

Dependence of Image Quality on the Degree of Edge Enhancement

Hironori Hayashi, Pranchalee Ratanasakornchai, Hu Mei, and Yasushi Hoshino
Nippon Institute of Technology
Saitama, Japan

Abstract

Edge enhancement is an important image processing in imaging systems. When the enhancement is insufficient, we feel the image is out of focus, but when it is too strong, we feel unnatural. So, the optimum degree of the edge enhancement is investigated by using subjective evaluation. Several types of image are prepared by digital still camera (D1, Nikon). The image capturing conditions are no edge enhancement, no image data compression and taking care of low noise. The edge enhancement is carried out on adjusting neighboring 4 pixels according to Laplacian operation. The degree of the edge enhancement is adjusted by controlling the intensity of Laplacian operation. In every images, the image quality is improved by certain degree of edge enhancement. It is observed that the optimum degree of edge enhancement shows difference among the categories of images.

Introduction

Digital image processing becomes popular recently with the progress of DSC (Digital Still Camera), computer and network. Various method of image processing is studied and used in imaging systems. The reproduction of tone and color is important points of imaging system and edge enhancement is also important image processing because it improves image sharpness.

Edge enhancement is fundamental processing and is usually picked up in the books on the image processing.¹ The edge enhancement is carried out in analogue processing and is also important processing in digital processing. The function of the edge enhancement is implemented in DSC and image scanner. The processing makes the slope and the difference of the image data at the edge increase, so the edge becomes to be felt sharp. The degree of the edge enhancement is usually determined by trial and error.

Recently, it is reported that image quality is greatly improved by adaptive edge enhancement.^{2,3} To obtain the optimum degree of edge enhancement is important point.

In this paper, to understand the optimum condition of the edge enhancement, the subjective evaluation of image quality is carried out on various degree of edge enhancement. The characteristics of the imaging system for the edge of black-white are measured and the results of the

subjective evaluation are discussed from the viewpoint of human recognition mechanism.

Experimental

The images prepared in these experiments are building, faces and flower. The images of building and faces are shown in Fig. 1. The conditions of photographing are as follows:

DSC: D1, Nikon,
 Mode: no compression, no edge enhancement,
 Image size: 2000 x 1312 pixels.

The edge enhancement is carried out using the matrix shown in Fig. 2. The matrix means the following processing,

$$P_{ij}' = (1+4\alpha)P_{ij} - \alpha P_{i-1,j} - \alpha P_{i+1,j} - \alpha P_{i,j-1} - \alpha P_{i,j+1}, \quad (1)$$

where, P_{ij} is the preprocessed image value of position (i,j) , P_{ij}' is the processed value, and α is the parameter for controlling the degree of edge enhancement. Equation (1) corresponds to the following relation:

$$\phi' = \phi - \alpha \Delta \phi, \quad (2)$$

where, ϕ means preprocessed image value, ϕ' means processed image value and Δ means Laplacian operator. We define α as the degree of edge enhancement. A value α is changed from 0 to 5.5 by 0.5 step. The matrix of edge enhancement used in this experiment is shown three dimensionally in Fig. 3.

The processed images of various degree of edge enhancement are printed (Pictography 3000, Fuji Film). The print size is 12.7cm x 8.33cm. The resolution of the printer is 400 dpi and every pixel can express 256 tone levels. The images are estimated subjectively by pair comparison. The evaluation is accomplished on 15 students under the office level fluorescent lamp illumination.



(a) Building

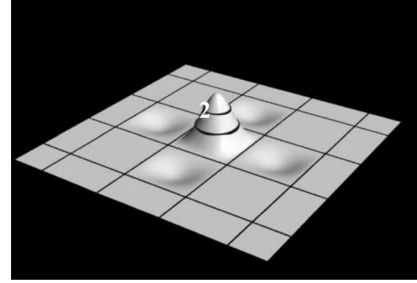


(b) Face

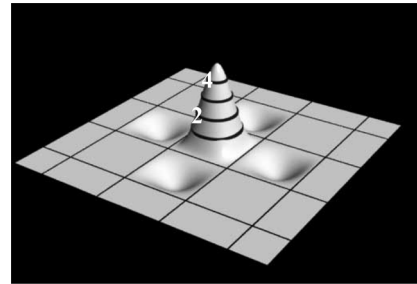
Figure 1. Images used for the experiment.

