An Improved Image Contrast Assessment Method

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Abstract

Contrast is an important factor affecting the image quality. In order to overcome the problems of local band-limited contrast, a novel image contrast assessment method based on the property of HVS is proposed. Firstly, the image by low-pass filter is performed fast wavelet decomposition. Secondly, all levels of band-pass filtered image and its corresponding low-pass filtered image are obtained by processing wavelet coefficients. Thirdly, local band-limited contrast is calculated, and the local band-limited contrast entropy is calculated according to the definition of entropy, Finally, the contrast entropy of image is obtained by averaging the local band-limited contrast entropy weighed using CSF coefficient. The experiment results show that the best contrast image can be accurately identified in the sequence images obtained by adjusting the exposure time and stretching gray respectively, the assessment results accord with human visual characteristics and make up the lack of local band-limited contrast.

Keywords: image quality assessment, contrast, wavelet transform, contrast sensitivity, human visual system

1. Introduction

The contrast is one of the most basic characteristics of the image, which has a significant impact on image quality. Too large or too small contrast will lead to the blur of the details of the image and degrade image quality. At present, the contrast of the image has many definitions, in simple mode, there are two basic definition [1]: Weber contrast and Michelson contrast, these two global definition contrast can give better assessment, but when incentives become more complex and contain a wide frequency range, the above two methods will fail; the apparent contrast, inherent contrast and modulation contrast [2] are commonly used in the visible light detection, in addition, contemporary contrast [3], average contrast [4], power spectral contrast [5], root mean square error contrast [6] are also more commonly used; in complex mode, there are mainly band-limited contrast [7], local band-limited contrast [8], S. Winkler isotropic contrast [9].

The Lubin local band-limited contrast [8] is found defects in evaluating complex image, the Lubin local band-limited contrast gives a high evaluation result to lossing details images because of the gray stretch and under exposure, the assessment results are not in accordance with human visual characteristics. To improve the above method, based on the research results that the assessment method considering the human visual system (HVS) characteristics is better than those without consideration of HVS assessment method [10], and the log-change performance is more in line with human visual characteristics. On the basis of local band-limited contrast, introducing contrast sensitivity(CSF) characteristics of HVS, a novel image contrast assessment method based on the property of HVS is proposed in this article, The experiment results show the effectiveness of the method which solves the shortage of local band-limited contrast, the assessment results accord with human visual characteristics.

2. Image Contrast Assessment Based on Human Visual System

The system framework of the assessment method is shown in Figure 1.

Figure 1. Assessment Algorithm Block Diagram

Firstly, the image by low-pass filter is performed fast wavelet decomposition. Secondly, all levels of band-pass filtered image and its corresponding low-pass filtered image are obtained by processing wavelet coefficients. Thirdly, local band-limited contrast is calculated, and the local band-limited contrast entropy is calculated according to the definition of entropy, Finally, the contrast entropy of image is obtained by averaging the local band-limited contrast entropy weighed using CSF coefficient.

2.1. Image Preprocessing

At this stage, we analyze only the gray image, the assessment of color image contrast is the next topic. Therefore, if the image is a color image, it is extracted luminance component X, And then is low-pass filtered to obtain the image F in order to eliminate noise interference.

In the fast wavelet transform algorithm, the fast wavelet transform is achieved through iterative using of the digital filter. A two-dimensional fast wavelet transform (FWT) filter bank is shown in Figure 2 [11].
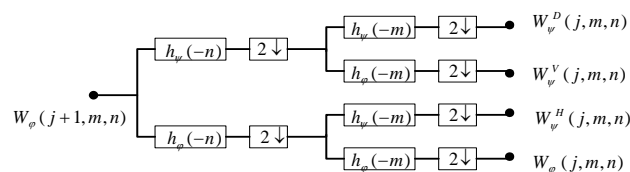

Figure 2. Two-dimensional Fast Wavelet Transform Filter Banks

Considering the evaluation effect and running speed, the image after pre-processing is performed k=5 level fast wavelet decomposition, after a large number of simulation experiments, the Symlets sym4 of discrete wavelet series is selected as the wavelet function, the image Plane and its 5 scale wavelet transform is shown in Figure 3.
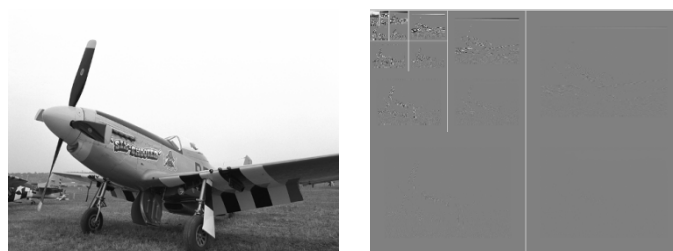

