Local image enhancement using adaptive unsharp masking and noise filter

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Abstract

We describe the image enhancement method of applying two spatial filters with different characteristics adaptively. An adaptive method is introduced so that sharpness enhancement is performed only in regions where the image exhibits significant dynamics, while noise reduction is achieved in smooth regions. Simulation results show that the proposed method improved the image quality.

1. Introduction

In recent times, flat-panel displays such as PDP and LCD have been quickly replacing CRTs as the home television. Among them, the AC-PDP is one of the powerful candidates for the HDTV market because of the large screen size and higher picture quality. In general, image sharpness and noise are factors needed to acquire better subjective image quality in display.

Up to now, noise reduction and sharpness enhancement have been implemented in series as depicted in Fig.1 [1]. In the spatial frequency domain, this arrangement cannot achieve an optimal result. This is because noise reduction is commonly a low pass filtering operation, whereas sharpness enhancement is a high pass filtering operation. Hence, there is a conflicting spectral demand on the two filters. Generally, the optimization of one (between noise reduction and sharpness enhancement) leads to deterioration of the other. If the noise reduction is done after the sharpness enhancement, then the noise filter will reduce the sharpness increased by the sharpness enhancement filter. Usually, the sharpness enhancement is done after the noise reduction as this leads to a better picture quality. However, this also requires some compromise because the sharpness enhancement filter tends to increase the remaining image noise.

In this paper, we present a new method to achieve optimization of both features using the adaptively selected filter as local image statistic.

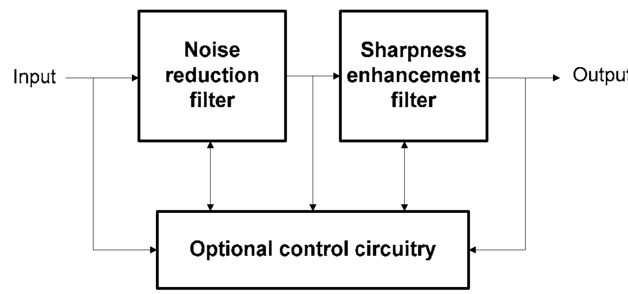

Figure1.Cascaded noise and sharpness filter

The rest of the paper is organized as follow. Section 2 describes the proposed image enhancement algorithm. Section 3 presents simulation results that illustrate the effectiveness of our approach. The concluding remarks are presented in section 4.

2. Algorithm

If we consider a typical image sequence as comprising homogenous and detailed textures, then it is desirable to use more noise reduction in the homogenous areas along the edges and sharpness enhancement in the detail area across the edges. The block diagram of the proposed method is depicted in Fig.2. This is achieved by effectively separating pixels in the neighborhood of the input signal into two independent streams for each pixel to be filtered. One stream comprises neighboring pixels that have a gray value close to that of the original pixel. These pixels are averaged together to reduce noise. The other stream comprises neighbor pixels whose gray levels differ considerably from that of the original pixel. These pixels are used for sharpness enhancement.

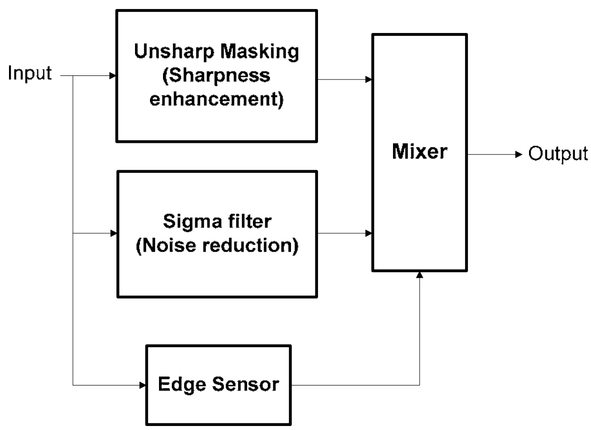

Figure2. Proposed filter

In our method, these local image properties are analyzed with the edge sensor. Our filter system emphasizes noise reduction or sharpness enhancement depending on the value of edge sensor.

