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# Adaptive logarithm quantization-based tone mapping for high-dynamic range images

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**Abstract-** The high-dynamic range imaging technique is an attractive method using improved image capturing hardware. In this paper, a two-step adaptive logarithm quantization-based tone mapping method is proposed. First, the proposed method converts the RGB color space to the CIE XYZ color space. After that, the tone mapping from an HDR image to an LDR image is performed. In this step, the proposed method uses different tone mapping functions according to statistical characteristics of the input HDR image. Simulation results show that the proposed method outperforms other conventional approaches.

**Keywords-** Adaptive logarithm quantization (ALQ), tone mapping, high dynamic range (HDR), low dynamic range (LDR)

## 1. Introduction

The high-dynamic range (HDR) image acquisition technique is an attractive method with improved image capturing hardware. HDR imaging has many practical applications such as medical visualization [1], satellite imagery [2], and digital camera use [3]. Although HDR images include nearly real world luminance, image display devices (e.g., CRT, LCD, and LED) have a low dynamic range (LDR). This is why a tone mapping method from an HDR image to an LDR image is needed. In order words, the tone mapping method is a technique that can be used to display HDR images on conventional display devices.

In previous works, tone mapping was classified as a global operator [4-6], where the same tone mapping function is applied in all regions, or as a local operator [7]-[8], where different tone mapping functions are applied during the modeling of spatial adaptations.

The rest of this paper is organized as follows. In the next section, the concept of logarithm quantization is introduced. In Section 3, the proposed adaptive logarithm quantization (ALQ) -based tone mapping method is described. Section 4 compares subjective image qualities. Finally, this paper is concluded in Section 5.

## 2. Concept of Logarithm Quantization

In this section, conventional logarithm quantization is described. Due to the wide range of HDR images, pixel values of HDR images are mainly mapped to small values if scalar quantization is adopted. In order to solve this problem, many conventional approaches use schemes based on logarithm quantization. Implementation of this process consists of two steps. In the first step, an HDR image is tone mapped using the logarithm function (e.g., $log_e(\,)$). After that, scalar quantization is adopted and applied to tone mapped pixel values. Figure 1 illustrates these steps.

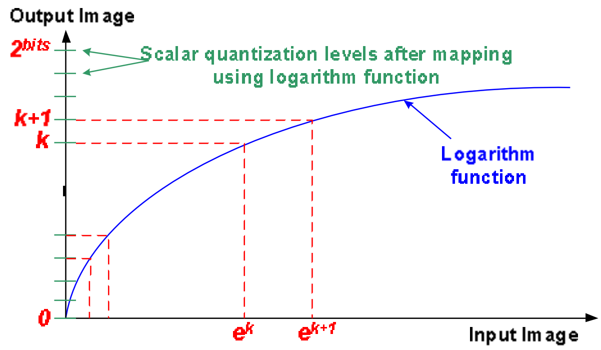


Fig.1. Principle of logarithm quantization.

As shown above, scalar quantization after tone mapping using a logarithmic function has a similar effect to logarithmic quantization. Each quantization step size $Q_{Step}(k)$ is given as follows:

$$Q_{Step}(k) = e^{k+1} - e^{k} \tag{1}$$

If $k$ is a small value, $Q_{Step}(k)$ is also a small value, and vice versa. This means that smaller pixel values of HDR images are quantized more finely.

## 3. ALQ-based HDR Tone Mapping

Most conventional approaches based on logarithmic tone mapping do not consider image characteristics such as mean value. If the pixel values of an HDR image are biased to a higher value, an LDR image with lower contrast is created because most pixels are sparsely quantized. In order to solve this problem, the proposed adaptive logarithm quantization (ALQ) method converts the RGB color space to the CIE XYZ color space in the first phase. It then performs tone mapping on the luminance component using difference tone mapping functions, which consider the HDR image characteristics. Finally, by reconverting the color space, an LDR image is acquired. Figure 2 presents a block diagram of the proposed algorithm.

