale dynamic range to effectively control to further improve the performance of the algorithm, the paper fixed value clipping method, which is an improvement to the method of image enhancement based on JND.

As the lack of information in traditional image histogram, this paper described the image enhancement algorithm based on human visual model. The algorithm, considering the nonlinear characteristics of human visual model in gray scale adjustment process, use the different proportions of gray levels assigned into different visual sensitivity information for its regional characteristics. In order to test the effect of this kind of mechanism to enhance, we use the analysis results based on objective assessment of the quality of image enhancement algorithm. The test results show that the results of the analysis of objective assessment is agree with the subjective evaluation.

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References

[1] H. D. Cheng, M. Xue and X. J., "Shi Contrast enhancement based on a novel homogeneity measurement[J]", Pattern Recognition, vol. 36, no. 11, **(2003)**, pp. 2687-2697.
[2] B. Xue, W. Liu and J. Wang, "Research on iris image preprocessing algorithm[J]", Journal of Optoelectronics Laser, vol. 14, no. 7, **(2003)**, pp. 741-744.
[3] C. Yang and L. Huang, "Weighted adaptive histogram equalization based on exponential function[J]", Journal of Optoelectronics. laser, vol. 5, **(2002)**, pp. 021.
[4] S. M. Pizer, E. P. Amburn and J. D. Austin, "Adaptive histogram equalization and its variations[J]", Computer vision, graphics, and image processing, vol. 39, no. 3, **(1987)**, pp. 355-368.
[5] J. Y. Kim, L. S. Kim and S. H. Hwang, "An advanced contrast enhancement using partially overlapped sub-block histogram equalization[J]", Circuits and Systems for Video Technology, IEEE Transactions on, vol. 11, no. 4, **(2001)**, pp. 475-484.

[6] Kim J Y, Kim L S, Hwang S H. An advanced contrast enhancement using partially overlapped sub-block histogram equalization[J]. Circuits and Systems for Video Technology, IEEE Transactions on, 2001, 11(4): 475-484.
[7] Ji T L, Sundareshan M K, Roehrig H. Adaptive image contrast enhancement based on human visual properties[J]. Medical Imaging, IEEE Transactions on, 1994, 13(4): 573-586.
[8] Winkler S. Issues in vision modeling for perceptual video quality assessment[J]. Signal Processing, 1999, 78(2): 231-252.
[9] Poirson A B, Wandell B A. Appearance of colored patterns: pattern—color separability[J]. JOSA A, 1993, 10(12): 2458-2470.
[10] Girod B. What's wrong with mean-squared error.Digital images and human vision. MIT press, 1993: 207-220.
[11] Teo P C, Heeger D J. Perceptual image distortion. 1994 International Symposium on Electronic Imaging: Science and Technology. International Society for Optics and Photonics, 1994: 127-141.
[12] Eskicioglu A M, Fisher P S. Image quality measures and their performance[J]. Communications, IEEE Transactions on, 1995, 43(12): 2959-2965.
[13] Eckert M P, Bradley A P. Perceptual quality metrics applied to still image compression[J]. Signal processing, 1998, 70(3): 177-200.
[14] Wang Z, Bovik A C, Sheikh H R, et al. Image quality assessment: from error visibility to structural similarity[J]. Image Processing, IEEE Transactions on, 2004, 13(4): 600-612.
[15] Wang Z, Sheikh H R, Bovik A C. No-reference perceptual quality assessment of JPEG compressed images[C]//Image Processing. 2002. Proceedings. 2002 International Conference on. IEEE, 2002, 1: I-477-I-480 vol. 1.
[16] Poirson A B, Wandell B A. Appearance of colored patterns: pattern—color separability[J]. JOSA A, 1993, 10(12): 2458-2470.
[17] B.Girod..What is wrong with mean-squared error..In Digital images and Human Vision, the MIT press.1993:207~220.
[18] Teo P C, Heeger D J. Perceptual image distortion[C]//IS&T/SPIE 1994 International Symposium on Electronic Imaging: Science and Technology. International Society for Optics and Photonics, 1994: 127-141..
[19] Eskicioglu A M, Fisher P S. Image quality measures and their performance[J]. Communications, IEEE Transactions on, 1995, 43(12): 2959-2965.
[20] Eckert M P, Bradley A P. Perceptual quality metrics applied to still image compression[J]. Signal processing, 1998, 70(3): 177-200.

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