이미지 저주파 성분 덜어냄을 이용한 에지 강화 기법

장원우*, 김주현*, 곽부동**, 박근우**, 강봉순*
*동아대학교 전자공학과 **삼성전기(주)

Edge-Enhancement Method by Subtracting Low Frequency Components of an Image

Wonwoo Jang*, Juhyun Kim*, Boodong Kwak**, Keunwoo Park** and Bongsoon Kang*
*Department of Electronic Engineering, Dong-A University
**SAMSUNG Electro-Mechanics Co. Ltd

요 약

이 논문에서 제시된 알고리즘은, 원 이미지에서 저주파를 성분을 덜어내어 얻은 성분과 원 이미지의 컴비네이션을 통해 대상 이미지를 좀 더 선명하게 하는 역할을 하도록 고안되었다. 여기에서 이미지의 저주파를 선택하기 위해 가우시안 스무딩 방법이 선택되었다. 또한 이미지의 전체적인 밝기를 유지하기 위하여 제시될 필터의 이득의 크기도 고려하였다. MATLAB으로 검증된 알고리즘을 바탕으로, 제안한 알고리즘을 통해 이전 보다 더 상세하고 선명한 이미지를 확인 할 수 있었다.

Abstract

In this paper, we present the algorithm to enhance the high frequency components of the image by subtracting smoothing version of an image from the original image. In a word, this is the technique to get more a precise and vivid image. The method of Gaussian smoothing is accepted to get the components of the flat image. Moreover we need to consider the size of the gain of the proposed filter in order to preserve the overall brightness of a image. Based on the algorithm verified by MATLAB, we can obtain more vivid and fuller detail of the image than an original image.

Keywords : Gaussian smoothing

Ⅰ. Introduction

When one watches a scene, one feels to see more a vivid image.[1] For the sake of highlight fine detail in an image, we apply a high-pass filtering process, which attenuates the low-frequency components without disturbing high-frequency information on the image.[2] This filtering process can be considered not only in the spatial domain but also in the frequency domain. The most fundamental relationship between the spatial and frequency domains is established by an well-known result called the convolution theorem.[3]

In this paper, we describe the algorithm to sharpen images consists of subtracting a blurred version of an image from the image itself. This process, called unsharp masking, is expressed as,

$$f_s(x,y) = f(x,y) - \bar{f}(x,y) \qquad (1)$$

where $f_s(x,y)$ denotes the sharpened image obtained by unsharp masking, and $\bar{f}(x,y)$ is a blurred version of $f(x, y)$. [4]

The method of Gaussian smoothing is accepted to get the components of the flat image. Based on the algorithm verified by MATLAB, we can obtain more vivid and fuller detail of the image than an original image.

II. The Fundamental Algorithm

1. Unsharp masking

The unsharp filter is a simple sharpening operator which derives its name from the fact that it enhances edges via a procedure which subtracts an smoothed version of an image from the original image. The unsharp filtering technique is commonly used in the photographic and printing industries for crispening edges. [5]

Unsharp masking consists simply of generating a sharp image by subtracting from an image a blurred version of itself. In frequency domain, this sentence means to obtain a high-pass-filtered image by subtracting from the image to a lowpass filtered version of itself. This is,

$$f_{hp}(x, y) = f(x, y) - f_{lp}(x, y) \quad (2)$$

where $f_{hp}(x, y)$ denotes the sharpened image obtained by unsharp masking, and $f_{lp}(x, y)$ is a blurred version of $f(x, y)$. Eq. (2) can be transformed into Eq. (3), in the frequency domain by using 2-D Fourier transform.

$$F_{hp}(u, v) = F(u, v) - F_{lp}(u, v) \quad (3)$$

where

$$F_{lp}(u, v) = H_{lp}(u, v)F(u, v) \quad (4)$$

H_{lp} is the transfer function of a lowpass filter. Substitution of Eq. (4) into Eq. (3) yields

$$\begin{aligned} F_{hp}(u, v) &= F(u, v) - H_{lp}(u, v)F(u, v) \\ &= F(u, v)(1 - H_{lp}) \end{aligned} \quad (5)$$

where

$$F_{hp}(u, v) = H_{hp}(u, v)F(u, v) \quad (6)$$

H_{hp} is the transfer function of a high-pass filter. Substitution of Eq. (6) into Eq. (5) yields

$$F(u, v)H_{hp}(u, v) = F(u, v)(1 - H_{lp}) \quad (7)$$

$F(u, v)$ is existing each side of Eq.(7). Hence, Eq.(7) can be expressed as

$$H_{hp}(u, v) = 1 - H_{lp}(u, v) \quad (8)$$

Therefore, unsharp masking can be implemented directly in the frequency domain by using the composite filter.