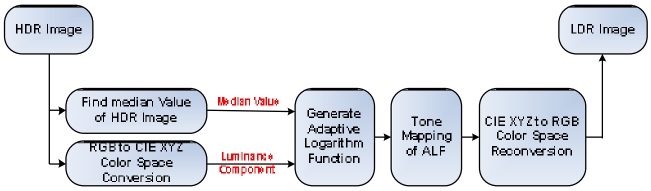


Fig. 2. Block diagram of the proposed method.

### 3.1. Color space conversion

The tone mapping of the proposed method adopts only the luminance component. The pixel value of an HDR image consists of floating point RGB values, which are run-length encoded. In order to extract the luminance component from the RGB color space, the proposed method uses an RGB to CIE XYZ color space conversion. The standard matrix for the luminance component is given by

$$Luminance_{HDR} = \log(0.2126 \cdot R + 0.7152 \cdot G + 0.0722 \cdot B) \quad (2)$$

where $Luminance_{HDR}$ is the luminance component of an HDR image and R, G, and B are the red, green, and blue components, respectively.

### 3.2. ALQ function modeling

After color space conversion, tone mapping from HDR to LDR is carried out using the adaptive logarithm function (ALF). ALF is the α power logarithm function of $Luminance_{HDR}$. During this process, the median value of an HDR image is used. ALF and α included in ALF are given by

$$\boldsymbol{Luminance_{LDR} = log_e(Luminance_{HDR}{}^{\alpha})} \quad (3)$$

$$\alpha = log_e(a \cdot median(Luminance_{HDR}) + b) \quad (4)$$

$$a = (e^1 - e^{0.1})/0.03 \; b = e^{0.1}$$

where *median(·)* is the median function, and *a* and *b* values are determined experimentally.

Figure 3 describes α in Eq. (4) according to the median value that is scaled to [0 1] and the ALF shapes for several α values. As shown in Figure 3 (b), the region with smaller pixel values has a higher slope when α value is small. This means that this region is more finely quantized. Alternatively, the region with higher pixel values has a lower slope when the α value is small. This means that this region is more sparsely quantized. Through the process described above, the proposed method allocates more quantization levels to the region with greater pixel distribution. This method can generate $Luminance_{LDR}$ with higher contrast ratio.

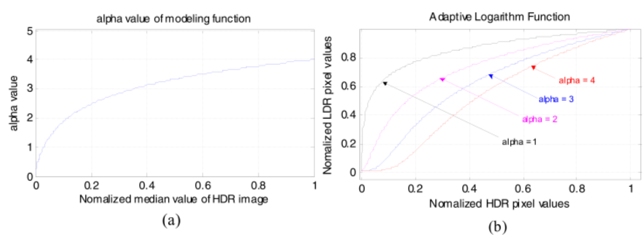


Fig. 3. The shapes of (a) α according to the normalized median value of an HDR image and (b) adaptive logarithm functions for several α values.

## 4. Simulation and Discussion

For the performance evaluation, $Luminance_{LDR}$ from the proposed method was compared to two conventional approaches (the photographic ([7]) and SVD-based tone reproduction methods ([6])). Figure 4 compares the subjective video qualities of the three methods. As shown in the results, the proposed method yields higher subjective quality. Especially, the proposed method outperforms other approaches for dark HDR images.

Fig. 4. The subjective quality comparison
(first column: Photographic ([7]), second column: SVD-based tone reproduction ([6]), third column: the proposed method)

## 5. Conclusions

In this paper, an ALQ-based tone mapping method was proposed. The method uses different tone mapping functions, named ALF, according to the median value of an HDR image. Therefore, each region of an HDR image has a different number of quantization levels. Because the number of quantization levels affects the contrast ratio, the proposed method selects the proper number of quantization levels using the statistical characteristic of an input HDR image. Experimental results show that the proposed method yields higher subjective image quality than other conventional approaches.

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