$$d_x(n,m) = s(n,m-1) - s(n,m+1) \qquad (1)$$

It is a band-pass filter which discriminates between signal and noise. To this purpose, two implicit hypotheses are made on the significant image details: first, they are represented by local gradient values which are larger than those produced by noise; second, they contribute to the data spectrum mainly in mid-frequency range. These properties make the edge sensor less sensitive to the Gaussian distributed noise which is always present in image data.

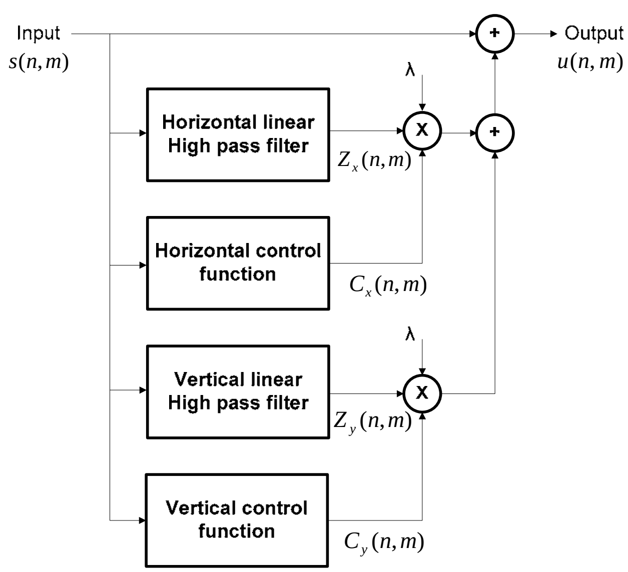

Figure3. Rational unsharp masking

One stream is composed of pixels whose gray levels differ considerably from that of the original pixel. These pixels are entered into the sharpness enhancement filter. Linear unsharp masking is a widely used filter for sharpness enhancement of images [2]. Even if this method is simple to implement, it suffers from two drawbacks: noise sensitivity and excessive overshoot on sharp details. To cope with such problems, we modified the linear unsharp masking with an adaptive control which uses the local spatial image data. Fig.3 shows the sharpness enhancement filter, called rational unsharp masking in the proposed method. Let s(n,m) be the input signal. The sharpness enhanced signal u(n,m) is obtained as

$$\begin{aligned} u(n,m) = s(n,m) &+ \lambda z_x(n,m) c_x(n,m) \\ &+ \lambda z_y(n,m) c_y(n,m) \end{aligned} \qquad (2)$$

where

$$\begin{aligned} z_x(n,m) &= 2s(n,m) - s(n,m-1) - s(n,m+1) \\ z_y(n,m) &= 2s(n,m) - s(n-1,m) - s(n+1,m) \end{aligned}$$

respectively are the outputs of a Laplacian filter applied horizontally and vertically to the input image.

c_x and c_y are non-linear control functions which use local image content to avoid noise amplification and excessive overshoot near sharp edges and emphasize medium contrast details [3].

$$c_x(n,m) = \begin{cases} \dfrac{d_x(n,m)^2}{kd_x(n,m)^4 + h} & \text{, if } \dfrac{d_x(n,m)^2}{kd_x(n,m)^4 + h} \le 1 \\ 1 & \text{otherwise} \end{cases} \qquad (3)$$

