Surround-Adaptive Local Contrast Enhancement for Preserved Detail Perception in HDR Images

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Abstract. In high dynamic range rendering technology, tone mapping operators cause loss in terms of image quality. In order to compensate the defect, we use the base-detail decomposition before tone mapping and attempt to compensate details in bright area of an image using a surround-adaptive sharpening filter. It is effective to bright surround images which are sensitive to human eyes. It is confirmed that our proposed method adaptively enhance the details reduced during tone mapping.

Keywords: High dynamic range, Base-detail separation, Contrast sensitivity function, Human vision

1 Introduction

HDR (high dynamic range) rendering technologies commonly include TMOs (tone mapping operators), these operators make it possible to convert an HDR image to an LDR (low dynamic range) image on a display device. HDR techniques constantly have been introduced such as histogram adjustment, photographic reproduction, iCAM06 [1], logarithmic mapping and local eye adaptation, etc. However, in the process of reducing the dynamic range, TMOs cause losses of color saturation, contrast, and sharpness [2]. In this paper, we compensate the image quality using CSF (contrast sensitivity function) which is the property of visual acuity. Our method suggests the FIR sharpening filter based on CSF simply applicable to display systems. In order to evaluate our method, the results are compared with those of conventional iCAM06 which contains base-detail decomposition. As a result, comparisons show that contrast and sharpness is enhanced, therefore, image degradation by TMO is effectively compensated.

2 Surround-Adaptive Local Contrast Enhancement

According to CSF, variation of average luminance causes contrast sensitivity which is changing at each frequency in HVS (human visual system) [3]. Thus, the sharpening filter designed using characteristic of CSF is adaptive to luminance of image. The proposed sharpening filter, $_{fsharpening,}$ is as follows:

$$f_{sharpening} = 1 + (A - 1) \oplus f_{band-pass} , \tag{1}$$

where A is a compensation gain, $f_{band-pass}$ is band-pass filter. In order to design $f_{band-pass}$, first, minimum luminance level is fixed at 5 cd/m^2. Then ΔCSF is found by subtracting CSF of minimum luminance level from each CSF. And, compensation gain A and band-pass filter $f_{band-pass}$ are modeled on ΔCSF. The base function, H_{bp} , is designed as follows:

$$H_{bp}(f) = \exp\left\{ -\frac{(f-f_0)^2}{2\sigma^2} \right\}, \text{if} \, f = l, \text{with} \int f \quad \tag{2}$$

where σ_L represents width of left H_{bp}, σ_R represents right width, and f_0 is a center frequency of H_{bp} as shown in Fig. 1(a).

The variation of center frequency of ΔCSF according to luminance is only about 1 cycles/degree. In addition, variation of width of ΔCSF according to luminance is also not great enough to change the design of the filter. In other words, because variation of f_0, σ_R, and σ_L is negligible, these parameters is fixed.

The gain A is modeled according to variation of luminance. The more luminance of image is high, the more H_{bp} is amplified, and sharper images appear. These gain A is defined as follows:

$$A(L) = \max(CSF(L)) / \max(CSF(L_{reference})) , \tag{3}$$

where L is a luminance level and $L_{reference}$ is 5 cd/m^2. Luminance range is assumed to be 5 ~ 2000 cd/m^2.

The final sharpening filter, $f_{sharpening}$, through specifying gain A and $f_{band-pass}$ is shown in Fig. 1(b). Because $f_{sharpening}$ is the spatial filter, it is necessary to convert into FIR filter to be applicable discrete images.
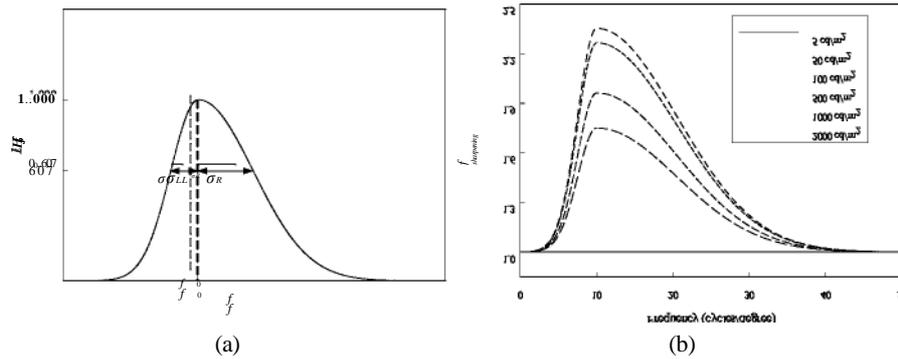

(a)   (b)

Fig. 1. (a) The base function, H_{bp} and (b) the designed sharpening filter, $f_{sharpening}$.

