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An Efficient Objective Quality Assessment to Access the Quality of Tone Mapped Images

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Abstract

Tone-mapping operators (TMOs) that convert high dynamic range (HDR) to low dynamic range (LDR) images pro-vide practically useful tools for the visualization of HDR images on standard LDR displays. Different TMOs create different tone-mapped images, and a natural question is which one has the best quality. Without an appropriate quality measure, different TMOs cannot be compared, and further improvement is directionless. Subjective rating may be a reliable evaluation method, but it is expensive and time consuming, and more importantly, is difficult to be embedded into optimization frameworks. Here we propose an objective quality assessment algorithm for tone-mapped images by combining: 1) a multiscale signal fidelity measure on the basis of a modified structural similarity index and 2) a naturalness measure on the basis of intensity statistics of natural images. Validations using independent subject-rated image databases show good correlations between subjective ranking score and the proposed tone-mapped image quality index (TMQI). Furthermore, we demonstrate the extended applications of TMQI using two examples—parameter tuning for TMOs and adaptive fusion of multiple tone-mapped images

I. INTRODUCTION

There is increasing interest in high dynamic range (HDR) images, HDR imaging systems, and HDR displays. The visual quality of high dynamic range images is vastly higher than that of conventional low-dynamic-range (LDR) images, and the significance of the move from LDR to HDR has been compared to the momentous move from blackand-white to color television [1]. In this transition period, and to guarantee compatibility in the future, there has been a need to develop methodologies to convert an HDR image into its ‘best’ LDR equivalent. For this conversion, tone mapping operators (TMOs) have attracted considerable interest. Tone mapping operators have been used to convert HDR images into their LDR associated images for visibility purposes on non-HDR displays. Unfortunately, TMO methods perform differently, depending on the HDR image to be converted, which means that the best TMO method must be found for each individual case. A survey of various TMOs for HDR images and videos is provided in [2] and [3]. Traditionally, TMO performance has been evaluated subjectively. In [4], a subjective assessment was carried out using an HDR monitor. Mantiuk et al. [5] propose an HDR visible difference predictor (HDR-VDP) to estimate the visibility differences of two HDR images, and this tool has also been extended to a dynamic range independent image quality assessment [6].

However, the authors did not arrive at an objective score, but instead evaluated the performance of the assessment tool on HDR displays. Although subjective assessment provides true and useful references, it is an expensive and time-consuming process. In contrast, the objective quality assessment of tone mapping images enables an automatic selection and parameter tuning of TMOs [7], [8]. Consequently, objective assessment of tone-mapping images, which is proportional to the subjective assessment of the images, is currently of great interest. Recently, an objective index, called the tone mapping quality index (TMQI) was proposed in [2] to objectively assess the quality of the individual LDR images produced by a TMO. The TMQI is based on combining an SSIM-motivated structural fidelity measure with a statistical naturalness:

$$\mathrm{TMQI}(H, L) = a[S(H, L)]^{\alpha} + (1 - a)[N(L)]^{\beta} . \quad (1)$$

where S and N denote the structural fidelity and statistical naturalness, respectively. H and L denote the HDR and LDR images. The parameters α and β determine the sensitivities of the two factors, and a ($0 \le a \le 1$) adjusts their relative importance. Both S and N are upper bounded by 1, and so the TMQI is also upper bounded by 1 [8]. Although the TMQI clearly provides better assessment for tone-mapped images than the well-known image quality assessment metrics, like SSIM [9], MS-SSIM [10], and FSIM [11], its performance is not perfect. Liu et al. [12] replaced the pooling strategy of the structural fidelity map in the TMQI with various visual saliency-based strategies for better quality assessment of tone mapped images.

