Some advance on high contrast tone mapping and application to Two layer coding

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1 ABSTRACT

High dynamic range (HDR) images have wider dynamic range than the conventional 8-bit images, for example, JPEG, BMP, and PNG. To display it on common display devices, its dynamic range should be compressed by tone-mapping. It is important to compress data size of the HDR images since they have huge one. Two layer coding methods have been proposed in the last decade. Those coding methods encode the tone-mapped (LDR) image as a first layer, and the residual image as a second layer respectively. In conventional two layer coding method, the residual image is generally calculated by dividing the HDR image by the LDR image. In the conventional method, the decoder can reconstruct the HDR image from the LDR image and residual image. However when high contrast tone-mapping is used to create the LDR image, the residual as well as the LDR image has much high frequency component. If the LDR image has many high frequency components, over all coding efficiency of the residual image degrades. To address the issue, this paper proposes new a efficient two layer coding method which allows the first layer to include many high frequency components. Our two layer coding method achieves both of the high contrast tone-mapping and the high coding efficiency.

2 CONVENTIONAL METHOD

One of the most well-known two layer HDR image coding methods is Ward's method[1]. This method encodes the tone-mapped HDR image as a first layer. The second layer is calculated by dividing the HDR image by the first layer. When user need only LDR image, user decode only LDR image. When user need HDR image, user decode both first layer and second layer. When the LDR image has high contrast, the conventional two layer coding method becomes inefficient, since many high frequency components remain in the second layer. To overcome this problem, Jinno et al. proposed a new two layer coding method which can reconstruct the HDR image from the LDR image and a side information by using an invertible tone-mapping[2]. They[2] use Multi-Scale Contrast Enhancement(MSCE) and a simple tone-mapping as the invertible tone-mapping system. Fig.1 explains the block diagram of [2]. This simple tone-mapping is expressed by

$$LDR = \frac{HDR}{1 + HDR}. \tag{1}$$

MSCE uses N-level Gaussian pyramid as the multi-scale representation. MSCE uses maps to enhance local contrast of each level image, and can perform inverse processing by using the maps. The details of MSCE are explained in Sec.2.1. The maps is up-sampled one down level image in Gaussian pyramid, and the lower level maps can be calculated by using the highest level maps G_1. The decoder needs only the highest level maps G_1 to perform the inverse processing, that is, we need to transmit only G_1 as the side information. Since this side information G_1 can be calculated from only the HDR image, it is not affected by the high frequency components of the LDR image. Therefore this two layer coding method [2] uses the side information G_1 as the second layer. Who has quarter size since G_1 is down-sampled image.

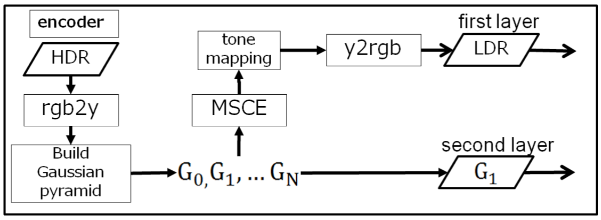


Fig. 1 The block diagram of Jinno's method : (rgb2y)color → luminance, (y2rgb)luminance → color, (MSCE)Multi-Scale Contrast Enhancement, (TM)tone-mapping, (ITM)inverse tone-mapping

2.1 Multi-Scale Contrast Enhancement.

The block diagram of MSCE is illustrated in Fig.2. MSCE uses N-level Gaussian pyramid as the multi-scale representation, and enhances the contrasts of each level images to enhance visibility of the details. Contrast Enhancement(CE) in each level is performed by using simple mapping function as show in Fig.3. This simple mapping function varies pixel by pixel according to the map, and it is easy to calculate the inverse mapping function. MSCE uses the $UP(G_{n+1})$ as the map in the n level CE, where $UP(.)$ is up-sampling

