Dependence of edge enhancement condition on pixel size

Cheng HongMei, and Yasushi Hoshino, Nippon Institute of Technology, Miyashiro, Saitama, Japan

Abstract

The edge enhancement is effective to improve the subjective evaluation of the image quality. However, when the edge is enhanced too much, the image seems unnatural. Although there are various elements which affect the effect of edge enhancement, it is considered that the pixel size influences the edge enhancement. Considering the expression of a digital image, a detail that the image is expressible depends on the pixel size. The effect of the edge enhancement changes when the pixel size differs in the edge enhancement, and the effect of the edge enhancement is different. In the present study, image size is 207.2mm×155.4mm, and the resolution is 400dpi (3264pixel×2448pixel) and 200dpi (1632pixel×1224pixel) respectively. The samples with different edge enhancement degree are prepared and the subjective evaluation was carried out. The influence of pixel size on the edge enhancement is examined.

Introduction

Digital imaging system has been highlighted as the essential system of digital technology according to the growth of digital medias. The edge enhancement is necessary processing for getting high-quality image in digital image system[1]. The edge enhancement is effective because it makes the image feel sharp. However, when the edge of image is emphasized too much, the image looks unnatural[2][3].

The edge of photographic image is not so sharp in general, and a little blur. Therefore, it is necessary to emphasize the outline, and it is known that the effect depends on pixel size (or observation distance).

The purpose of this study is to obtain the optimum conditions of edge enhancement on several pixel size conditions.

Experimental

In this experiment, a digital camera (OLYMPUS E-500) was used with the minimal edge enhancement condition.

The photographic image is captured in the format of 24bit RGB color and size 3264 × 2448pixels. Output image size is 20.7 × 15.54cm and the resolution is 400dpi. The image quality evaluation is carried out in the method of subjective evaluation with the free observation distance. The original sample image is shown in Fig.1.The used subjective evaluation standards are shown in Table 1. The images with different edge enhancement degree are prepared. The prepared images were compared with the original image (no-edge enhanced image). Experiment was carried out with the testee of 10 students. The images are prepared by two processes which are described below.

Process 1

The resolution of the original image is 400dpi. Then, without changing the size of the original image, two other images of 200dpi and 100dpi were prepared. The degree of edge enhancement is controlled by adjusting the strength factor of Laplacian.

Process 2

In this process, the edge enhancement is carried out as described below;

Case 1: When the original image $f(i,j)$ is processed by Laplacian-type edge enhancement, the enhanced image is expressed as $f^{\Delta(\alpha)}(i,j)$, where $\Delta(\alpha)$ means the edge enhancement with the strength of Laplacian α.

Case 2: The edge enhancement in low resolution layer is expressed as, $f^{2\times\Delta(\alpha)\times 1/2}(i,j)$,

where the suffix 2xΔ(α)x(1/2) means as: (1/2) means that the image data is changed to low resolution (in this case half resolution), the meaning of the $\Delta(\alpha)$ is the same as above (1), and 2 means that image data is interpolated to high resolution (in this case twice).

Case 3: The image is enhanced in the low resolution layer and the addition of the lost data when image is changed to low resolution is carried out,

$$f^{2\times\Delta(\alpha)\times 1/2}(i,j)+(f(i,j)-f^{2\times 1/2}(i,j)) \quad . \qquad (1)$$

Figure 1. *Sample image.*

Table 1. Subjective evaluation standard.

Evaluation	Comparison with no-enhanced image
5	Feel better than no-enhanced image
4	Feel a little bit better than no-enhanced image
3	Feel the same as no-enhanced image
2	Feel a little bit worse than no-enhanced image
1	Feel worse than no-enhanced image

Operator of edge enhancement

The edge enhancement is carried out using the matrix as shown in Fig. 2. The degree of edge enhancement is controlled by adjusting α [4][5][6].

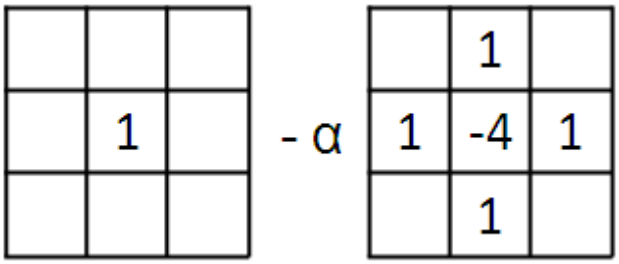

***Figure 2**. Edge enhancement operator.*

$$\phi' = \phi - \alpha \cdot \Delta\phi \qquad (2)$$

Concerning the pixel value, the processed by Eq.(2) is expressed as follows;

$$P'_{ij} = (1+4\alpha)P_{ij} - \alpha P_{i-1,j} - \alpha P_{i,j-1} - \alpha P_{i+1,j} - \alpha P_{i,j+1} \qquad (3)$$

Where, Pi,j is the preprocessed image value of position (i, j), P' i,j is the processed value, and α is the parameter for controlling the degree of edge enhancement[4][6].

