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TONE MAPPING METHODS: A SURVEY

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ABSTRACT

The ultimate aim of realistic graphics is the creation of images that provoke the same responses that a viewer would have to a real scene. While research into ways of rendering images provides us with better and faster methods, we do not necessarily see their full effect due to limitations of the display hardware. The low dynamic range of a standard computer monitor requires some form of mapping to produce images that are perceptually accurate. Tone reproduction operators attempt to replicate the effect of real world luminance intensities. This paper reviews the work on tone reproduction techniques.

Keywords*: *High Dynamic Range, Low Dynamic Range, Tone Mapping Operators.

I.INTRODUCTION

In recent times the aim has been to improve dynamic range of digital camera.Dynamic range is the ratio between the darkest and lightest area. Dynamic range of the Human Visual System (HVS) can be dened as the range of intensities of light to where HVS can adapt or the range to where HVS can adapt in one occasion. one occasion HVS can only adapt to around 3-5orders of magnitude.To visualize High Dynamic Range images on standard Low Dynamic Range Displays, Tone mapping Operators (TMO) presenteffective tools as convertors to convert high dynamic range images to Low dynamic range image. Many TMO's were proposed till now. Some of the TMO are reviewed in [1], [2]. This paper reviews tone mapping techniques. Following section describes classification of TMO with work done by different operators.

II. CLASSIFICATION OF TONE MAPPING OPERATOR

Tone mapping operators are planned inthis mannerthat they replicate visibility and the overall impression of radiance and visibility a contrast and colour of the real world onto finite dynamic range output devices. [3]

2.1 Global Tone Mapping Operators

Global operators apply the same transformation to every pixel of an image. The advantage of global operator is they are computationally efficient and are generally faster than any other operator.The global operators are the linear mapping and the methods of Pattanaik*et al*. (2000), Larson *et al*. (1997) and Drago *et al*. (2003). Adaptive logarithmic mapping was introduced by Drago *et al*. (2003) [4]. This method addresses the need for a fast algorithm suitable for interactive applications which automatically produces realistically looking images for a wide variation of scenes exhibiting high dynamic range of luminance. This global tone mapping function is based on logarithmic compression of luminance. To preserve details while providing high contrast compression, a family of logarithmic functions ranging from log2 to log10 with increasing compressive power are used. The log10 is applied for the brightest image pixel and for remaining pixels the logarithm base is smoothly interpolated between values 2–10 as a function of their luminance. Tone mapping function given below is used to compute a displaying value L_d for each pixel.

$$L_d(x,y) = \frac{\frac{L_{d,max}}{100}}{Log_{10}(1+L_{w,max})} \cdot \frac{Log_{10}(1+L_w(x,y))}{Log_{10}\left[2+8\left\{\left(\frac{L_w(x,y)}{L_{w,max}}\right)^{Log_{10}(p)/Log_{10}(0.5)}\right\}\right]}$$

The maximum display luminance value $L_{d,max}$ is display dependant and should be specified by user.*P* is the bias parameter value.

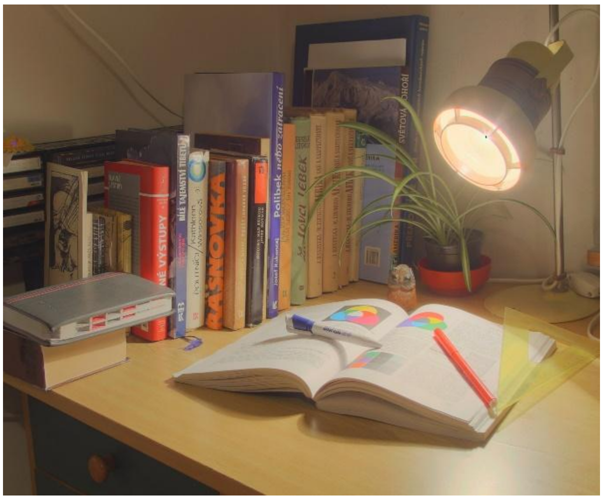

Figure 1 : Tone mapping image of Drago's method.

Logarithmic and exponential mappings are among the most straightforward nonlinear mappings. Their main use is providing a baseline result against which all other operators may be compared. For medium dynamic range images these very simple solutions may in fact be competitive with more complex operators.

The logarithmic is a compressive function for values higher than 1, and therefore range compression may be achieved by mapping luminance as follows.

$$L_d(x,y) = \frac{\log_{10}(1+L_w(x,y))}{\log_{10}(1+L_{max})}$$

Where the displayed luminance L_d is derived from ratio of world luminance L_w and maximum luminance in scene L_{max}. This mapping ensures that what-ever the dynamic range of the scene is, the maximum value is remapped to one (white) and other luminance values are smoothly incremented. Exponential mapping converts world luminance to display luminance by means of exponential function as follows.

$$L_d(x,y) = 1 - \exp\left\{-\frac{L_w(x,y)}{L_{av}}\right\}$$

Where L_{av} is the average luminance. This function is bound between 0 for black pixels and 1 for infinitely bright pixels. Because the world luminance's are always smaller than infinity, the resulting display luminance will in practice never quite reach 1.For images with a dynamic range that only just exceeds the capabilities of the chosen display device, these approaches may well suffice. For images with a higher dynamic range, however, other approaches may be more suitable.In global operator a single tone mapping curve is used throughout the image due to which there is a limit to dynamic range of input image beyond which successful compression becomes difficult.

