Dependence of Image Quality on Edge Enhancement Condition

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Abstract

Edge enhancement is effective to improve image quality. The optimum condition of edge enhancement has been studied. When the edge of object is enhanced, our visual system becomes easy to recognize the shape. But if the edge is enhanced too much, it is considered that the image become to feel unnatural. We found that the optimum edge enhancement depends on the categories of image. In this paper, the quality of image is improved by adjusting the strength and extent of edge enhancement. The images are captured under no-edge-enhancement and no-data-compressing conditions by digital still camera. The strength of the edge enhancement is modified by controlling the amount of Laplacian component and the extent of the edge enhancement is modified by the number of neighboring pixels processed. The image quality of various strength and extent is estimated by subjective evaluation. It is obtained that the edge enhancement is effective in human visual system when we concentrate on the shape of image.

Introduction

In recent years, the importance of digital image processing in the progress of Digital Still Camera (DSC), computer and network is increasing. 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.[1]

The goal of image enhancement is to improve the overall quality of an image for use in pattern recognition systems or for viewing by the human visual system.[2] Edge enhancement technique accentuates all edge details in an image without discriminating as to spatial orientation. Edge enhancement is performed by applying a high pass filter to the image. The easiest method available to implement edge enhancement is convolution of which there are a number of techniques. All of the techniques use weighting which is defined as determining a pixel's data by comparing the data of neighboring pixels. Edge enhancement is fundamental processing and is usually picked up in the books on the image processing. The edge enhancement is carried out in analogue processing and is also important processing in digital processing.[3]

Gaussian Derivative Operator

The derivative of Gaussian filter can be pre-computed analytically, since it is independent of the image under consideration. Thus, the complexity of the composite operation is reduced. The basic Gaussian derivative function in two dimensions is defined by[4-6]

$$G(r) = \frac{1}{2\pi\sigma^2}\exp\left(-\frac{r^2}{2\sigma^2}\right); \quad r^2 = x^2 + y^2 \tag{1}$$

where x, y are the image co-ordinates and σ is a standard deviation. The 2nd order of Gaussian derivative operator is defined by:

$$\begin{aligned}\nabla^2 G(x,y) &= \frac{\partial^2 G(r)}{\partial x^2} + \frac{\partial^2 G(r)}{\partial y^2} \\ &= \frac{1}{\pi\sigma^4}\left(\frac{r^2}{2\sigma^2} - 1\right)\exp\left(-\frac{r^2}{2\sigma^2}\right)\end{aligned} \tag{2}$$

The standard deviation σ is the parameter of the Gaussian derivative, it is proportional to the size of the neighborhood on which the operator. The size of neighborhood is m×m where m = 8σ+1. The 2D shape of Gaussian Derivative is shown in Fig. 1.

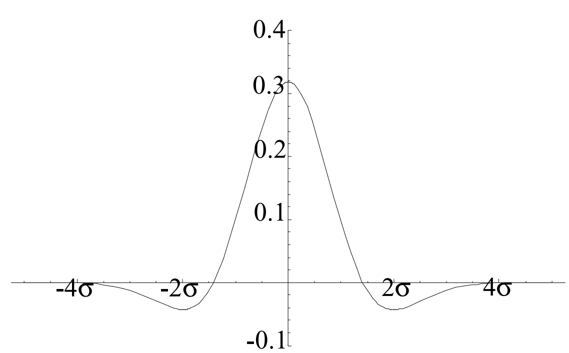


Figure 1. The second derivative of the one-dimensional Gaussian operator

The 2nd order Gaussian Derivative operator is applied to image by:

$$I'(x, y) = I(x, y) - \alpha \nabla^2 G(x, y) I(x, y) \tag{3}$$

$$I'(x, y) = I(x, y) - \alpha \left[\frac{1}{\pi\sigma^4} \left(\frac{r^2}{2\sigma^2} - 1 \right) \exp\left(-\frac{r^2}{2\sigma^2} \right) \right] I(x, y) \tag{4}$$

where *I(x,y)* is the input image, *I'(x,y)* is the enhanced image and α is the degree of the edge enhancement.