Results and Discussions

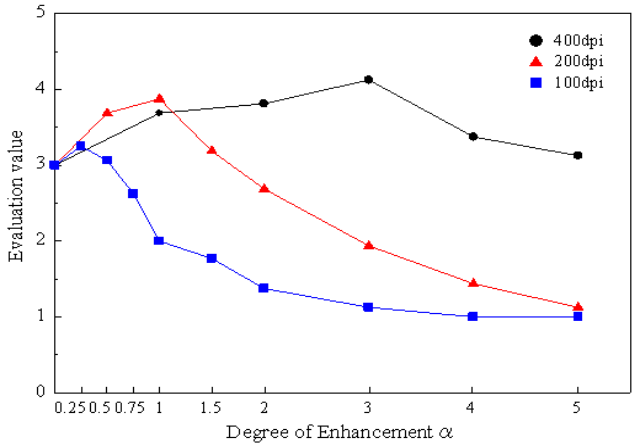

***Figure 3.** Result of the subjective evaluation of process 1.*

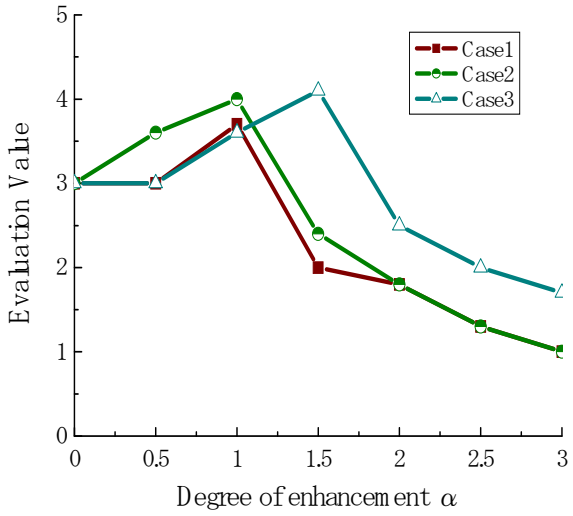

***Figure 4.** Result of the subjective evaluation of process 2.*

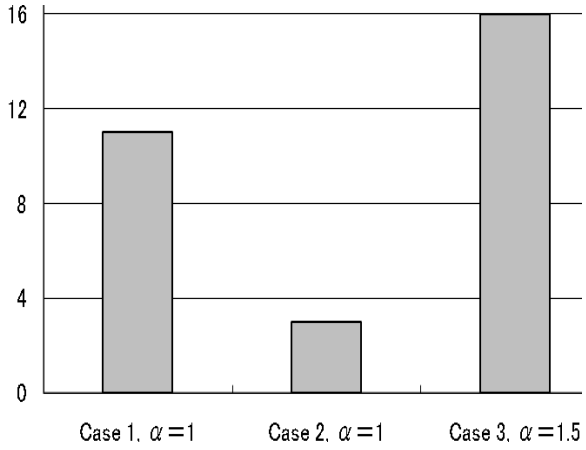

***Figure 5.** Result of the pair comparison evaluation of process 2.*

The evaluated results dependence on degree of enhancement of process1 is shown in Fig. 3. From Fig. 3 it can be found that the peak values decrease as the resolution decreases. Remarkable point is that the peak shift to weak edge enhancement side as the resolution decreases. It is found that the edge enhancement have strong effect in the scale of the edge enhancement degree α, as the resolution decreases.

Fig.4 shows the evaluated results dependence on degree of enhancement in process 2. It is found that the evaluated values show peaks around α=1~1.5. So, the image quality of three peaks is evaluated by a pair's comparison. The result is shown in Fig.5. It is confirmed that the image quality of process2 (3) is best.

