Deep Learning-based Image Processing Algorithms in 8K Era

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ABSTRACT

This paper presents the deep learning-based inverse tone mapping algorithms for high dynamic range imaging. Specifically, the technical contents of various deep learning-based inverse tone mapping techniques, which are currently being studied, are explained, and the performance of representative methods are compared.

1 INTRODUCTION

Recently, the display technology with high resolution and wide color gamut has been researched. In particular, displays capable of outputting 4K (3840 x 2160) and 8K (7,680 x 4,320) pixel resolution images have been developed and sold in the commercial market. In general, an ultra-high-resolution display with 4K or 8K resolution provides a high dynamic range (HDR) image together to output a high-quality image. To represent HDR images, it is necessary to be able to express more information on the individual pixel. Therefore, the pixel bit depth of the conventional display becomes wider, and the wide range of the gray level is expressed using the pixels with the wide bit depth. Specifically, the gray level that expresses the image using 8-bit depth based on RGB individual color has been increased to 12-bit depth due to the improvement of the dynamic range, and it has become possible to output information that has not been expressed before. Various HDR contents have been produced for this purpose, but the contents that can satisfy the hardware specification of the display are very few at present. Therefore, from the viewpoint of improvement of dynamic range, it is very necessary to develop a technology that can convert a low dynamic range (LDR) image, which is a general input image, into an HDR image. This technique is called inverse tone mapping.

In this paper, we describe the basic concept of this inverse tone mapping technology and the detailed contents. In addition, we will explain the technical contents of various deep learning-based inverse tone mapping techniques, which are currently being studied, and compare the performance of representative methods.

2 INVERSE TONE MAPPING METHODS

The inverse tone mapping technique must estimate missing information when the dynamic range is extended from the input LDR image to the HDR image. Various methods have been studied for this purpose. [1] detected a region having an upper gray level of an input image, and allocated additional bits to the region to increase the dynamic range. Specifically, it is a method of assigning additional information to the saturated region considering the distribution of the light. [2] defined the perceptual brightness that can reflect human cognitive characteristics and adaptively define the correlation between input and output video signals to generate the final HDR image. However, it is difficult to accurately analyze the characteristics of the input image, and hence, the optimum image signal output is impossible in the aforementioned methods. Therefore, the image quality deteriorates in the outputted HDR image.

Recently, several deep learning methods have been proposed to solve these problems. [3] constructed the neural network with many convolutional layers for the inverse tone mapping for HDR image reconstruction. Specifically, in the method, after dividing an upper gray level and a lower gray level of an input video signal, an image of a lower gray level region was used as an original input signal, and an image signal of a higher gray level was inferred through the neural network to generate the final HDR image. The resulting HDR output image was reconstructed from the information of the upper gradation saturated in the input LDR image. However, it has a problem that the low exposure image is restored well, but the restoration performance is decreased with respect to the normal exposure image. In the method of [4], a final HDR image was created using a multi-exposure stack with several LDR images of various exposure levels. To do this, it created a multi-exposure stack using the sub-network that can specifically increase or decrease exposure values, and then, it used this tone mapping technique to generate the HDR image. Therefore, the dynamic range was changed variably through the addition of subnetworks. In [5], a new neural network was designed to solve this problem, and the conditional generative adversarial network technique was further utilized to improve performance. In addition, the multi-exposure stack can be output through two directional modules considering the directionality of exposure for the efficient structure generation, which is advantageous in terms of the network size compared to the conventional one.

Fig. 1 HDR image results of various deep learning-based methods. (a) Ground truth, (b) deep chain HDRI, and (c) deep recursive HDRI

EV	Method	PSNR (dB)	SSIM
EV +2	Deep chain HDRI	31.12	0.955
	Deep recursive HDRI	30.22	0.953
EV +1	Deep chain HDRI	32.57	0.960
	Deep recursive HDRI	31.85	0.965
EV -1	Deep chain HDRI	30.18	0.964
	Deep recursive HDRI	32.68	0.967
EV -2	Deep chain HDRI	25.12	0.918
	Deep recursive HDRI	32.21	0.963

Table 1 PSNR comparison of various deep learning-based methods

3 RESULTS AND DISCUSSION

For the performance evaluation of the deep learning-based inverse tone mapping techniques, the peak signal-to-noise ratios (PSNRs) were calculated and compared quantitatively as shown in Table 1. Also, for qualitative evaluation, the output HDR images of various methods were compared as shown in Fig. 1. When comparing various methods, it was confirmed that the performance of the deep recursive HDR method [5] is the best quantitatively and qualitatively.

4 CONCLUSION

In this paper, we analyze the performance of the recent deep learning-based inverse tone mapping techniques. Therefore, it was confirmed that the deep recursive HDR method had excellent performance. Based on the analysis in this paper, the study of inverse tone mapping is expected to proceed.

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