They examined a number of visual saliency models and conclude that integrating saliency detection by combining simple priors (SDSP) into the TMQI provides better assessment capability than other saliency detection models. In this paper, we first propose a feature similarity index for tone-mapped images (FSITM) which is based on the phase information of images. It has been observed that phase information of images prevails its magnitude [13]. Also, physiological evidence indicates that the human visual system responds strongly to points in an image where the phase information is highly ordered [14]. Based on this assumption, several quality assessment metrics have been proposed [11], [15], [16]. In [11], the maximum moment of phase congruency covariance, which is an edge strength map, is used. Hassen et al. [15] used local phase coherence for image sharpness assessment. Saha et al. [16] proposed an image quality assessment using phase deviation sensitive energy features. Unfortunately, these metrics do not provide a reliable assessment for tone mapped images

Typical objective image quality assessment (IQA) approaches assume the reference and test images to have the same dynamic range [12], and thus cannot be directly applied to evaluate tone mapped images. Only a few objective assessment methods have been proposed for HDR images. The HDR visible differences predictor (HDR-VDP) [1], [13] is a human visual system (HVS) based fidelity metric that aims to distinguish between visible (suprathreshold) and invisible (subthreshold) distortions. The metric reflects the perception of distortions in terms of detection probability. Since HDR-VDP is designed to predict the visibility of differences between two HDR images of the same dynamic range, it is not applicable to compare an HDR image with an LDR image. A dynamic range independent approach was proposed in [14], which improves upon HDR-VDP and produces three types of quality maps that indicate the loss of visible features, the amplification of invisible features, and reversal of contrast polarity, respectively. These quality maps show good correlations with subjective classifications of image degradation types including blur, sharpening, contrast reversal, and no distortion. However, it does not provide a single quality score for an entire image, making it impossible to be validated with subjective evaluations of overall image quality.

The purpose of the current work is to develop an objective IQA model for tone mapped LDR images using their corre-sponding HDR images as references. Our work is inspired by the success of two design principles in IQA literature. The first is the structural similarity (SSIM) approach [15] and its multi-scale derivations [16], [17], which asserts that the main purpose of vision is to extract structural information from the visual scene and thus structural fidelity is a good predictor of perceptual quality. The second is the natural scene statistics (NSS) approach, which maintains that the visual system is highly adapted to the natural visual environment and uses the departure from natural image statistics as a measure of perceptual quality [18]. Here we propose a method that combines a multi-scale structural fidelity measure and a statistical naturalness measure, leading to Tone

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Mapped image Quality Index (TMQI). Moreover, we demonstrate that TMQI can be employed for optimizing parameters in TMOs and for adaptively fusing multiple tone mapped images.

II. QUALITY ASSESSMENT METHOD

Due to the reduction in dynamic range, TMOs cannot preserve all information in HDR images, and human observers of the LDR versions of these images may not be aware of this. Therefore, structural fidelity plays an important role in assessing the quality of tone-mapped images [19]. On the other hand, structural fidelity alone does not suffice to provide an overall quality evaluation. A good quality tone mapped image should achieve a good compromise between structural fidelity preservation and statistical naturalness, which are sometimes competing factors.

A. Structural Fidelity

The SSIM approach provides a useful design philosophy as well as a practical method for measuring structural fidelities between images [20]. The original SSIM algorithm is applied locally and contains three comparison components − lumi-nance, contrast and structure. Since TMOs are meant to change local intensity and contrast, direct comparisons of local and contrast are inappropriate. Let x and y be two local image patches extracted from the HDR and the tone-mapped LDR images, respectively. We define our local structural fidelity measure as

$$S_{\text{local}}(x, y) = \frac{2\sigma'_x\sigma'_y + C_1}{\sigma'^2_x + \sigma'^2_y + C_1} \cdot \frac{\sigma_{xy} + C_2}{\sigma_x\sigma_y + C_2} \qquad (1)$$

where σ_x , σ_y and $\sigma_{x\,y}$ are the local standard deviations and cross correlation between the two corresponding patches in HDR and LDR images, respectively, and C_1 and C_2 are posi-tive stabilizing constants. Compared with the SSIM definition[15], the luminance comparison component is missing, and the structure comparison component (the second term in (1)) is exactly the same. The first term in (1) compares signal strength and is modified from that of the SSIM definition based on two intuitive considerations. First, the difference of signal strength between HDR and LDR image patches should not be penalized when their signal strengths are both significant (above visibility threshold) or both insignificant (below visibility threshold). Second, the algorithm should penalize the cases that the signal strength is significant in one of the image patches but insignificant in the other. This is different from the corresponding term in the original SSIM definition where any change in signal strength is penalized.