2. Gaussian smoothing

The Gaussian smoothing operator is a 2-D convolution operator that is used to blur images and removes detail and noise in images. Fig. 3 shows an isotropic Gaussian distribution in the two dimension which has the form, Eq.(9).

$$G(x, y) = \frac{1}{2\pi\sigma^2} e^{\frac{-(x^2+y^2)}{2\sigma^2}} \quad (9)$$

where σ is the standard deviation of the distribution. We have also assumed that the distribution has a mean of (0, 0).

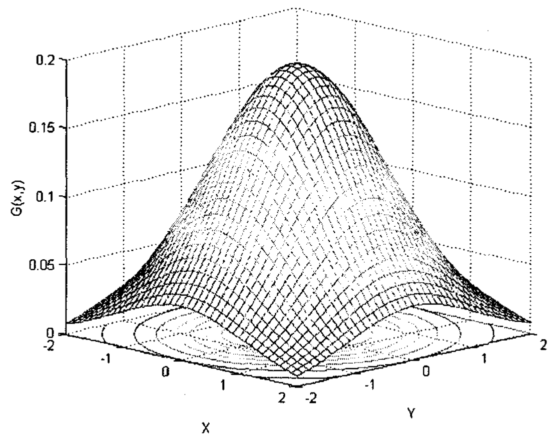


Fig. 1 Two Dimension Gaussian distribution with mean (0,0) σ= 0.9

The form of these filters in two dimension is given by

$$H(u,v)=e^{\frac{-D^2(u,v)}{2\sigma^2}} \tag{10}$$

where, as in Eq.(10), $D(u,v)$ is the distance from the origin of the Fourier transform, which we assure has been shifted to the center of the frequency rectangle. [6]

$$D(u,v)=[(u-M/2)^2+(v-N/2)^2]^{1/2} \tag{11}$$

The characteristic of Gaussian distribution is the width of distribution is related to standard deviation, the value of σ. The smaller the value of σ is, the wider the width is.

A discrete mask that 5 by 5 of Gaussian smoothing, lowpass filter, made by using Eq. (9). is shown in Eq. (12). Fig. 4 shows that Eq.(12) is lowpass filter in 2-D frequency domain.

$$h_G=\begin{bmatrix} 0.005 & 0.016 & 0.027 & 0.016 & 0.005 \\ 0.016 & 0.059 & 0.091 & 0.059 & 0.016 \\ 0.027 & 0.091 & 0.144 & 0.091 & 0.027 \\ 0.016 & 0.059 & 0.091 & 0.059 & 0.016 \\ 0.005 & 0.016 & 0.027 & 0.016 & 0.005 \end{bmatrix} \tag{12}$$

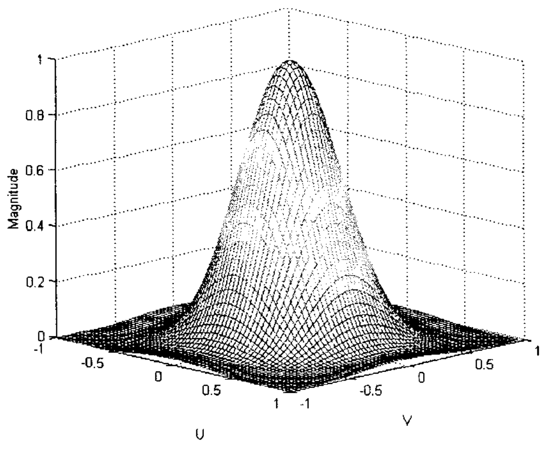


Fig. 2 Perspective plot of Eq.(12) lowpass filter transfer function

III. The Proposed Algorithm

We have an attention to consider the Eq.(8) in terms of the value of gain. If the gain of $H_{lp}(u,v)$ of Eq.(8) is the value which is larger than zero, the gain of $H_{hp}(u,v)$ of Eq.(8) is always smaller than 1. These points make the overall brightness of an image reduced. In order to maintain the value of the gain of $H_{hp}(u,v)$ as 1, we need to transform Eq.(8) into Eq.(13).

