

Dependence of optimization condition of edge enhancement on observation distances

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Abstract

It is important to emphasize the contour of image in imaging system to make us feel the image sharp. The edge enhancement is effective to improve subjective estimation of image quality. But if the edge is enhanced too much, the image becomes unnatural. The space frequency components of the image change when the observation distance is different and the effect of the edge enhancement is considered to be different. The image qualities of the simple object captured by digital camera and the object made by CG was examined under various conditions such as the observation distance, illumination. The optimization conditions of edge enhancement by a subjective evaluation are obtained. The results of subjective estimation are discussed from the viewpoint of HVS (Human Visual System).

Introduction

Digital image system has been highlighted as the essential component of digital technology since the growth of digital medias.. The edge enhancement is effective because it appropriately makes it to the image of the high-resolution in applied field. The edge enhancement is effective to improve the evaluation of the subjectivity of the image quality. However, when the outline is emphasized too much, the image looks unnatural. It is forecast that the space frequency element to eyes of the image changes when the observation distance is different and the effect of the edge enhancement is different.

The density distribution of an outline of the photographic image place is clearly seen. It grows dim the step, and a little however completely it. The sight characteristic includes the characteristic that the outline grows dim. Therefore, it is necessary to emphasize the outline, and the effect depends on the observation distance.

The image qualities of the simple object captured by digital camera and the object made with CG were examined under various conditions such as is obtained the observation distance, illumination, and the optimization conditions of edge enhancement by a subjective evaluation. The results of subjective estimation are discussed from the viewpoint of HVS (Human Visual System).

Experimental

Sample images can be shown in Fig. 1; (a) is a CG image. (b) is the photographic image of cubes made by metal and wood material. Illumination box (in Web dot studio WS-230D PRO) is used to control the environment. The photographic images are taken by digital camera (OLYMPUS E-500) with resolution 300ppi and output with resolution 2000×1600 pixels.

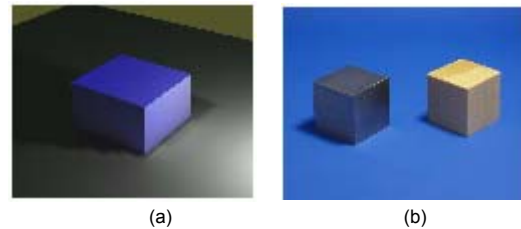


Figure 1. Experiment images, (a)CG, (b) Image

Operator of edge enhancement

The edge characteristic generated from the discrete area in a visual image can be extracted by the process corresponding to the density difference. The position where the contour exists is signified as 0 intersection positions of the second-order differentiation of the density distribution. In this regards, Laplacian filter of the second-order differentiation is not applicable to corresponding to the edge of a visual image when the noise appears. Laplacian filter is a derivative filters used to detect the discrete area or edge of a visual image. Since the derivative filters are very sensitive to noise, the image is generally applied some techniques in order to improve the noise such Gaussian filter. These two-steps processing names the Laplacian of Gaussian (LoG) operation. This $\nabla^2 G$ filter is corresponding to the receptive field sensitivity distribution of ganglion cells of retina well[1][2].

In the case of original image $f(x, y)$, smoothen by the gauss function and the calculation of the Laplacian are performed as follows. A two-dimensional isotropic gauss function of standard deviation σ the initial value is 0.

$$G(x, y) \equiv \frac{1}{2\pi\sigma^2} \exp\left\{-\frac{x^2 + y^2}{2\sigma^2}\right\} \quad (1)$$

Smoothing image $F(x, y)$ are provided by doing $f(x, y)$ and convolution of it.

$$F(x, y) = G(x, y) * f(x, y) \quad (2)$$

$$\begin{aligned} \nabla^2 F(x, y) &= \nabla^2 \{G(x, y) * f(x, y)\} \\ &= \{\nabla^2 G(x, y)\} * f(x, y) \end{aligned} \quad (3)$$

