LDR Image from HDR by Using Fast and Saliency Based Tone-Mapping Algorithm: A Review

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Abstract - This paper presents a comparatively analysis of the fast and saliency feature based tone mapping technique. After analysis of these techniques we had concluded that fast tone-mapping algorithm is most computationally efficient and easy but there may be some halo artifacts. While in Visual-Salience-based Tone mapping method for High dynamic range images the halo artifacts significantly reduced. Thus salience based tone mapping gives best visual image quality as compared to fast tone mapping method. The visual quality of tone-mapped image, especially attention-salient regions, is improved by the saliency-aware weighting. Experimental results show that the saliency-aware technique produces good results on a variety of high dynamic range images.

Keywords: HDR Imaging, Exposure Determination, Tone Mapping, Local Tone Mapping.

I. INTRODUCTION

We experience in our daily life that the real world scenes often have a very wide range of luminance values. Quality of the image can be improved with the concept of lots of images of same object at the same position can be taken as the raw images. Although it would be possible to capture high dynamic range (HDR) photos with the future digital cameras. In any one single shot only a part of the real world high dynamic scene is visible with the current technology. Such a scenario is illustrated in Figure(1). It is an indoor scene with the sunlight coming through the window and the camera was placed at the dark end. To make the features visible near the window, less exposure was used. However, this made the scene further away from the light source too dark [1]. We increased the exposure interval to make the features visible in the dark end.

To human observers, however, all features in the darkest as well as the brightest areas are equally clearly visible simultaneously. In fact, recent technologies have made it relatively easy to create numerical luminance maps that capture the full dynamic range of real world scene [1], [2].For a sequence of low dynamic range (LDR) images of the same scene taken under different exposure levels, a HDR radiance map of the scene can be generated. Several works try to select the most appropriate LDR images to generate the HDR image where many LDR images with various exposures are already captured and stored; it implies that larger storage, as well as higher energy consumption is needed for such scenarios. In addition, it is not guaranteed whether the proper LDR images are already captured [2]. One simple method for HDR imaging is to use the LDR images with different exposure value (EV). Although it is feasible to obtain the HDR image using these exposure settings, the HDR image quality is likely to be not promising due to the varying luminance condition, as well as the characteristics of each scene to be captured. To overcome this problem, the saliency based local tone mapping technique is used to dynamically determining the exposure parameters.

In this way, only the needed LDR images are captured. Moreover, not only an improved HDR image can be expected due to a supply of more suitable LDR images, but also a lower requirement of storage and power consumption can be achieved. Usually, there will be more details at the dark region for an image taken with a longer exposure time, and there will be more details at the bright region for the image taken with a shorter exposure time. That is the reason why we can use several LDR images with different exposure settings to make the HDR image generation possible. Then, HDR image can be generated by combining these LDR images .But a conventional low dynamic range (LDR) image represents a scene at an exposure level with a limited contrast range. This results in loss of details in bright or dark areas of the scene depending on the setting of exposure level. A high dynamic range (HDR) image overcomes the limitation of the LDR image, and it can preserve details in both the bright and dark areas of the scene well [1]. Therefore, an HDR image includes much more information than an LDR image. However, the display of an HDR image is an issue. Most current conventional

Fig 1: Digital HDR images of the same scene taken with different exposure intervals.

display devices only have limited dynamic ranges and hence are unable to display HDR images. Due to the huge discrepancy between the ranges of HDR images and display devices, it is necessary to compress HDR images such that the appearance of both extremes of bright and dark regions can be reproduced on these ordinary LDR display devices simultaneously. Visual saliency was widely applied for the processing of the conventional LDR images, such as image/video compression, visual search, object recognition, etc. [3]–[5], [9].

Since visual saliency aims to predict the attentional gaze of observers viewing a scene, it is highly demanded for the HDR images, especially for the display of the HDR images .This paper is organized as follows. The section II includes the fast tone mapping method. Section III covers the Visual-saliency based local tone mapping technique. Section IV presents experimental results and section V concludes the paper.

II. FAST TONE MAPPING METHOD

In few years a number of techniques have been developed for tone reproduction for high contrast images. There are two broad categories of technology [6]. Tone reproduction curve (TRC) based techniques manipulate the pixel distributions. previous pioneering work in this category include that of [7] which introduced a tone reproduction method that attempted to match display brightness with real world sensations. Recently, [8] presented a tone mapping method that modelled some aspects of human visual system. Recently, we have developed a learning-based TRC tone mapping method [10] and a fast TRC tone mapping method [11], for high dynamic range compression. Often at multiple scales Tone reproduction operator (TRO) based techniques involve the spatial manipulation of local neighbouring pixel values [2]. This type of technique is based on the image formation model:

$$I(x, y) = Q(x, y)\, R(x, y) \tag{1}$$

Which is elaborated in [2], [6] and [7]. Recent development has also attempted to incorporate traditional photographic technology to the digital domain for the reproduction of high dynamic range images [12]. An impressive latest development in high dynamic range compression is that of [13]. Human visual system is only sensitive to relative local contrast based on the observation that the authors developed a multi-resolution hill domain technique [2].