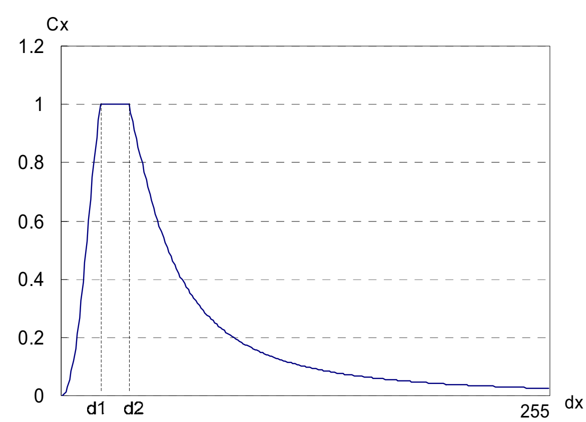

Figure4. Plot of control function

Fig.4 shows the control term c_x as a function of edge sensor d_x. The parameters k and h are chosen to achieve the best trade-off between enhancement of details having low and medium sharpness, reduction of noise amplification and overshoot for already sharp edges. In fact, sharp edges yield high values of d_x, so c_x becomes small. In this way, undesired overshoots in the output image are avoided. On the other hand, in homogeneous areas, where the noise is usually more visible, noise yields small values of d_x, and then small value of the added high-frequency component. We can achieve the balance among these effects by setting the value of d_1 and d_2. The relationships between the parameters d_1, d_2, k and h are:

$$k = \frac{1}{d_1^2 + d_2^2} \qquad h = \frac{d_1^2 d_2^2}{d_1^2 + d_2^2}$$

The intensity of the sharpness enhancement can be obviously adjusted by changing the value of λ.

The other stream comprises neighboring pixels that have a gray value close to that of the original pixel. These pixels are averaged together to reduce noise in homogenous area. Generally, Gaussian average filter is used in order to reduce white Gaussian noise. But there is a drawback in conventional Gaussian average filter; that is a burring in sharp detail area. To overcome this problem, we use a sigma filter which can preserve fine details [4]. Sigma filter averages the pixels whose gray level is similar to that of the original pixel. Thus, the noise reduction filter output is obtained as

$$\text{Sigma filter Output}[s(i,j)] = \frac{\sum_{k=i-m}^{i+m}\sum_{l=j-n}^{j+n}\delta(k,l)\cdot s(k,l)}{\sum_{k=i-m}^{i+m}\sum_{l=j-n}^{j+n}\delta(k,l)} \quad (4)$$

$$\delta(k,l) = \begin{cases} 1 & , |s(k,l) - s(i,j)| \le \text{threshold} \\ 0 & , |s(k,l) - s(i,j)| > \text{threshold} \end{cases}$$

3. Simulation results

The image employed to test the image enhancement capability of our algorithm is a 512 x 512 pixel portion of the image “Lena” shown in Fig.5. It was chosen to include homogenous areas and high detail.

Fig.6 describes the result of the edge sensor. This figure is divided into two regions. Rational unsharp masking for sharpness enhancement is applied to black gray level region and sigma filter for noise reduction is applied to white gray level region.

Figure5. Original image

Figure6. Result of edge sensor

Fig.7 shows the output image acquired by the conventional cascaded noise and sharpness filter. Fig.8 presents the output image obtained by the proposed filter. Comparing the output image of our method with that of conventional filter, we can see that the homogenous areas of the output image of our algorithm are less noisy than the same areas in Fig.5. and Fig.7. In addition, good sharpness is obtained in the detail areas. In particular, the control function in our rational unsharp masking enhances the medium contrast detail.

Figure7. Output image of cascaded filter

Figure8. Output image of proposed method

4. Conclusion

In this paper, we proposed an adaptive selected filter for sharpness enhancement and noise reduction which outperforms a cascaded system. Our filter balances noise reduction with sharpness enhancement in an explicit way. Edge sensor analyzes a local image property and then selects one of two filters which is used for image enhancement. Whereas the sharpness enhancement filter in a cascaded system has a tendency to increase remaining noise, both functions in our filter are mutually exclusive. Thus, the advantage of sharpness enhancement and noise reduction is so mutually maximized that we can acquire better perceptual image quality.

5. Acknowledgement

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6. References

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