Figure 3. Plane and Its 5 Scale Wavelet Transform

2.2. Frequency Decomposition

According to the definition of Lubin local band-limited contrast, the frequency coefficient matrix is decomposed, the j(j of 1,2,3,4) level band-pass frequency coefficients $Bp_j(u,v)$ and

the corresponding low-pass frequency coefficient $Lp_{j+2}(u,v)$ are extracted respectively from the filter banks, u, v are respectively the abscissa and ordinate of any point in frequency coefficient matrix. The second band pass frequency coefficients and the corresponding low frequency coefficient of image plane are shown in Figure 4.

Figure 4. The Second Level Band-pass and Low-pass Frequency Coefficient

2.3. IFWT

The extracted various band-pass frequency coefficients $Bp_j(u,v)$ and the corresponding low–pass frequency coefficients $Lp_{j+2}(u,v)$ are performed inverse fast wavelet transform to obtain the bandpass filtered image $bp_j(x,y)$ and low-pass filtered images $lp_{j+2}(x,y)$. The third level band-pass filter image and the corresponding low-pass filter image of plane image are shown in Figure 5.

Figure 5. The Third Level Band-pass and Low-pass Filter Images

2.4. Computing Local Band-limited Contrast

$$C_j^L(x,y) = \frac{\mid bp_j(x,y) \mid + c1}{\mid lp_{j+2}(x,y) \mid + c2}$$

(1)

Where, c1, c2 are constants and greater than zero for preventing the molecule and denominator are zero so that the result is no significance, in the paper, After a large number of simulation test, c1 = 0.00001, c2 = 0.001.

2.5. Computing Local Band-limited Contrast Entropy

$$CE_j^L(x,y) = -aC_j^L(x,y) \times \log_2 C_j^L(x,y)$$

(2)

Where, a is adjustment factor, reasonable selection of a can make the results in a suitable range. In this paper, a = 10.

2.6. Computing Contrast Sensitivity Weight

The commonly used CSF function is proposed by Mannos and Sakrison [12], the concrete form is:

$$A(f) = 2.6 \times (0.0192 + 0.114f) \exp(-(0.114f)^{1.1})$$

(3)

Where the spatial frequency $f = \sqrt{f_x^2 + f_y^2}$ (cycles/degree), f_x and f_y are horizontal and vertical spatial frequency respectively.

For image F, each pixel spatial frequency value f is calculated. the image is blocked pixel by pixel, the block size is M*N, then the row space frequency and column space frequency of the image block are shown below respectively [13].

$$f_R = \sqrt{\frac{1}{MN} \sum_{x=0}^{M-1} \sum_{y=1}^{N-1} [F(x, y) - F(x, y-1)]^2}$$

(4)

$$f_C = \sqrt{\frac{1}{MN} \sum_{x=0}^{N-1} \sum_{y=1}^{M-1} [F(x, y) - F(x-1, y)]^2}$$

(5)

The image spatial frequency:

$$f = \sqrt{(f_R)^2 + (f_C)^2}$$

(6)

The f is unitary processed:

$$f_{norm} = \frac{f - f_{min}}{2 \times (f_{max} - f_{min})}$$

(7)

Where f_{max} and f_{min} are the maximum and minimum values of the image blocks spatial frequency respectively; f_{norm} is normalized spatial frequency value. The CSF weight $Q(x, y)$ of image is obtained through putting f_{norm} into formula (3), in this paper M = N = 3. The CSF weighed image of plane is shown in Figure 6.

Figure 6. CSF Weighed Image of Plane

2.7. Calculation of image contrast entropy

To reflect the characteristics of human visual system, the contrast entropy of image (HVSNRC) is obtained by averaging the local band-limited contrast entropy $CE_j^L(x, y)$ weighed using CSF coefficient $Q(x, y)$, the specific calculation formula is as follows:

$$HVSNRC = \frac{1}{k-1}\sum_{j=1}^{k-1}\frac{1}{mn}\sum_{x,y}Q(x,y)CE_j^L(x,y)$$

(8)

Where m, n are image length and width respectively, k is wavelet decomposition level.