Experiments

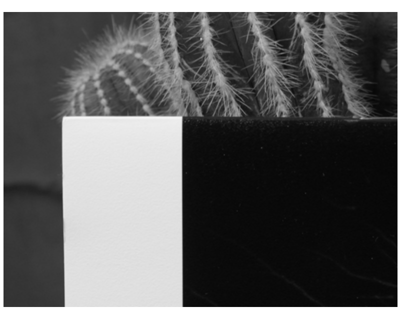
The sample images are captured and printed out under the condition as follows:

Digital still camera: D1, Nikon,
Mode: no-edge-enhancement and no-data-compressing,
Image size: 2560×1920 pixels,
Printer: Pixus 9900i, Canon.

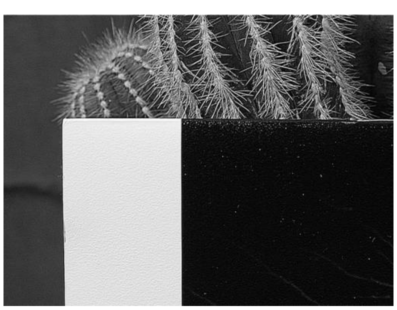
For the processing in this experiment, the 2nd order of Gaussian derivative is applied to image by the difference of α and σ values in Eq. 4. The variation of the standard deviation, σ, modifies the size of neighborhood and the degree of the edge enhancement is controlled by various α value.

Experimental Results

The results of the edge enhancement are shown in Fig. 2, the enhanced image Fig. 2(b) is compared with the original image Fig. 2(a).



(a) original image



(b) enhanced image

Figure 2. Comparison of the original and the enhanced image

In the image, we concentrate on the characters image to see the edge enhancement. From Fig. 3(d), when σ is 1.0 (the size of neighborhood = 9 × 9) and α is 1.0, the edge of characters is clearer than the original image. Figure 3 is the close up of the character in the enhanced image for comparing the result with the difference of α and σ value. A larger σ value (larger neighborhood) and a larger α value produces the enhanced character clearer than a smaller one.

(a) original

(b) α=1.0, σ=0.5

(c) α=2.0, σ=0.5

(d) α=1.0, σ=1.0

(e) α=1.0, σ=1.5

Figure 3. The comparison of sharpening effects in characters of difference α and σ value in close up: (a) is original image, (b)-(d) are the enhanced image.

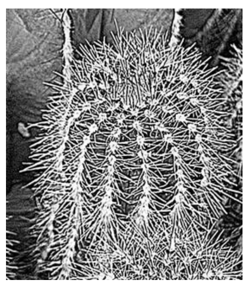
In addition to, human can recognize the shape of object by function of edge enhancement.[7] In this experiment, when the edge of object is enhanced, human visual system easily recognizes the shape of cactus's thorn. In Fig. 4, the thorn of a cactus is sharpened by increasing the value of α and σ in the edge enhancement.

(a) original

(b) α=1.0, σ=0.5

(c) α=2.0, σ=0.5

(d) α=1.0, σ=1.0



(e) α=1.0, σ=1.5

Figure 4. The results of varying the value of α and σp: (a) is original image, (b)-(d) are the enhanced image.

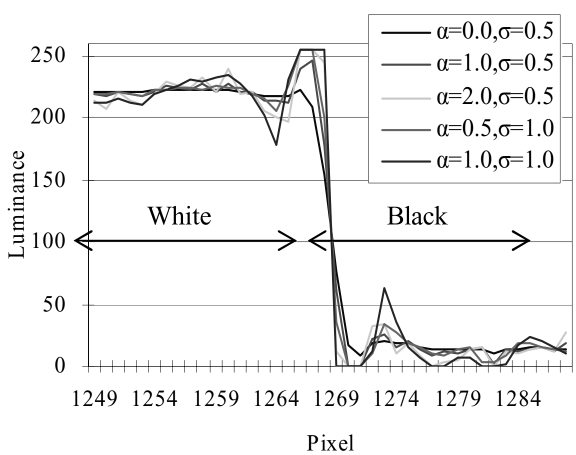


Figure 5. The result of the line scanning

The comparison of variation of α and σ value in the sharpened edge profiles along the scan line is illustrated in Fig. 5. The increase of α and σ values shows the sharpness of the edge change from white to black.

Conclusions

The increase of degree of enhancement and size of neighborhood produce the human easy to recognize the shape of object. Thus, we can feel the sharpness of cactus's thorn and can read the character clearly. However, when the increase is too much, it affect to another parameter of the image. From the experimental results, the edge enhancement is effective in human visual when we concentrate on the shape of image. However, the shape and colors of the image feel unnatural, if its edge was too enhanced.

References

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Biographies

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