Operation: Let $I(x, y)$ be the high dynamic input image. We first calculate the logarithmic value image $QI(x, y) = \log(I(x, y))$.

Let $Q_{\min} = MIN\{QI(x, y)\}$ $Q_{\max} = MAX\{QI(x, y)\}$.

Plotting the histogram is to use the probability of the occurrence of the pixel, $H[k] = prob[QI(x,y) = k]$ is first constructed. The algorithm then divides the dynamic range $[Q_{\min}, Q_{\max}]$ into N intervals using a hierarchical division procedure. First, a control parameter a, 0≤ a ≤1, is defined (this is the only user defined parameter in the algorithm). We then find a value b_o , $Q_{\min} \le b_o \le Q_{\max}$, such that pixel populations on both sides of the value are equal:

$$\sum_{k=Q_{\min}}^{b_o} H[k] = \sum_{k=b_o}^{Q_{\max}} H[k] \tag{2}$$

After that divide the dynamic range into 2 segments by finding a cutting value, $C0$:

$$C_0 = \frac{Q_{\min} + Q_{\max}}{2} + a\left(b_0 - \frac{Q_{\min} + Q_{\max}}{2}\right) \tag{3}$$

The dynamic range is now divided into two intervals: $[Q_{\min}, C_0]$ and $[C_0, Q_{\max}]$ These two intervals are then again each divided into two subsequent intervals following a similar rule. For the segment, $[Q_{\min}, C_0]$ we find a value $b_{1,0}$, $Q_{\min} \le b_{1,0} \le C_0$ such that pixel populations on both sides of the value are equal:

$$\sum_{k=Q_{\min}}^{b_{1,0}} H[k] = \sum_{k=b_{1,0}}^{C_0} H[k] \tag{4}$$

We then divide the interval into 2 segments by finding a cutting value, $C_{1,0}$:

$$C_{1,0} = \frac{C_0 + Q_{\min}}{2} + a\left(b_{1,0} - \frac{C_0 + Q_{\min}}{2}\right) \tag{5}$$

Similarly, for the segment $[C_0, Q_{\max}]$ we find a value $b_{1,1}$

$C_0 \le b_{1,1} \le Q_{\max}$ such that

$$\sum_{k=C_0}^{b_{1,1}} H[k] = \sum_{k=b_{1,1}}^{Q_{\max}} H[k] \tag{6}$$

We then divide the interval into 2 segments by finding a cutting value, $C_{1,1}$:

$$C_{1,1} = \frac{C_0 + Q_{\max}}{2} + a\left(b_{1,1} - \frac{C_0 + Q_{\max}}{2}\right) \tag{7}$$

the dynamic range will be divided into 4 intervals

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$[Q_{\min}, C_{1,0}], [C_{1,0}, C_0], [C_0, C_{1,1}] and [C_{1,1}, Q_{\max}]$

Then repeatedly perform the procedure for each of the intervals and divide each into two segments. After n iterations, the dynamic range would have been divided into $N = 2^n$ segments. Pixels that fall into the same segments are then mapped to the same display value in the low dynamic range devices. If a=0 the mapping is linear and gives low visibility and if a=1 the mapping is histogram equalized and gives artificial contrast. By setting a single parameter we can strike a balance between good visibility and well-preserved visual contrast. This method is computationally very simple.

III. VISUAL-SALIENCE-BASED TONE MAPPING

In this While in Visual-Salience-based Tone mapping method for High dynamic range Images, a saliency-aware local tone-mapping algorithmic introduced for HDR images. Among the existing saliency models in [15]–[17], the saliency model in [16] and [17] is chosen to be extended from LDR domain to HDR domain due to its simplicity and robustness. The extended saliency model is adopted to set up a saliency-aware weighting for the processing of HDR images. The proposed saliency-aware weighting and a new edge-aware weighting are fused together to build up a content-aware weighting which is incorporated into the guided image filter in [14] to form a perceptually guided image filter. The new filter and the saliency-aware weighting are then applied to design a local mapping algorithm for HDR images. The three major components of the proposed local tone-mapping algorithm are the decomposition of the HDR luminance component into a base layer and a detail layer, the compression of the base layer, and the amplification of the detail layer. The proposed filter is applied for the decomposition of the luminance component of an HDR image. Since the proposed filter preserves sharp edges in the base layer better than the guided filter in [14], halo artifacts are significantly reduced in the tone-mapped image. After analyse of these two methods we concluded that if tone-mapped image has some halo artifacts then these types of artifacts can be minimized by using a saliency-aware local tone-mapping algorithm.