To distinguish between significant and insignificant signal strength, we pass the local standard deviation σ through a nonlinear mapping, which results in the σ^{-} value employed in (1). The nonlinear mapping should be designed so that signif-icant signal strength is mapped to 1 and insignificant signal strength to 0, with a smooth transition in-between. Therefore, the nonlinear mapping is related to the visual sensitivity of contrast, which has been an extensively studied subject in the literature of visual psychophysics [21]. Practically, the HVS does not have a fixed threshold of contrast detection, but typically follows a gradual increasing probability in observ-ing contrast variations. Psychometric functions describing the detection probability of signal strength have been employed to model the data taken from psychophysical experiments. Generally, the psychometric function resembles a sigmoid shape [22], [23] and the sensory threshold is usually defined at the level of 50% of detection probability. A commonly adopted psychometric function is known as Galton's ogive [21], which takes the form of a cumulative normal distribution function given by

$$p(s) = \frac{1}{\sqrt{2\pi}\theta_s} \int_{-\infty}^{s} \exp\left[-\frac{(x-\tau_s)^2}{2\theta_s^2}\right] dx \qquad (2)$$

where p is the detection probability density, s is the amplitude of the sinusoidal stimulus, τ_s is the modulation threshold, and θ_s is the standard deviation of the normal distribution that controls the slope of detection probability variation. It was

$$k = \frac{\tau_s}{\theta_s} \qquad (3)$$

is roughly a constant, known as Crozier's law [21], [24]. Typical values of k ranges between 2.3 and 4, and

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k = 3 makes the probability of false alarm considerably small [21].

The reciprocal of the modulation threshold τ_s is often used to quantify visual contrast sensitivity, which is a function of spatial frequency, namely the contrast sensitivity function (CSF) [21]. A CSF formula that fits well with data collected in various psychological experiments is given by [25]

$$A(f) \approx 2.6[0.0192 + 0.114f]\exp[-(0.114f)^{1.1}] \quad (4)$$

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where f denotes spatial frequency. This function is normalized to have peak value 1, and thus only provides relative sensitivity across the frequency spectrum. In practice, it needs to be scaled by a constant λ to fit psychological data. The local structural fidelity measure Slocal is applied to an image using a sliding window that runs across the image space.This results in a map that reflects the variation of structural fidelity across space. The visibility of image details depends on the sampling density of the image, the distance between the image and the observer, the resolution of the display, and the perceptual capability of the observer's visual system. A singlescale method cannot capture such variations. Following the idea used in multi-scale [16] and information-weighted SSIM [17], we adopt a multi-scale approach, where the images are iteratively low-pass filtered and downsampled to create an image pyramid structure [27], as illustrated in Fig. 1. The local structural fidelity map is generated at each scale. Fig. 2 shows two examples of such maps computed at multiple scales for the LDR images created from two different TMOs. It is interesting to observe these fidelity maps and examine how they correlate with perceived image fidelity. For example, the structural details of the brightest window regions are missing in Image (b), but are more visible in Image (a). For another example, there are detailed structures in the top-right dark regions that are not easily discerned in Image (a), but are better visualized in Image (b). All of these are clearly reflected in the structural fidelity maps.

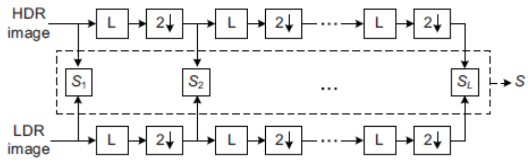

Fig. 1. Framework of multiscale structural fidelity assessment.