3. Experimental Results and Analysis

In order to verify the validity of the proposed assessment method, the contrast images caused by gray-scale stretch and exposure time are chosen to carry out the experiments, and the results are compared to the Lubin local-band contrast (LubinC).

3.1. Gray Stretch Images

a) original image

b) gray stretch 45   c) gray stretch 30

d) gray stretch 15   e) gray compression 15
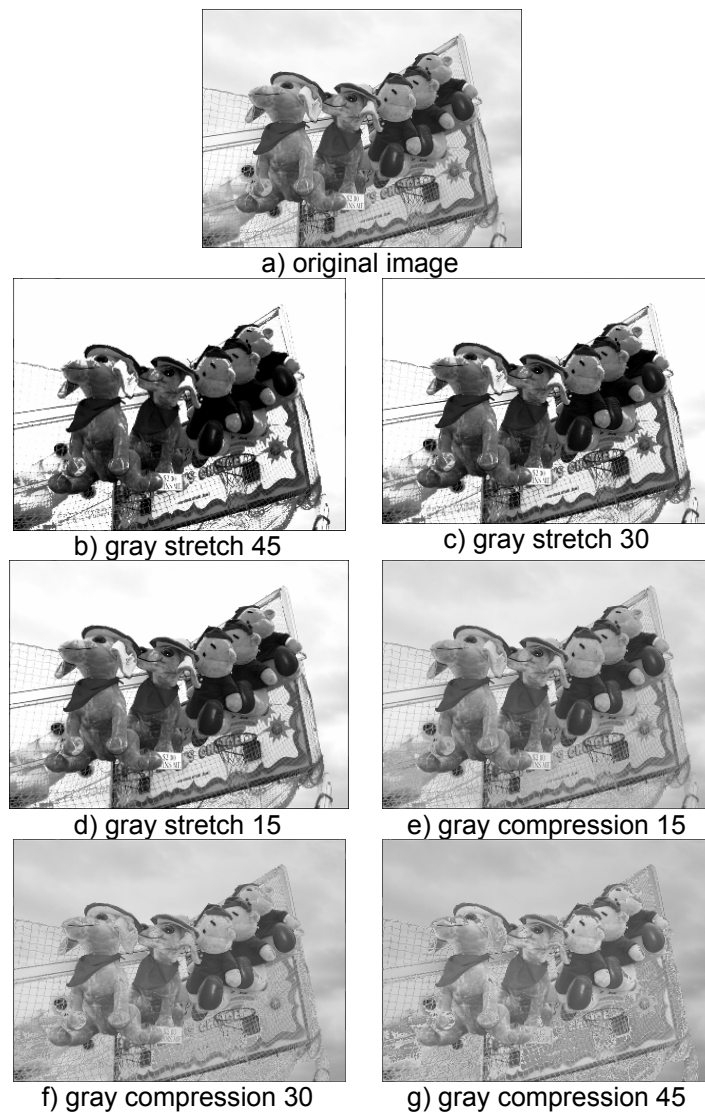
f) gray compression 30   g) gray compression 45

Figure 7. Carnivaldolls and Its Typical State

The original image Carnivaldolls selected in the LIVE Database Release2 image library is processed: the gray of each pixel is stretched to the both sides of mean, the gray value of pixels higher than the mean in the image are increased 45, 40, 35, 30, 25, 20, 15, 10, 5 respctively, while the gray value of pixels lower than the mean in the image are decreased 45,