	$-\alpha$	
$-\alpha$	$1+4\alpha$	$-\alpha$
	$-\alpha$	

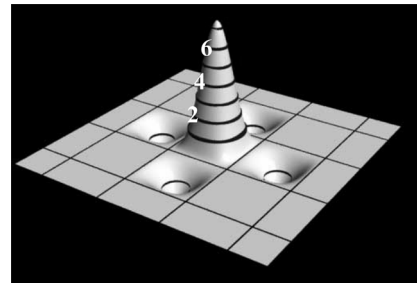
Figure 2. Laplacian filter.



(a) $\alpha = 0.5$



(b) $\alpha = 1.0$



(c) $\alpha = 1.5$

Figure 3. 3D plot of edge enhancement filter, lines means contour line.

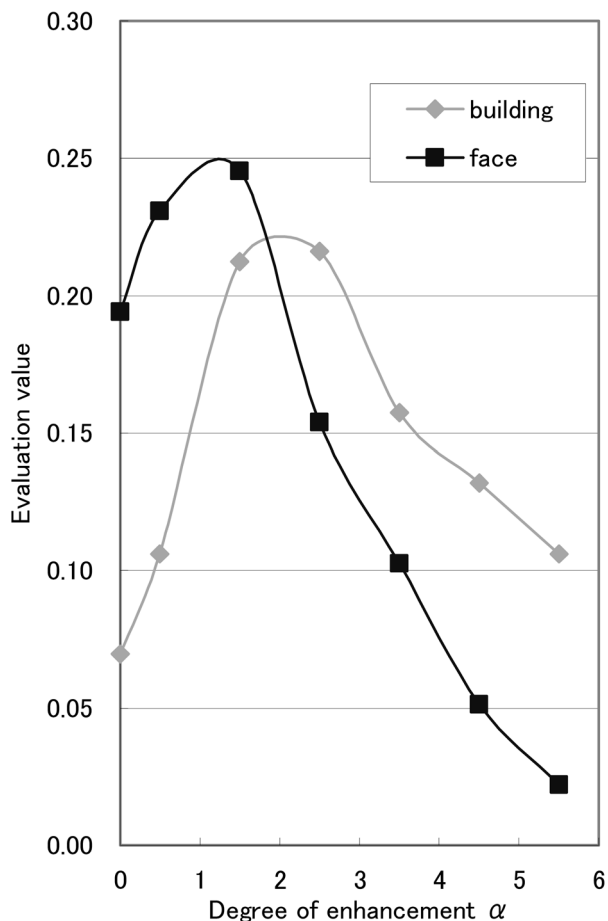


Figure 4. Result of the subjective evaluation.

Results

The result of the subjective evaluation is shown in Fig. 4. It is found that the evaluation value shows a peak versus the degree of the edge enhancement. It is noticed that the position of peaks and the tendency of the curves are different. Face image shows high evaluation value at the weak enhancement and the value decreases abruptly with the increase of the degree of enhancement. Concerning the building, the value shows a peak at the degree of enhancement of 1.5 - 2.5. The examples of the images around the peak are shown in Table 1. We can understand the edge becomes clear at $\alpha = 2.5$, however for human face the details of fine wrinkle are too enhanced.

To examine the effect of enhancement in this imaging system, edge of black to white is photographed by DSC, and the effect of enhancement is plotted in Fig. 5. From Fig. 5, it is found that the evaluation value is high when the edge is more enhanced than the original.