(*) means convolution in an expression

The LoG filter provided by a Laplacian operator of $F(x, y)$ next is an Eq.(4).

$$\nabla^2 G(x, y) = \frac{x^2 + y^2 - 2\sigma^2}{2\pi\sigma^6} \exp\left\{-\frac{x^2 + y^2}{2\sigma^2}\right\} \quad (4)$$

Table 1. Condition of step2

	$\sigma=0.6$	$\sigma=0.8$	$\sigma=1.0$	$\sigma=1.2$	$\sigma=1.4$
step2-1	a=1.8	a=1.3	a=1.0	a=0.6	a=0.5
step2-2	a=2.7	a=1.9	a=1.5	a=0.9	a=0.7
step2-3	a=3.6	a=2.5	a=2.0	a=1.2	a=0.9

Table 2. Condition of step3

	$\sigma=0.6$	$\sigma=0.8$	$\sigma=1.0$	$\sigma=1.2$	$\sigma=1.4$
step3-1	a=1.0	a=0.6	a=0.3	a=0.1	a=0.1
step3-2	a=1.7	a=1.0	a=0.4	a=0.2	a=0.2
step3-3	a=3.9	a=2.3	a=1.0	a=0.6	a=0.4
step3-4	a=6.7	a=4.0	a=1.7	a=1.0	a=0.7

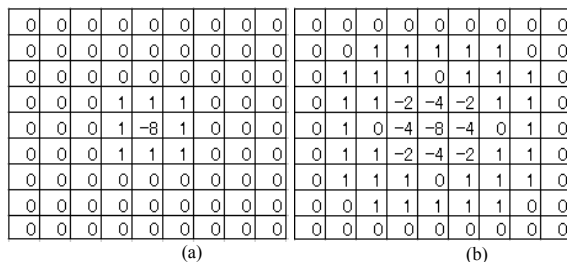


Figure 2. *LoG filter, (a) $\sigma=0.6$, (b) $\sigma=1.4$.*

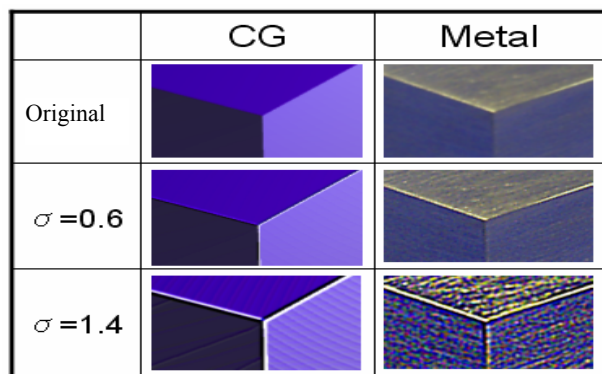


Figure 3. Comparison of sharpened image images.

Table 3. Subjectivity evaluation Standard

Evaluation	no-enhanced Image and Comparison
5	Feel better than no-enhanced image
4	Feel a little better than no-enhanced image
3	Feel the same and no-enhanced image
2	Feel a little worse than no-enhanced image
1	Feel worse than no-enhanced image

Smoothing and the Laplacian can be done simultaneous by doing convolution of this function and image $f(x,y)$.

The edge enhancement is generated as Eq. (5)

$$f'(x, y) = f(x, y) - \alpha \nabla^2 G(x, y) \quad (5)$$

α shows the degree of the edge enhancement[2][3].

In this research, the operator of the LoG filter of the edge enhancement is calculated by Eq. (3).

We adopt the edge enhancement technique to the experimental images. The size of the operator is 9x9 matrixes. The center of the matrix contains the value as 8, which is the general number used in edge enhancement technique.

Since the Laplacian filter technique used for edge enhancement by changing the degree, it generates the different significance affecting the contour perception. In this study, we control σ of the LoG filter in order to investigate the affect of it's for the human perception.