In order to design a 9-tap FIR filter, frequency domain in cycles/degree is converted to sampling frequency domain. In viewing conditions of full HD monitors, two pixels represent one cycle and viewing angle is about 30 degree. Thus, sampling

frequency of the viewing condition is 32 cycles/degree. Through conversion, 32 cycles/degree is matching sampling frequency and $_{fsharpening}$ is proportionally mapping.

The filter, $_{fsharpening}$, in sampling frequency is able to convert into 9-tap FIR filter using MATLAB. Because the 9-tap FIR filter is identical to a filter mask whose size is 1 x 9, image can be linearly filtered with the 9-tap FIR filter in spatial domain. As FIR filter is changing according to luminance level, first, luminance range of 5 ~ 2000 cd/m^2 is normalized to be 0 ~ 1, and then, coefficients of FIR filter is modeled according to the normalized luminance (L_{an}). Because FIR filter is symmetric, 5 functions about $_{Lan}$ are needed from tap 1 to tap 5. General function for modeling is as follows:

$$f(L_{an}) = a(L_{an}) + b \quad , \quad + 5.2$$

^{an}where a and b are parameters of functions. These parameters are shown in Table 1.

The system diagram of proposed method is shown in Fig. 2. First, image is decomposed into base part and detail part by bilateral filter. After the decomposition, filtering of detail part with CSF-based sharpening filter proceeds. Because of pre-processing, CSF-based sharpening filter can be applied in only bright area according to L_{an}.

Table 1. Parameters in modeling FIR filter coefficients.

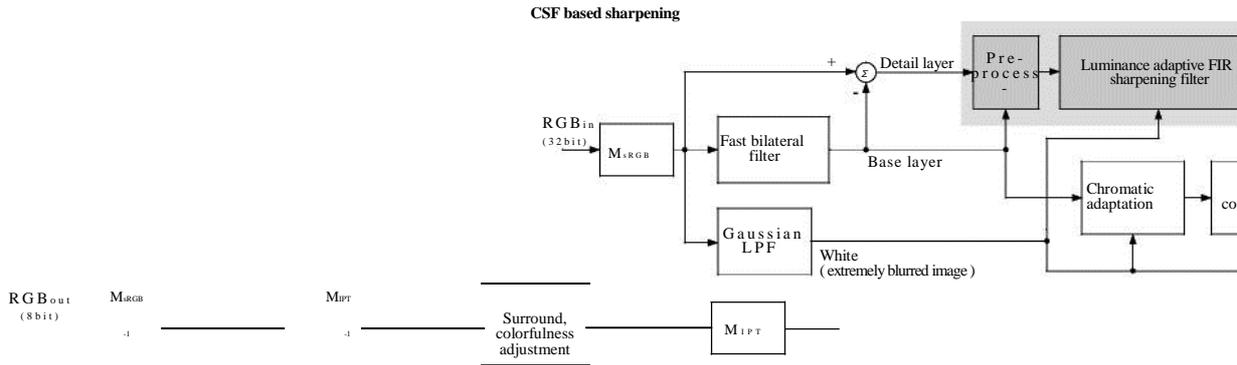| general function : $f(L_{an}) = a(L_{an})^{+b}$		
$L_{an} + 35.2$	a	
tap 1	-0.098	0.049
tap 2	-0.060	0.302
tap 3	-0.295	1.480
tap 4	-0.100	0.499
tap 5	1.930	30.600

Fig. 2. The block diagram of the proposed method.

3 Simulation Results

Result images are shown in Fig. 3. Sharpness in proposed image is clearly better than that in iCAM06. In particular, this enhancement through proposed method is obvious in center of image in an outdoor part. Because of pre-processing, defect of noise in dark area isn't seen.

Fig. 3. Result images; (a) iCAM06 image, (b) the proposed image.

4 Conclusions

In this paper, the proposed contrast enhancement is adaptively applied to detail part. Applying to detail part is so as to compensate defect of image quality which is reduced by process compressing dynamic range by TMO. The superiority of the proposed method is confirmed using comparison with result images.

References

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