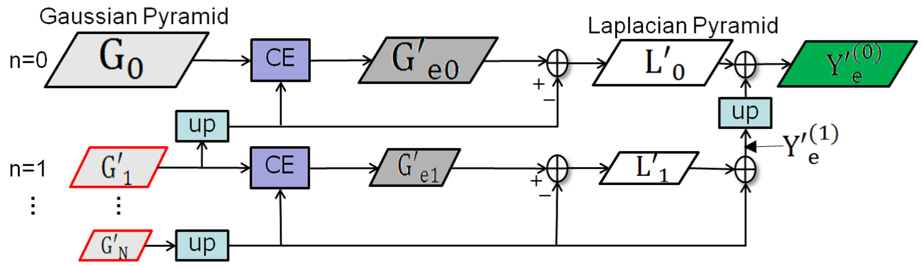


Fig. 2 The block diagram of MSCE

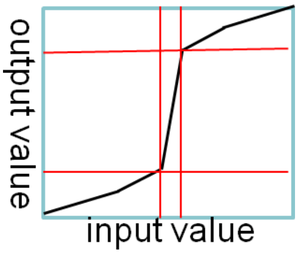


Fig. 3 Mapping function

and G_{n+1} is the one level down image. The mapping function enhances the local contrasts according to the difference between G_n and $UP(G_{n+1})$. Since the small difference indicates that its pixel exists in the detail region, the mapping function enhances the details. In the large difference region, the edges are already large, thus the mapping function enhances the edges weekly. To use the same side information G_1 in both the encoder and decoder, our encoder also uses the decoded version of G_1. To indicate that, drift at the decoder is avoided and coding efficient is increase . Therefore our Gaussian pyramid consists of G_0,G'_1,G'_2...G'_{N-1} in the encoder, where the prime ' denodes the decoded version. MSCE calculates a $(N-1)$-level enhanced Laplacian pyramid by using the N-level Gaussian pyramid and the $(N-1)$-level enhanced Gaussian pyramid, and then MSCE derives enhanced image from the enhanced Laplacian pyramid L_n as following equation.

$$Y_e{}^{(n)} = UP(Y_e^{(n+1)}) + L_n \tag{2}$$

where $Y_e{}^{(N)} = UP(G_N)$, $Y_e{}^{(0)}$ is enhanced image and $n = N-1, N-2, ..., 0$. The inverse MSCE processing is explained as follows. Applying MSCE to G'_1, G'_{e1} and $Y'^{(1)}_e$ are acquired. Then G_{e0} is calculated as following equation.

$$G'_{e0} = Y'^{(0)}_e + UP(G'_1) - UP(Y'^{(1)}_e) \tag{3}$$

Since CE can perform its inverse processing, [2] can reconstruct G'_0 from G'_{e0}. However, when applying the heavy contrast enhancement, it causes large error in near large edges of the decoder. Detail is heavy contrast enhanced by mapping function. When error occurs in the encoder, it is difficult to estimate the accurate inverse mapping function. As the result, error of encoder amplified in the decoder. Fig.4 shows the decoded HDR image in the case.

(a)Original HDR image (b)Decoded HDR image

Fig. 4 Problems

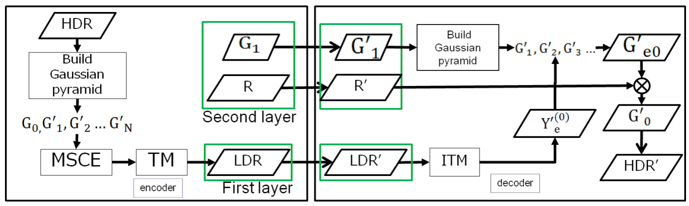


Fig. 5 The block diagram of propose method

3 PROPOSED METHOD

Some heavy contrast enhancement often amplifies coding error and quantized error in inverse processing. To reconstruct G'_0 from G'_{e0}, our new proposed method uses a residual R as shown in Eq.4.

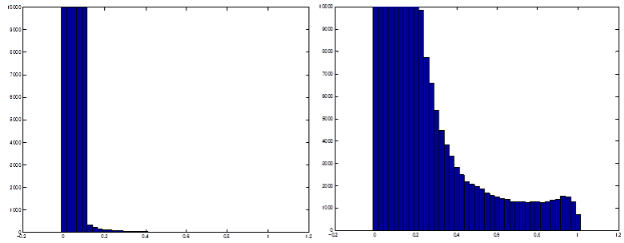
$$R = \frac{G_0}{G'_{e0}} \tag{4}$$

Fig.5 shows the block diagram of propose method. Our encoder calculates the residual R, and sends it to the decoder, including the side information. That is to say, proposed method uses both R and the G_1 as the second layer. The decoder reconstructs G'_0 by using R instead of performing the inverse CE processing. There is no needs to perform the inverse CE, so proposed method can avoid being affected by the noise of R. Fig.6 shows the result of our new two layer coding method. Our second layer consists of the residual R and the side information G_1, and the second layer of Ward's method [1]. consists of only the residual. Coding efficiency of our second layer is, however, higher than Ward's one. G_1 has quarter number of pixels, thus its data size is small. Since G'_{e0} in our division R can predict G'_0 roughly, our method makes the data size of R small. R