We separate the study into 3 steps that use the σ value from 0.6 to 1.4 by increase 0.2 step for each level. In the first step, α is generated to 0.5, 1.0, 2.0, 2.5, and 3.0. We then generate the σ and α value according to table 1 in step 2. Final we generated the conditions according to table 3. Fig.2 shows the matrix of each generated operator.

Fig.4 shows Comparison of sharpened images. We can see that the degree of the emphasis is different depending on the size of σ .

The Experimental Methodology

The experiment is conducted by subject evaluation with the observation distance 1m, 2m, and 3m. The subjectivity evaluation standard can be shown in Table 3[4]. The images are evaluated subjectively with 10 students by pair comparison under the office level fluorescent lamp illumination.

Results and Discussions

Step 1

Fig. 4 shows the result of subjective evaluation with the observation distance 1.0m and 3.0m, for the CG images. It is found that human can detect the effect of σ in irregular at the short distance when σ was small value. The perception tends to decrease when the observation distance increases.

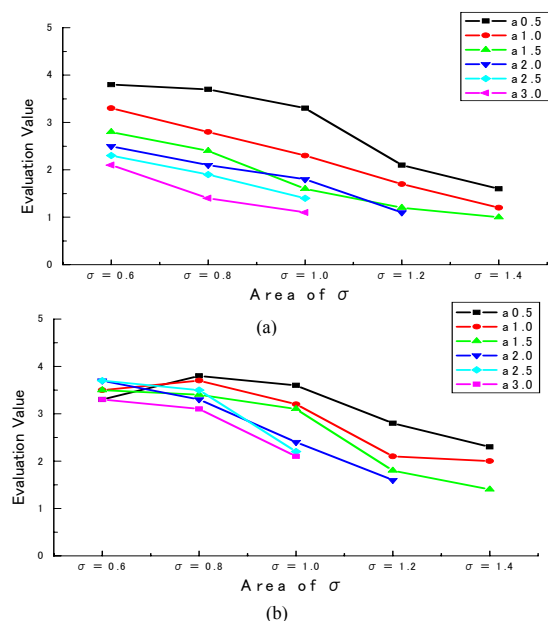


Figure 4. Result of the subjective evaluation on observation distance, (a) CG, 1.0m, (b) CG, 3.0.

Fig.5 shows the result of subjective evaluations when σ is 0.6 and 1.0 for the photographic images. The σ value has no influence with perception when σ is 0.6.

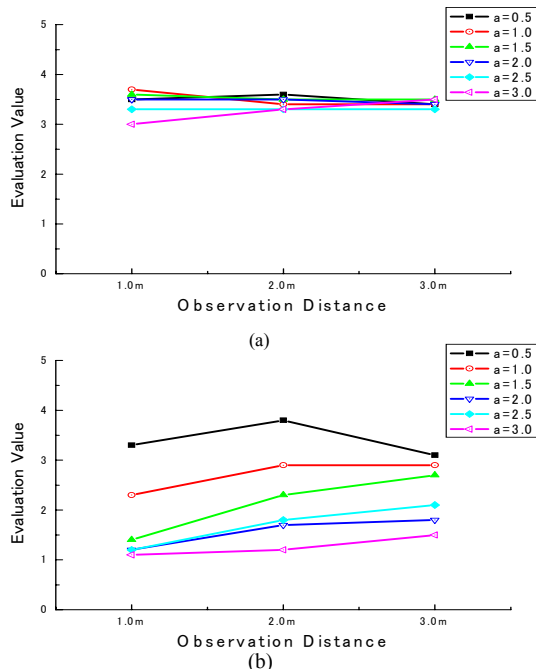


Figure 5. Result of the subjective evaluation by degree, (a) image, sig=0.6, (b) image, sig=1.0.

Whereas the σ value influence the perception when σ is 1.0. It can be said that the perception tends to decrease when α increases.