$$H_{hp}(u,v)=2-H_{lp}(u,v) \tag{13}$$

Moreover, substitution of Eq. (10), Gaussian distribution in two dimension, into $H_{hp}(u,v)$ of Eq.(13) yields

$$H_{hp}(u,v)=2-e^{\frac{-D^2(u,v)}{2\sigma^2}} \tag{14}$$

In order to apply Eq.(14) to be implemented into algorithm of hardware, we should transform Eq.(14) into spatial domain by using properties of the 2-D fourier transform. Substitution of Eq.(9) into $G(x,y)$ of Eq.(14) yields

$$h_{hp}(x,y)=2\times\delta(x,y)-\frac{1}{2\pi\sigma^2}e^{\frac{-(x^2+y^2)}{2\sigma^2}} \tag{15}$$

A discrete mask, 5 by 5 of proposed mask, high-pass filter, made by using Eq. (2). is shown in Eq. (16). Fig. 5 shows that Eq.(16) is high-pass filter in 2-D frequency domain.

$$h_{hp}=-1\times\begin{bmatrix} 0.005 & 0.016 & 0.027 & 0.016 & 0.005 \\ 0.016 & 0.059 & 0.091 & 0.059 & 0.016 \\ 0.027 & 0.091 & -1.856 & 0.091 & 0.027 \\ 0.016 & 0.059 & 0.091 & 0.059 & 0.016 \\ 0.005 & 0.016 & 0.027 & 0.016 & 0.005 \end{bmatrix} \tag{16}$$

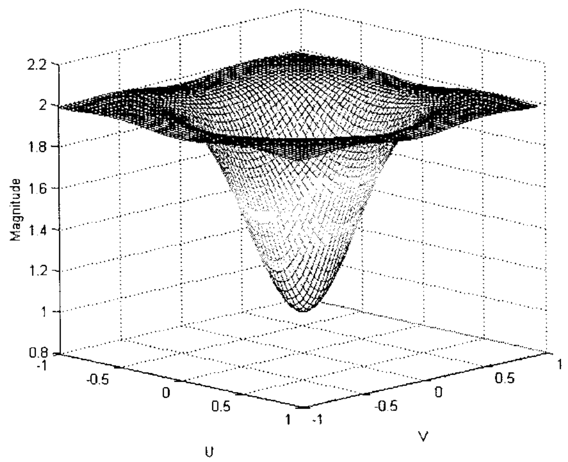


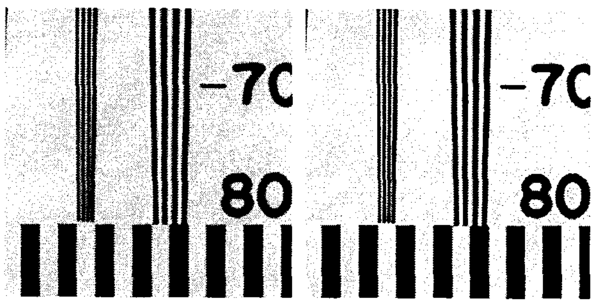
Fig. 3 Perspective plot of Eq. (16) high-pass filter transfer function

Ⅳ. Results

In order to carry out the experiment on images with a proposed filter, we make use of RGB images such as Lenna image, EIA1956 image.

(a) (b)

Fig. 4 (a) Original Image of Lenna (200x200) (b) Result of Proposed filtering



(a) (b)

Fig. 5 (a) Original Image of the piece of test image of IEA1956 (200x200) (b)Result of Proposed filtering

We now demonstrate to obtain the enhanced image with our proposed filter. The effects using the proposed algorithm are presented in Figs. 4-5.

We see that Fig. 4(b) has a much better description of the violet wool of her hat. Moreover, the blurring of the overall outline of Lenna face in Fig. 4(a) is eliminated.

Next. we consider test image of IEA1956. We see that the smallest lines in Fig. 5(b) is more vivid than those in Fig. 5(a). Moreover the shape of text, 80, is sharpened.

Ⅴ. Conclusions

In this paper, we have proposed the improved algorithm to attenuate a slice of the low frequency components of an image in order to enhance the high frequency components of a image. This method does not detect edges in an image. Instead, that is, at once, this algorithm does two things which is subtracting smoothing version of an image from the original image and strengthening the high frequency components of the original image.

In order to take low frequency components out of the image, we accept the concept, Gaussian smoothing. Moreover, we need to consider the gain of the proposed filter to remain the overall brightness of an image.

Finally, this method sharpens an image by increasing a contrast along the edges and functions as the effect to engrave edges in an image.

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