Fig. 6 Decoded HDR image

(a)Special case (b)Common case

Fig. 7 HDR image samples



(a)Special case (b)Common case

Fig. 8 Image histograms

yields much noise when a simple division is used due to the sensitivity of the operation. To relieve the problem, we introduce the following Eq.5

$$R = \frac{G_0}{G'_{e0} + nl}, \tag{5}$$

where nl is a parameter of the nonlinearity. The parameter controls the shape of the nonlinear mapping curve of Eq.5. The parameter is image-dependent, and improper value worsens the coding efficiency. The smaller the parameter is, the more heavy nonlinearity is. To improve the coding efficiency, the parameter nl should be optimized for R. This paper decides the parameter nl by using the HDR image. Fig.7,8 shows the HDR image sample and histograms of HDR images where need heavy nonlinear and others. Fig.9 expresses a flow of deciding the parameter value. The histogram of the HDR image is important to decide the parameter nl. Our method first decides initial value of the parameter by using experimental results, and then $nl = 0.45$. Even if 0.45 is used as the parameter value, our method can achieves high coding efficiency in many of the HDR images. This paper optimizes the parameter value to improve the coding efficiency more. Experimental result, histogram of need heavy nonlinear

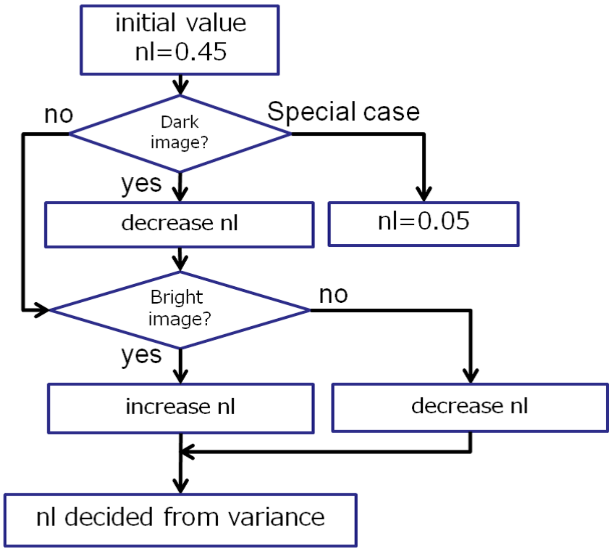


Fig. 9 Flow of deciding parameter

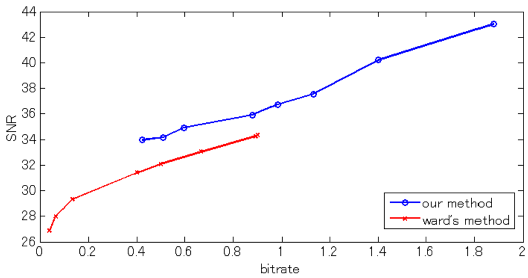
images is bias in dark region. These images often occur many coding error. First, we calculate the ratio of dark pixels in HDR image from histogram. we calculate bin which cumulative-histogram reaches 98%, nl parameter is controlled by threshold of bin. When the HDR image has many low luminance pixels, we apply special case of flow Fig.9. When there are few low luminance pixels, it does not take any process. Second, we calculate percent of blight pixels from histogram of the HDR image. When there are many bright luminance pixels, nl is decrease, other is increase. The reason of this process doing, nl often over effected by before process, This process is another calculating method. Finally, we calculate the variance of histogram, the smaller variance is, the smaller nl is. Therefore, we calculate the parameter by using the histogram to improve the coding efficiency.

4 result

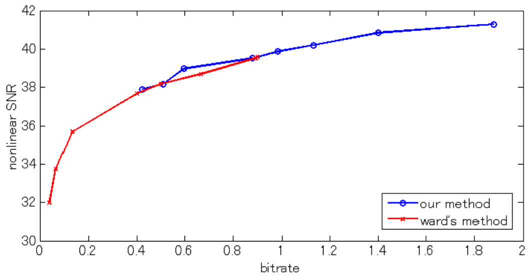
This paper uses both SNR and nonlinear SNR as the criteria for evaluating the decoded HDR image. The nonlinear SNR maps both the HDR image and the decoded one nonlinear by using a Daly's nonlinearity [4] before calculating SNR. Daly's nonlinearity is expressed by

$$output = \frac{220 * input}{input + 12.6 * input^{0.63}} \tag{6}$$

Daly's nonlinearity indicates a response to the luminance in the HVS, that is, nonlinear SNR can evaluate the HDR image according to the HVS. Fig.10 illustrate the R-D curves calculated by using SNR and Nonlinear SNR, respectively of "Rockies7.hdr". Fig.11 shows some LDR image. R-D curves in Fig.10 explain that our two layer coding method has higher coding efficiency than the conventional one [1]. Although our two layer method has large file size, our method can reconstruct more accurate than the conventional one.This paper achieves high coding efficiency two layer coding for the HDR images. This method, however, has had some problems yet. One of them is the halo effect, and it shown in tone-mapped "SpheronNice.hdr" in Fig.11. Our future works are removing the Halo effects more, applying this methods to a multiple bit-depth representation and improving the quality of the tone-mapped image.



SNR



Nonlinear SNR

Fig. 10 R-D curve(Rockies7.hdr)

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Fig. 11 Tone-mapped images