40, 35, 30, 25, 20, 15, 10, 5 respctively to get 9 pieces of contrast enhanced images; And then the image is to do the opposite process, the gray value of pixels higher than the mean in the image are decreased 45, 40, 35, 30, 25, 20, 15 ,10, 5 respctively, while the gray value of pixels lower than the mean in the image are increased 45, 40, 35, 30, 25, 20, 15, 10, 5 respctively to get another 9 pieces of low contrast images Figure 7 shows the original image and its typical state. In order to facilitate the comparison and analysis, the evaluation values were normalized. Figure 8 shows the comparison for HVSNRC and LubinC, where the serial number of original image is 10, the gray stretching and compressing images are at its right and left sides respectively.
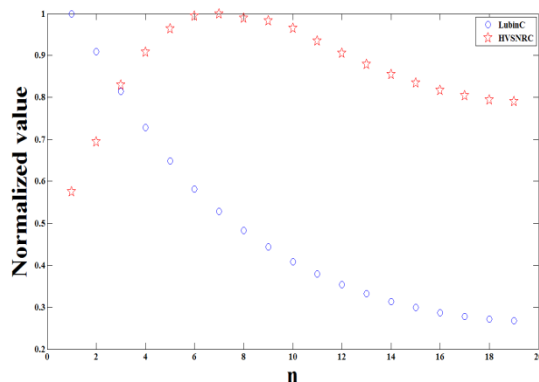

Figure 8. Comparison for 2 Kinds of Methods

As shown in Figure 7, the gray stretch amplitude between 5 and 15 to the original image can enhance image contrast, make the details of the image more clearly, thereby improve the image quality, in which the image d is the best; but with the increasing gray stretch amplitude, image details can not be fully embodied and even lost cause image distortion, image quality is reduced gradually, the B is the worst. The gray compression to the original image also makes the image details become blurred, image quality is reduced gradually, the g effect is the worst. Compared with b and g, the background of image b has been completely lost, the image distortion is very serious, the quality is worse. As you can see from Figure 8, the LubinC assessment results on gray stretch image give the high assessment value, which do not accord with the characteristics of human vision, while the HVSNRC in this paper can accurately identify the best image of contrast in a series of gray image, the assessment result is more consistent with human visual system, and consistent with human subjective feeling.

3.2. Different Exposure Time Images

At present, some people have done a lot of research works in image automatic dimming field [14-15], and image contrast assessment function plays a key role in automatic dimming technology based on image processing.

This part of images are a series of BMP images continuously shot by high-speed camera MS50K produced in Canadian Mega Speed company, the resolution is set to 512* 512, other conditions remain unchanged during filming, the exposure time is adjust ed from 1000μs to 400000μs, the image is selected every 1000us, and 40 pieces of images from the lack of exposure to excessive exposure are selected, Figure 9 shows 6 pieces of images of different exposure time. In order to facilitate the comparison and analysis, the evaluation values were normalized. Figure 10 shows the comparison for HVSNRC and LubinC.

a) 2000µs   b) 7000µs

c) 15000µs   d) 24000µs
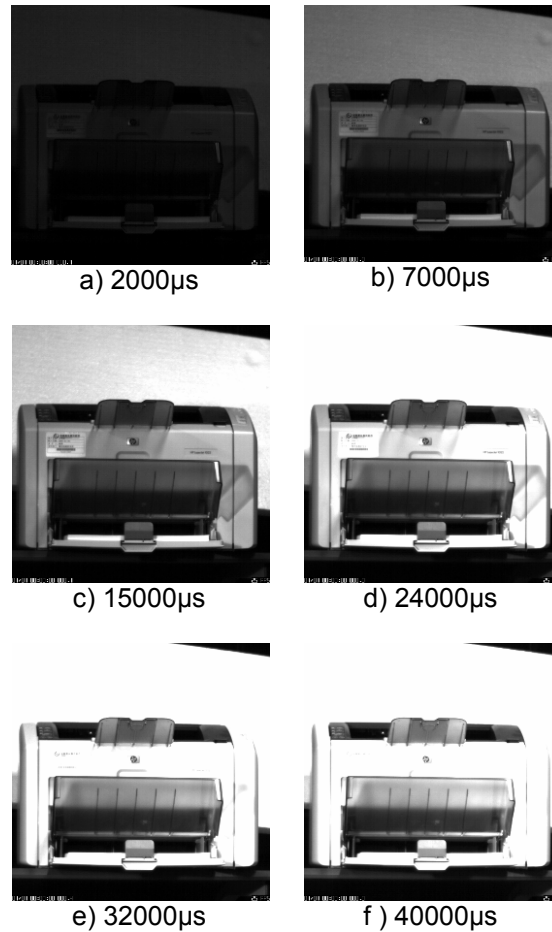
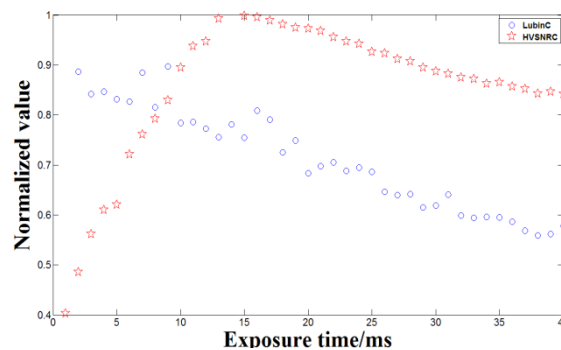e) 32000µs   f) 40000µs