2.2Local Tone Mapping Operators

Local operators adapt their scales to different areas of an image. Local operator compresses each pixel according to its luminance value as well as to luminance value of neighbouring pixel.The local operators are the fast bilateral filtering presented by Durand and Dorsey (2002), Ashikhmin*et al*. (2002), and Reinhard*et al*. (2002) methods.Reinhard et al. presented a photographic tone reproduction inspired by photographic film development and the printing process (Reinhard*et al*., 2002) [5]. The luminance of an image is initially mapped by using a global tone mapping function to compress the range of luminance into the displayable range. Tone mapping operator to allow high luminance to burn out in a controllable fashion is given by expression

$$L_d(x,y) = \frac{\mathrm{L(x,y)}\left(1 + \frac{L(x,y)}{L_{white}^2}\right)}{1 + \mathrm{L(x,y)}}$$

Where L_{white} is the smallest luminance that will be mapped to pure white. To enhance the quality of an image, a local adaptation is based on photographic “dodging and burning” technique which allows a different exposure for each part of the applied image. The most recent version of this method operates automatically, freeing the user from setting parameters (Reinhard, 2003). To automate processes, low contrast regions are found by a centre-surround function at different scales. Then, a tone mapping function is locally applied. The automatic dodging and burning method enhances contrast and details in an image while preserving theoverall luminance characteristics.

Ashikhmin operator [6] attempts to model only those aspects of human visual perception that are relevant to dynamic range compression. It applies a locally linear mapping over much of the image with the coefficientapplied depending on the particular image neighbourhood so that mapping would preserve details throughout the image. They compute local adaptation level $L_a(x,y)$ as the average luminance over some local image area. Then apply tone mapping function TM(L) to $L_a(x,y)$ which would create tone mapped adaptation image $TM(L_a(x,y))$. The main purpose of this function is to compress a high dynamic range image to the display range while trying to convey the overall impression of brightness. Once the adaptation image and its tone mapped version are produced, we can state the requirement of local contrast preservation as $c_d(x,y) = c(x,y)$ where subscript *d* to refer to display.

Local contrast c at a pixel is defined as

$$c(x,y) = \frac{\mathrm{L(x,y)}}{L_a(x,y)} - 1$$

Using above equation final formulae to obtain tone mapping is

$$L_d(\mathrm{x,y}) = \frac{\mathrm{L(x,y)TM}(L_a(x,y))}{L_a(\mathrm{x,y})}$$

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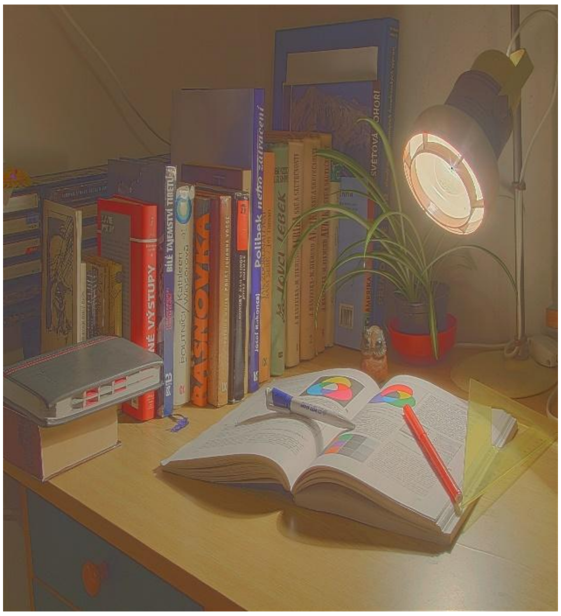
This will give a greyscale tone mapped image. To Re-assemble colour image apply scaling obtained for luminance to each of the original channel. Perform gamma correction to obtains pixel value for display.



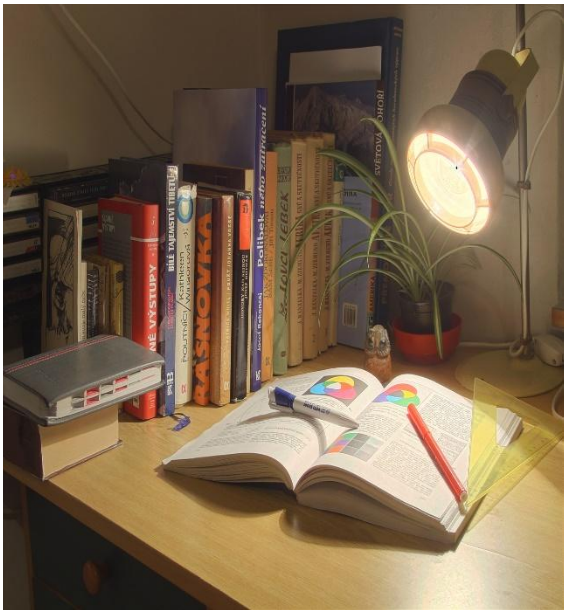


Figure 2 : Tone mapping images of Ashikhmin (L)and Reinhard's (R) method.