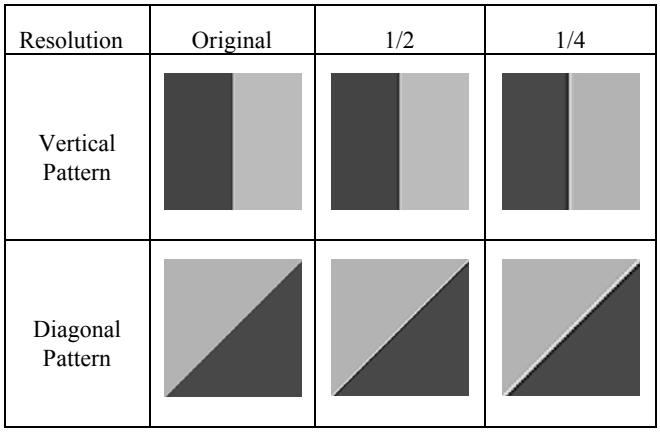

Figure 6. *Pattern images.*

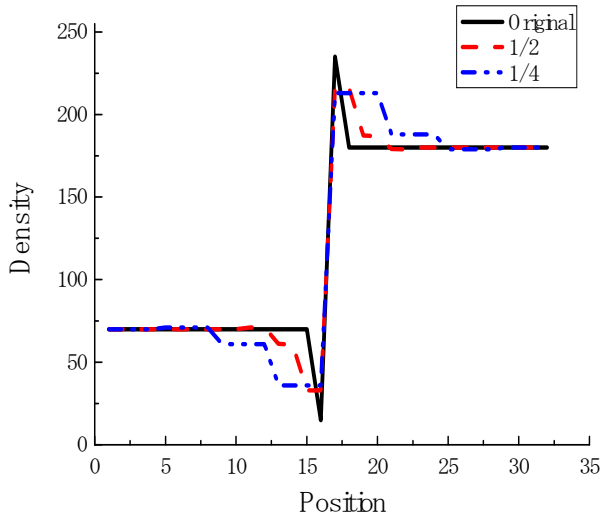

Figure 7 . *Edge profiles in horizontal scan for vertical pattern.*

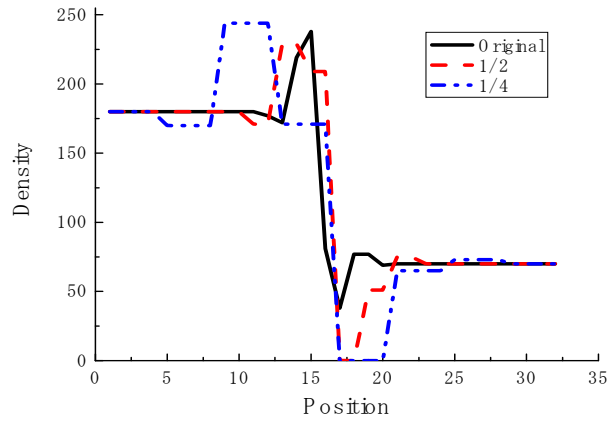

Figure 8. *Edge profiles in horizontal scan for diagonal pattern.*

Simple density jump patterns of original resolution, half resolution and one forth resolutions are shown in Fig. 6. Two types of vertical and horizontal pattern are prepared. The edge enhancement is felt stronger as the resolution becomes low. In order to get deeper understanding, density changes around the edge by edge enhancement are plotted in Fig. 7and Fig.8. From these Figures, it is found that the area or volume of edge enhancement increases as the resolution becomes low. Therefore it is considered that edge enhancement effects stronger in the low resolution.

Conclusions

The edge enhancement is effective to improve the subjective evaluation of the image quality, so optimum degree of edge enhancement is studied. The images of the resolutions of 400dpi, 200dpi and 100dpi are processed with different degrees of edge enhancement and subjective evaluation is carried out on these images. It is found that the peaks of image quality shift to weak side of degree of edge enhancement as the resolution becomes low. The method of edge enhancement in low resolution layer is proposed and its effect is confirmed by subjective evaluation.

References

[1] H. Kotera, H. Wang, "Multi-Scale Image Sharpening with Noise Reduction", IS& T's NIP18: International Conference on Digital Printing Technologies, (2000) pp.814-817.

[2] H. Cheng, P. Kajondecha, Z. Jiang, Y. Hoshino "Object dependence of optimum edge enhancement condition", IS& T's NIP24: International Conference on Digital Printing Technologies, (2008) pp.411-414.

[3] H. Cheng, P. Kajondecha, Z. Jiang, Y. Hoshino "Dependence of optimum edge enhancement condition on observation distances and objects", PPIC'08 Pan-pacific Imaging Conference, (2008) pp.294-297.

[4] P. Ratanasakornchai, L. Shi, Y. Nakamura and Y. Hoshino, "Dependence of Image Quality on Edge Enhancement Condition", IS& T's NIP20: International Conference on Digital Printing Technologies, (2004) pp.474-476.

[5] H. Hayashi, P. Ratanasakornchai, M.Hu and Y. Hoshino, "Dependence of Image Quality on the Degree of Edge Enhancement", IS& T's NIP18: International Conference on Digital Printing Technologies, (2000) pp.678-681.

[6] J. Yue, H. Cheng and Y. Hoshino, "Dependence of Edge Enhancement on Object", 6th Korea_Japan Joint Symposium, (2005) pp.105-108.

Author Biography

HongMei Cheng is a PhD. Student in Hoshino Laboratory, Dept. of Systems Engineering , Nippon Institute of Technology, Japan. She has graduated in Computer and Information Technology from Qiqihar University, China. Her research interest includes image processing.

Yasushi Hoshino (IST Fellow) is Professor of Nippon Institute of Technology. He gained Bs., Ms. And Dr. degree from the University of Tokyo, 1970, 1972, and 1984 respectively. After he gained Ms. Degree, he joined Electrical Communication Laboratories of NTT and joined the developing of first LED printer, high speed laser printer, color-laser printer by using ultra elliptical laser beam scanning, photo-induced toning

technology and ion flow printing. He moved to Nippon Institute of Technology on 1994. His recent interests are toner technology, corona discharge and image processing. (E-mail: hoshino@nit.ac.jp)