Figure 9. Different Exposure Time Images

Figure 10. Comparison of Two Kinds of Methods

As shown in Figure 9, in the process of adjusting exposure time from 1000µs to 40000µs, at the beginning image exposure is serious inadequacy, the dark part of the details do not been shown up, and the image contrast is very low, while with the increasing exposure time, image contrast is increased gradually, and achieve the best state at 15000us, subsequently the exposure starts excessive, the bright part of the details information get worse and worse. As you can see from Figure 10, the LubinC can not give a good evaluation of images detail lost due to underexposed, the assessment result is not consistent with human visual properties, while HVSNRC could quickly and accurately find out the image of best contrast in a series of exposure image, the assessment result is more consistent with human visual characteristics.

4. Conclusion

In this paper, the analysis of the defects of the local band-limited contrast evaluation method and the human visual system characteristics have been carried out, one image contrast assessment method based on the human visual characteristics is proposed. The experiment results show that the best contrast image can be accurately identified in the sequence images obtained by adjusting the exposure time and stretching gray respectively, the assessment results accord with human visual characteristics and make up the lack of local band-limited contrast.

References

[1] E Peli. Contrast in complex images. *Optical Society of Ameriea.* 1990; 7(10): 2032-2040.
[2] DAIDe-de, SUNHua-yan, HAN Yi, et al. Image quality assessment of laser active imaging system. *Laser & Infrared.* 2009; 39(9): 986-990.
[3] Sanchez-marin FJ, Srinivas Y, Jabri KN, et al. Quantitative image quality analysis of a nonlinear spatio-temporal filter. *IEEE Transactions on Image Processing.* 2001; 10(2): 288-295.
[4] CHEN Yong, AI An-na, WANG Jie, et al. Automatic parameter optimization for lower layer image mining technique. *Journal of Optoelectronics Laser.* 2009; 20(7): 950-953.
[5] GUO Baoping, ZHANG Zhaodong. Application of Blind Image Quality Assessmentin the Intelligent Transportation System. *Transportation Information and Safety.* 2009; 1(27): 157-160.
[6] M Pavel, G Sperling, T Riedl, A Vanderbeek. Limits of visual communication: the effect of signal-to-noise ratio on the intelligibility of American Sign Language. *Opt. Soc. Am.*1987; A4: 2355-2365.
[7] RF Hess, A Bradley, L Piotrowski. Contrast- coding in amblyopia. I. Differences in the neural basis of human amblyopia. *Proc. R. Soc. London Ser.* B 1983; 217: 309-330.
[8] J Lubin. *A visual discrimination model for imaging system design and evaluation in Vision Models for Target Detection and Recognition.* World Scientific Publishing. 1995: 245–283.
[9] S Winkler, P Vandergheynst. *Computing isotropic local contrast from oriented pyramid decompositions.* Proceedings of ICIP. 1999: 420-424.
[10] Wang Kongqiao, Jari A. Kangas.Quality Assessment of Digital. *Images Measurment & Control Technology.* 2000; 19(5): 14-16.
[11] Rafael C Gonzalez. Digital Image Processing Using MATLAB. Publising House of Electronics Industry. 2005.
[12] JL Mannos, DJ Sakrison. The effects of a visual fidelity criterion on the encoding of images. *IEEE Transactions on Information Theory.* 1974; 20(4): 525-536.
[13] WEI Chongkui. Studying of the Method for Image Quality Assessment Model Via HVS. Chang Sha, National University of Defense Technology. 2003.
[14] Jin LX, Lv ZM, Xiong JW. Automatic light-adjusting system of CCD video camera. *Opt. Precision-Eng.* 2002; 10(6): 588-591.
[15] Guan Che, Wang Yan-Jie. Real-time auto light control system of CCD camera. *Opt. Precision-Eng.* 2008; 16(2): 358-366.