B. Statistical Naturalness

A high quality tone mapped LDR image should not only faithfully preserve the structural fidelity of the HDR image, but also look natural. Nevertheless, naturalness is a subjective quantity that is difficult to define quantitatively. A large literature has been dedicated to the statistics of natural images which have important significance to both image processing applications and the understanding of biological vision [28]. An interesting study of naturalness in the context of subjective evaluation of tone mapped images was carried out in [29] which provided useful information regarding the correlations between image naturalness and different image attributes such as brightness, contrast, color reproduction, visibility and reproduction of details.

The results showed that among all attributes being tested, brightness and contrast have more correlation with perceived naturalness. This motivates us to build our statistical naturalness model based on these two attributes. This choice may be oversimplifying in defining the general concept of statistical image naturalness (and may not generalize to other image processing applications that uses the concept of naturalness), but it provides an ideal compromise between the simplicity of our model and the capability of capturing the most important ingredients of naturalness that are related to the tone mapping evaluation problem we are trying to solve, where brightness mapping is an inevitable issue in all tone mapping operations. It also best complements the structural fidelity measure described in Section II-A, where brightness modeling and evaluation are missing.

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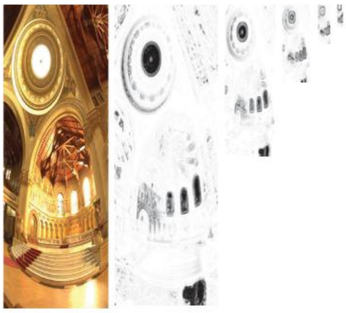
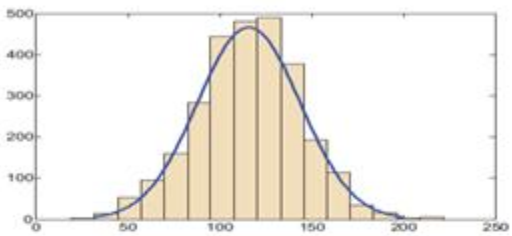
(a)



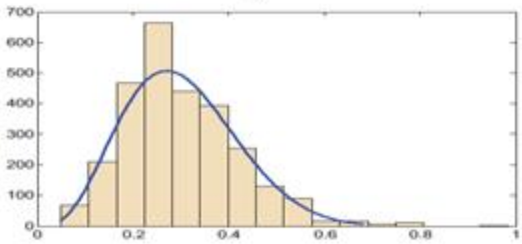
(b)

Fig. 2. Tone-mapped LDR images and their structural fidelity maps in five scales. The images were created using Adobe Photoshop "Highlight compression" and "Exposure and Gamma" methods (not optimized for quality), respectively. (a) $S = 0.9152$ ($S_1 = 0.8940$; $S_2 = 0.9341$; $S_3 = 0.9428$; $S_4 = 0.9143$; $S_5 = 0.8277$). (b) $S = 0.8614$ ($S_1 = 0.9161$; $S_2 = 0.9181$; $S_3 = 0.8958$; $S_4 = 0.8405$; $S_5 = 0.7041$).

Our statistical naturalness model is built upon statistics conducted on about 3,000 8bits/pixel gray-scale images obtained from [30], [31] that represent many different types of natural scenes. Fig. 3 shows the histograms of the means and standard deviations of these images, which are useful measures that reflect the global intensity and contrast of images.



(a)



(b)

Fig. 3. Histograms of (a) means (fitted by Gaussian PDF) and (b) standard deviations (fitted by Beta PDF) of natural images.

CONCLUSION

We develop an objective model to assess the quality of tone mapped images by combining a multi-scale structural fidelity measure and a statistical naturalness measure. The proposed measure not only provides an overall quality score of an image, but also creates multi-scale quality maps that reflect the structural fidelity variations across scale and space. Our experiments show that TMQI is reasonably correlated with subjective evaluations of image quality. Moreover, we demonstrate the usefulness of TMQI in automatic parameter tuning of tone mapping algorithms and in fusing multiple tone mapped images.