In addition to local and global operators, there are two other classes of operators that work in a fundamentally different way. First, it may be possible under favourable conditions to separate illuminance from surface reflectance. By compressing only illuminance component, an image may be successfully reduced in dynamic range. Second, we may exploit the fact that an image area with a high dynamic range tends to exhibit large gradients between neigh-boring pixels. This leads to a solution whereby the image is differentiated. Then the gradients are manipulated before the result is integrated into a compressed image.

2.3 Frequency Domain Operators

Frequency dependent operators are interesting from a historical perspective as well as for the observations about image structure they afford. These algorithms may therefore help us better understand the challenges we face when preparing HDR images for display.

Durand and Dorsey [7] introduced the bilateral filter to the computer graphics com-munity and showed how it may be used to help solve the tone-reproduction problem. Bilateral filtering is an edge-preserving smoothing operator that effectively blurs an image but keeps sharp edges intact. The bilateral filtering technique is used to separate an image into a base layer and a detail layer. The base layer tends to be low frequency and HDR, whereas the detail layer is high frequency and LDR. The tone-reproduction operator then proceeds by compressing the base layer before recombining it with the detail layer. At the same time, the output of the bilateral filter may be seen as providing a local adaptation value for each pixel.

2.4 Gradient Domain Operators

High-frequency components in an image cause rapid changes from one pixel to the next. On the other hand, low-frequency features cause the differences between neighbouring pixels to be relatively small. It is therefore possible to partially distinguish between illuminance and reflectance in a different way by considering the gradients in the image. Although such separation depends on thresholding, tone reproduction does not necessarily require separation of illuminance and reflectance. In addition, HDR imagery frequently depicts scenes that deviate significantly from the assumption of diffuse reflection. Fattal et al. [8] have shown that image gradients may be attenuated rather than thresholded, leading to a capable tone-reproduction operator.

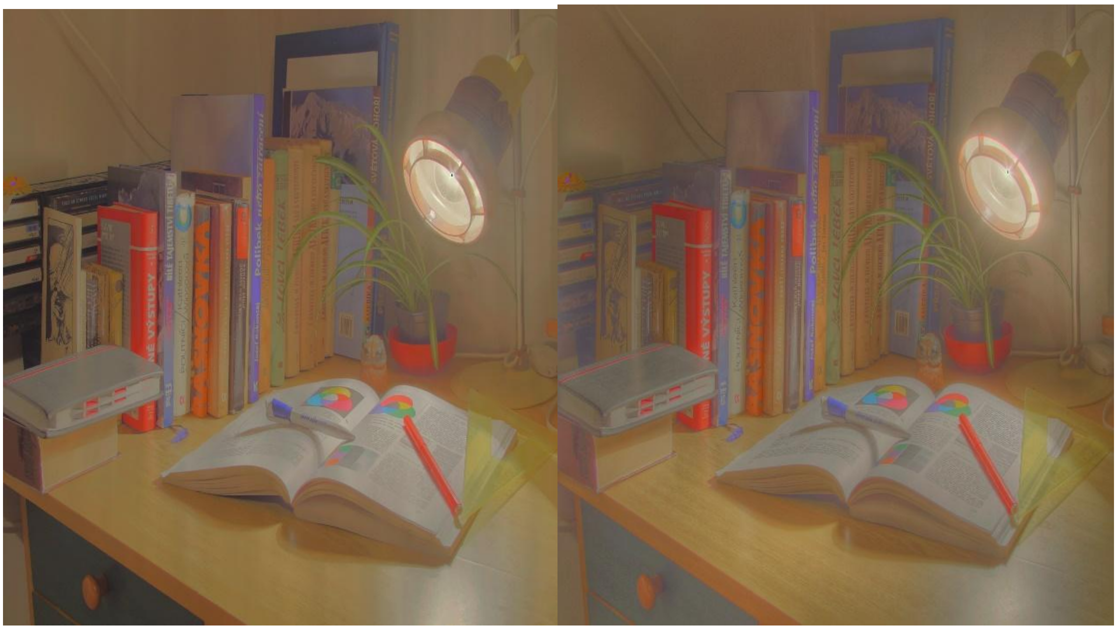


Figure 3: Tone mapping images of Durand and Dorsey (L) and Fattal's (R) method.

III CONCLUSION

A brief study of the various operators is given above which helps in identifying the operators according to the need of enhancement. This study helps in discovering the new operator which enables the HDR picture to LDR. Until advances in hardware provide us with a more advanced form of display we will have to depend on tone reproduction operators to deliver the desired perceptual effect. Evolution of display technology has seen the beginning of a move away from the standard monitor but these have still to become commonplace, and have disadvantages of their own. Although our display capabilities are limited, it is important to ensure that the Information is stored in a relevant device-independent representation so that none of the HDR information is lost, thus preserving display options.

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