The luminance value of the HDR image is obtained by computing a linear combination of the red, green, and blue

Components as follows

$$X_h(p) = .299R_h(p) + .587G_h(p) + .114B_h(p) \quad (8)$$

The luminance component of the HDR image in (8) is decomposed as

$$X_h(p) = X_b(p)X_d(p) \quad (9)$$

Where X_b and X_d are the base layer and the detail layer, respectively. The dynamic range of the detail layer X_d is small, while the base layer X_b could vary a great deal, often much more than the detail layer X_d. The overall dynamic range is reduced by using a global tone-mapping algorithm to scale down the base layer X_b as $\hat{X}_b$. The detail layer X_d is preserved or even amplified as $\hat{X}_d$ to enhance local contrasts. The compressed luminance value X_l is the product of $\hat{X}_b$ and $\hat{X}_d$. The HDR image $\{R,G,B\}_h$, X_h and X_l are finally adopted to generate the output LDR image $\{R,G,B\}_l$. As shown by the "just noticeable difference" experiment [28], the decomposition is performed in the log domain as

$$L_h(p) = L_b(p) + L_d(p) \quad (10)$$

Where $L_b(p)$ and $L_d(p)$ are $log(X_b(p))$ and $log(X_d(p))$ respectively. The local tone-mapping algorithm are based on the decomposition of L_h *by a* Perceptually Guided Filter Inspired by the guided filter in [18], L_b is assumed to be a

$$L_b(p) = a_{p'}L_h(p) + b_{p'}, \forall p \in \Omega_{p_2}(p') \quad (11)$$

where $a_{p'}$ and $b_{p'}$ are supposed to be constant in the window $\Omega_{p_2}(p')$.The linear coefficients $(a_{p'}, b_{p'})$ are obtained by minimizing the difference between L_h and L_b while maintaining the linear model (11), i.e., by minimizing the following cost function:

$$\sum_{p \in \Omega_{p_2}(p')} \left[W(p')(a_{p'}L_h(p) + b_{p'} - L_h(p))^2 + \lambda a_{p'}^2 \right] \quad (12)$$

By comparing the cost function $E(a_{p'}, b_{p'})$ in (12) with the cost function in [16], it can be found that the cost function $E(a_{p'}, b_{p'})$ in (8) contains a content-aware weighting $W(p')$ which is responsible for reducing the halo artifact and preserving fine details according to the saliency-aware weighting.

IV. PROPOSED EXPERIMENTAL RESULTS

Tone mapping of HDR images is a very hot research topic in the fields of image processing and computation photography; there are dozens of tone-mapping algorithms. The fast tone-mapping technique has been tested on a variety of high dynamic range images. The luminance signal is calculated as: L = 0.299*R+0.587*G+0.114*B. Log(L) is computed to compile a histogram.

(a)

(b)

Fig 2: (a) The result of fast tone mapping method (b) result of Local tone mapping method after colour correction.

The vibrant range was separated into 256 interims thus reducing the original high dynamic range to 256 values for display. We custom the following formula to get the output LDR pixels as

$$R_{out} = \left(\frac{R_{in}}{L_{in}}\right)^{\gamma} L_{out};;$$

$$G_{out} = \left(\frac{G_{in}}{L_{in}}\right)^{\gamma} L_{out},$$

$$B_{out} = \left(\frac{B_{in}}{L_{in}}\right)^{\gamma} L_{out} \quad (13)$$

Where L_{in} and L_{out} are luminance values before and after compression, γ controls display color (setting it between0.4 and 0.6 worked well).


(a) (b)

Fig 3:(a) The result of fast tone mapping method (b) result of Local tone mapping method after colour correction.

The high dynamic range compression technique is very simple and efficient but it certainly loose some fine details of the scene. Fig 2 (a) and 3(a) show examples of mapped HDR images using fast tone mapping algorithm A saliency-aware weighting and an edge-aware weighting into tone mapping of HDR images, the proposed local mapping algorithm provide best visual image quality and also free from halo effects when we compare with fast tone-mapping algorithm of HDR images. Fig 2 (b) and 3(b) shows the examples of mapped LDR images using saliency based local tone mapping algorithm. Therefore from observation of two figures we see that the visual quality of tone mapped image is improved by using local tone mapping algorithm.

V. CONCLUSION

In this work we analysed the Novel saliency-aware weighting and edge-aware weighting and fast tone mapping methods for LDR images. The fast tone mapping algorithm is computationally efficient and very simple LDR imaging technology. The Novel saliency-aware weighting and edge-aware weighting applied to design a local tone-mapping algorithm for the display of HDR images on display devices with low dynamic ranges. Experimental results show that most of the halo artifacts have been avoided from appearing.

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