As one of the first attempts on the research topic, our method has several limitations that may be resolved or improved in the future. First, TMQI is designed to evaluate grayscale images only, but most HDR images of natural scenes are captured in color. One simple method to evaluate tone mapped color images is to apply the TMQI to each color channel independently and then combine them. Color fidelity and color naturalness measures may be developed to improve the quality measure.

Second, simple averaging is used in the current pooling method of the structural fidelity map. Advanced pooling method that incorporate visual attention models may be employed to improve the quality prediction performance.

Third, the current statistical naturalness measure is based on intensity statistics only. There is a rich literature on natural image statistics [28] and advanced statistical models(that reflects the structural regularities in space, scale and orientation in natural images) may be included to improve the statistical naturalness measure.

Fourth, using TMQI as a new optimization goal, many exist-ing TMOs may be redesigned to achieve better image quality. Novel TMOs may also be developed by taking advantage of the construction of the proposed quality assessment approach.

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Finally, the current method is applied and tested using natural images only. The application scope of HDR images and TMOs is beyond natural images. For example, modern medical imaging devices often capture HDR medical images that need to be tone-mapped before visualization. The TMQI and optimization methods may be adapted to these extended applications.

REFERENCES

1 E. Reinhard, G. Ward, S. Pattanaik, P. Debevec, W. Heidrich, and K. Myszkowski, High Dynamic Range Imaging: Acquisition, Display, and Image-Based Lighting. San Mateo, CA: Morgan Kaufmann, 2010.

2 E. Reinhard, M. Stark, P. Shirley, and J. Ferwerda, “Photographic tone reproduction for digital images,” in Proc. 29th Annu. Conf. Comput. Graph. Interact. Tech., vol. 21. 2002, pp. 267–276.

3 G. W. Larson, H. Rushmeier, and C. Piatko, “A visibility matching tone reproduction operator for high dynamic range scenes,” IEEE Trans. Visual. Comput. Graph., vol. 3, no. 4, pp. 291–306, Oct.–Dec. 1997.

4 F. Drago, K. Myszkowski, T. Annen, and N. Chiba, “Adaptive loga-rithmic mapping for displaying high contrast scenes,” Comput. Graph. Forum, vol. 22, no. 3, pp. 419–426, 2003

5 R. Fattal, D. Lischinski, and M. Werman, “Gradient domain high dynamic range compression,” in Proc. 29th Annu. Conf. Comput. Graph. Interact. Tech., 2002, pp. 249–256.

6 F. Drago, W. L. Martens, K. Myszkowski, and H.-P. Seidel, “Perceptual evaluation of tone mapping operators,” in Proc. SIGGRAPH Conf. Sketches Appl., 2003, p. 1.

7 A. J. Kuang, H. Yamaguchi, G. M. Johnson, and M. D. Fairchild, “Testing HDR image rendering algorithms,” in Proc. IS T/SID Color Imag. Conf., 2004, pp. 315–320.

8 P. Ledda, A. Chalmers, T. Troscianko, and H. Seetzen, “Evaluation of tone mapping operators using a high dynamic range display,” ACM Trans. Graph., vol. 24, no. 3, pp. 640–648, 2005.

9 A. Yoshida, V. Blanz, K. Myszkowski, and H. Seidel, “Perceptual evaluation of tone mapping operators with real-world scenes,” Proc. SPIE, Human Vis. Electron. Imag., vol. 5666, pp. 192–203, Jan. 2005.ˇ

10 M. Cadík, M. Wimmer, L. Neumann, and A. Artusi, “Image attributes and quality for evaluation of tone mapping operators,” in Proc. 14th Pacific Conf. Comput. Graph. Appl., 2006, pp. 35–44.