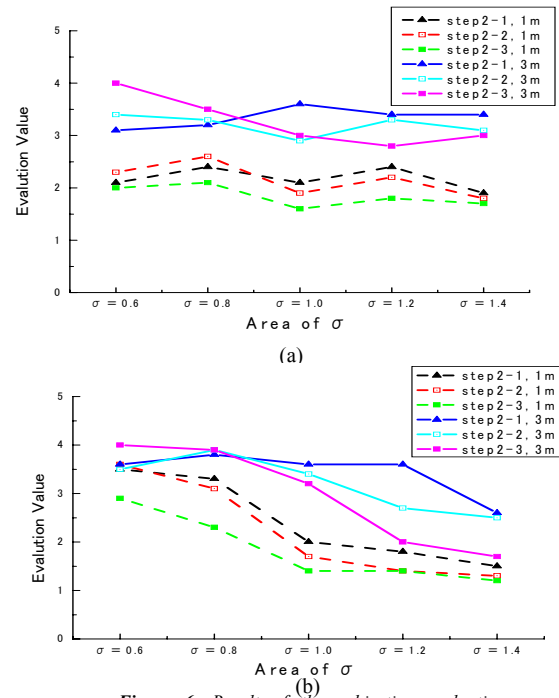


Figure 6. Result of the subjective evaluation on observation distance and step2 lever, (a) CG, (b) image

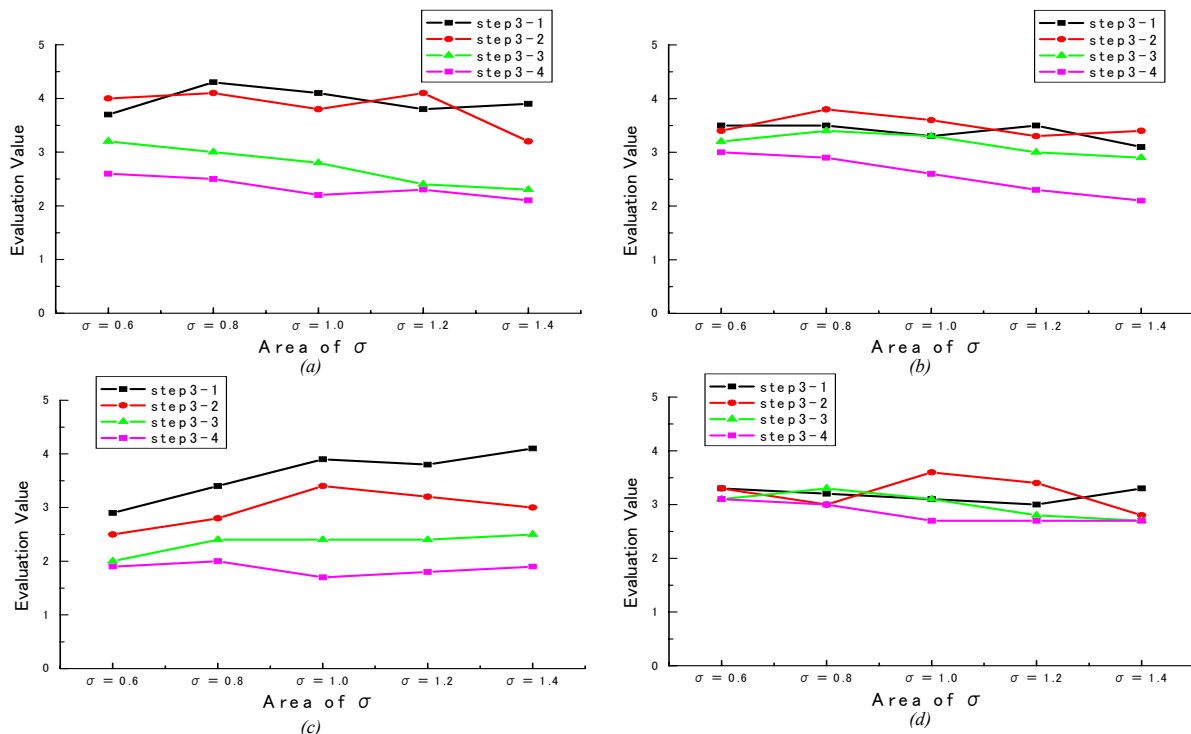


Figure7 Result of the subjective evaluation, (a) on observation distance 1m, image, (b) on observation distance 3m, image, (c) on observation distance 1m, CG, (d) on observation distance 3m, CG.