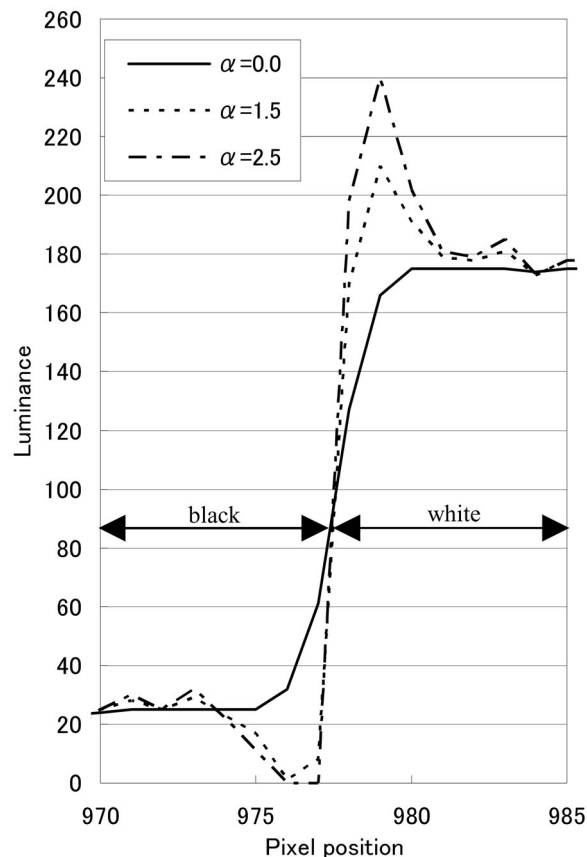


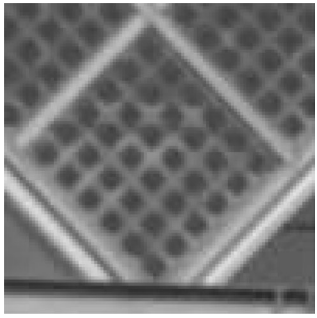
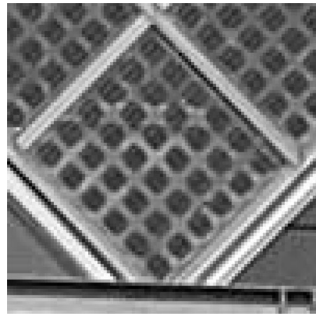
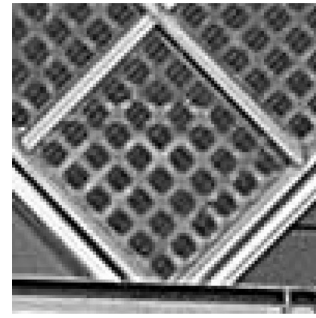


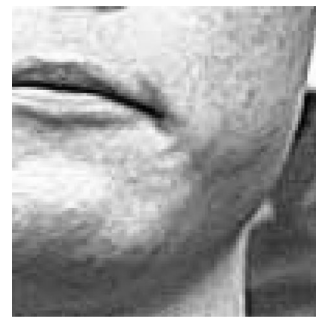
Figure 5. Edge profiles in scan line after enhancement.

Discussions

Human vision system has function of edge enhancement for recognizing the shape of object.⁴ The function is known as Mach effect. When the edge of object is enhanced, our vision system become easy to recognize the shape, so it is considered that the value of subjective evaluation increases. However, if the edge is enhanced too much, it is considered that the image become to feel unnatural and the evaluation value decreases.

Why the position of peaks has the dependence on object. The reason is considered from the difference of the points on which our attention is focusing. When our attention is focused on color, the edge enhancement is not so important. However, when our attention is focused on shape or edge, the edge enhancement is preferable and unnatural characteristics that arise from the enhancement is hard to be felt eyesore. The dependence is also suggested from the following things: human visual system has the function of edge enhancement in shape recognition, however the system has no function of edge enhancement in color recognition. From the viewpoint of application, object dependent edge enhancement is considered effecting in DSC.

Table 1. Comparison of sharpened images.

Degree of enhancement images	$\alpha = 0.0$	$\alpha = 1.5$	$\alpha = 2.5$
building			
face			

Summary

It is obtained from the subjective evaluation that the optimum degree of edge enhancement depends on the image. The optimum degree of the enhancement of human face is weaker than the degree of the enhancement of building. It is considered that when our sense concentrates on shape, the enhancement is effective, however when our sense concentrate on color, the enhancement is not so necessary.

Acknowledgements

The authors would like to express their thanks to the persons who cooperate for the subjective evaluation.

References

1. J. C. Russ, "The Image Processing Hand Book" Third Edition CRC/IEEE Press, (1999) pp.243-247.
2. H. Kotera, Y. Yamada, K. Shimo, "Adaptive Edge Sharpening by Multiple Gaussian Filters", *IS&T's NIP16 2000 International Conference on Digital Printing Technologies*, (2000) pp. 814-817.
3. H. Kotera, "Intelligent Image Processing", *ICIS'02*, Tokyo (2002) pp. 606-607.
4. E. M. Lowry and J. J. DePalma, "Sine-wave response of the visual system, I. The Mach phenomenon", *J. Opt. Soc. Am.* **51** (1961) pp.740-746.

Biography

Hironori Hayashi is graduate course student of Nippon Institute of Technology. He gained Bs. Degree from Nippon Institute of Technology and is now studying image processing engineering in Hoshino laboratory of Nippon Institute of Technology. E-mail:hayashi_hironori@hotmail.com

Hoshino Yasushi is Professor of Nippon Institute of Technology. He gained Bs., Ms. And Dr. degrees from University of Tokyo, 1970, 1972, and 1984 respectively. After he gained Ms. Degree, he joined Electrical Communication Laboratories of NTT and developed 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.