Step2

Fig.6 shows the result of subjective evaluation respectively by the CG image and the photographic image. In the result of (a), the evaluation value of 3m in observation distance is greater than the evaluation value of 1m.

Fig. 6 (a) shows that the perception tends to stable though the σ value increases for the CG image. Fig. 6 (b), on the other hand, shows that the perception tends to decrease when the σ value increases for the photographic image.

Step3

Fig.7 shows the results of step 3 when the σ is fixed. The results from Fig. 7 (a) and (b), which is the photographic image, show that the observation distances slightly affect the perception. Whereas Fig. 7 (c) and (d) show the result in another way. The observation distance tends to affect the perception for the CG image. It can be said that the CG image with observation distance 1m looks unnatural that observation distance 3m.

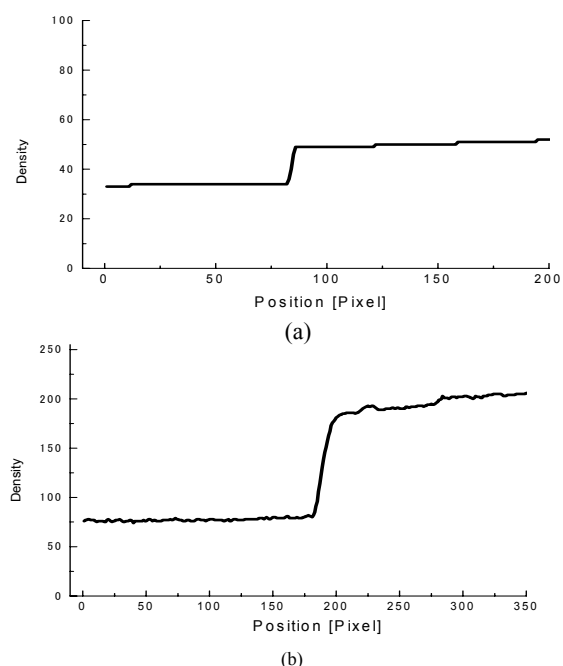


Figure 8. Edge profiles in scan line, (a) CG image, (b) Photographic image.

Fig.8 shows that the CG image provide the smoothly edge profile whereas photographic image provide the edge profile with noise. The result shows that σ value influence the edge profile for photographic image. The noise increases when the σ value increases. It can be said that human can detect noise in photographic image easier then the CG image.

It was confirmed that the subjectivity evaluation was different depending on the area within the range of processing. The area and the height of the receptive field on the retina change into it by the environment. It is thought that the area and the height of the receptive field change at the same time to fill the same effect with a different condition. As for it, the tendency has been understood from the experiment result of this research.

The difference, which is the rank between maximum and minimum of evaluation value, arises when the observation distance less than 1.0m. On the other hand, the difference tends to decrease

when the observation distance more than 3.0m. Author result shows that human can percept the texture of image easily when the observation distances less than 1.0m. The σ influences the resolution of the image and evaluation value. The textures of an image seem to be clear whereas the evaluation value tends to decrease when the σ value increases. That means an image seem to be unnatural when σ value high.

Conclusion

To obtain the optimal condition of edge enhancement for the photographic images and the CG images, subjective evaluations are carried out on various edge enhancement conditions. The LoG filter is used in this experiment. The filter is expressed 9x9 matrixes and the value of the center is 8. The subjective evaluation value increases. When the σ value of LoG decreases at the short observation distance. The peak of the subjective evaluation value at the greats σ is slightly different when the observation distance increases. Edge enhancement generated by LoG filter; addict the different characteristics of the subjective evaluation due to the roughness of the surface of object.

References

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Author Biography

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