International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 4, Special Issue 2, April 2014)
National Conference on Computing and Communication-2014 (NCCC'14)

Dynamic Tone Mapping Operator for Maximizing Tone Mapped Image Quality Index

Avinash Dhandapani J[1], Dr. Dejey[2]
[1]PG Scholar, [2]Assistant Professor / HOD, Regional Centre of Anna University Tirunelveli, Tirunelveli, Tamil Nadu, India.
avinash.dhandapani@gmail.com[1], dejeytilak@gmail.com[2]

***Abstract* – The use of photography and the application of the resultant picture has become vital in such a way that the picture should express all the information present in the environment. This is not possible unless Tone Mapping Operators (TMOs) are used. It converts the High Dynamic Range (HDR) image into an equivalent Low Dynamic Range (LDR) image with as much information possible. The method used to measure the quality of the Tone Mapping Operator is mostly subjective thereby an optimization framework is not possible. Here an objective evaluation technique is used which takes both Structural Fidelity as well as Statistical Naturalness measure. The results are verified by cross checking against the Subjective Evaluation scores. It is attached as an optimization framework to Gamma Tone Mapping operator to obtain the maximum possible quality obtainable from these tone mapping operator.**

***Keywords*—Tone Mapping; Tone Mapping Operator; High Dynamic Range; Low Dynamic Range; Structural Fidelity; Statisical Naturalness; Gamma TMO.**

I. INTRODUCTION

We are in a generation where the use of photography has increased. It is not just memories which act as an application of photography but nowadays it is used in a variety of fields like medical, security etc. Nowadays it is a must for a camera to replicate an image which our eye sees.

Dynamic range is the ratio between the largest and smallest value of a changeable quantity. It is measured as ratio or as a base 10 or base 2. Human beings have a high dynamic range because their hearing capacity is from 100 to 100000dB. Photographers use dynamic range for the luminance of a scene being photographed or the limits of luminance range that a given camera or film can capture or the opacity range of developed film images. Depending upon this the images can be classified as Low Dynamic Range (LDR) images and High Dynamic Range (HDR) images.

High Dynamic Ranging is a set of methods to capture an image which stimulates human eye. Non-HDR cameras take pictures at a fixed exposure thereby making it impossible to simulate human eye which results in loss of information either in dark or bright areas based on the exposure that is being set in the camera.

Tone mapping reduces the dynamic range, or contrast ratio, of the entire image, while retaining localized contrast (between neighboring pixels), tapping into research on how the human eye and visual cortex perceive a scene, trying to represent the whole dynamic range while retaining realistic color and contrast. It is a technique used in image processing and computer graphics to map one set of colors to another in order to approximate the appearance of high dynamic range images in a medium that has a more limited dynamic range.

Fig.1.1. Image at various Exposures

Fig.1.1 shows the six individual images taken at various exposures. In the low exposure images, the room is dark and unclear, but the details of the windows are visible. In the high exposure images, the windows are bright and unclear, but the details of the room are revealed.

In order obtain an image which is similar to what our human eye sees, tone mapping is carried out on the images at various exposures thus obtaining a single image which is similar to what our eye sees.

Fig.1.2. Tone Mapped Image

The tone mapped image shown in Fig.1.2 is a result of applying tone mapping on the six individual exposure images[3].

II. Related Works

A. Existing System

Despite lots of previous work, traditional evaluation methods are still far from satisfactory. It involves more time consumption as well as it varies from person to person because individual capabilities vary. It also can't be attached as an optimization framework for the Tone Mapping Operator.

B. Subjectiveness based Approaches

Patrick Ledda et al. (2007) proposed a series of psychophysical experiments [6] to validate six frequently used tone mapping operators against linearly mapped High Dynamic Range (HDR) scenes displayed on a novel HDR device. The purpose of this investigation was not simply to determine which algorithm is best, but more generally to propose an experimental methodology to validate such operators and to determine the participants' impressions of the images produced compared to what is visible on a high contrast ratio display. Each subject was instructed to evaluate all possible comparison pairs taken from the test set. Although by this means the trial is large and time consuming, it makes it easier to evaluate and compare the performance of each test subject.

Zicong Mai et al. (2011) proposed a Subjective Evaluation of Tone-Mapping Methods on 3D Images [19]. Sixteen subjects have been taken for experiment. They had diverse cultural backgrounds and differed in age. For each of the 64 3D images in the test, subjects were asked to evaluate two aspects: i) the 3D effect and ii) the overall quality.

The 3D effect score rates the impression of depth and how comfortable the 3D scene is perceived. A scoring bar ranging from 0 – 10 is associated with each aspect to be evaluated.

Mikko Kuhna, Mikko Nuutinen and Pirkko Oittinen (2011) proposed a human visual system [18] (HVS) function which classifies an image as unacceptable, acceptable and favorable. Image naturalness and pleasantness were used as the evaluated attributes.

Akiko Yoshida (2005) proposed [5] a method to perceptually evaluate tone mapping operators with real-world scenes. The subjects were asked to compare each of the 14 images with their corresponding real-world view and give ratings for image appearance and realism. Image appearance attributes judged in the experiment are overall brightness, contrast, detail reproductions in dark regions and detail reproductions in bright regions.

C. Objectiveness based Approach

Zhou Wang et al. (2004) proposed an image quality assessment such that the loss of perceptual quality is directly related to the visibility of the error signal [1]. The simplest implementation of this concept is the Mean Squared Error [8] (MSE) which objectively quantifies the strength of the error signal.

Tunc Ozan Aydın et al. (2008) proposed a Dynamic Range Independent Image Quality Assessment. This metric utilizes a model of the human visual system, and its central idea is a new definition of visible distortion based on the detection and classification of visible changes in the image structure. There are three types of structural changes: Loss of visible contrast**,** Amplification of invisible contrast, Reversal of visible contrast. Loss of visible contrast happens when a contrast that was visible in the reference image becomes invisible in the test image. Amplification of invisible contrast happens when a contrast that was invisible in the reference image becomes visible in the test image. Reversal of visible contrast happens when a contrast is visible in both reference and test images, but has different polarity

III. Proposed System

Inorder to have an evaluation mechanism that produces a quality score similar to a subjective evaluation a new method is proposed. This method considers both the structural fidelity between the High Dynamic Range (HDR) image and the Low Dynamic Range (LDR) image through a structural similarity score and also the statistical naturalness measure of the tone mapped image [13].

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 4, Special Issue 2, April 2014)
National Conference on Computing and Communication-2014 (NCCC'14)

Using this TMQI as an optimization framework a dynamic tone mapping operator is implemented thereby getting the maximum possible quality out of the given TMO.

A. Tone Mapped image Quality Index (TMQI)

The Tone Mapped image Quality Index score ranges between 0 to 1 where 0 means low and 1 means high. The Tone Mapped image Quality Index score is a combination of both Structural Similarity index and Statistical Naturalness measure.

The task of computing structural similarity is classified into three comparisons i.e. luminance, contrast and structure. First, the luminance of each signal is compared. Second, the mean intensity is removed from the signal. Third, the signal is normalized by its own standard deviation, so that the two signals being compared have unit standard deviation. Finally, the three components are combined to yield an overall similarity measure.

The main idea behind tone mapping is to change the dynamic range i.e. from High Dynamic Range to Low Dynamic Range. Hence direct comparison using image processing function is not applicable. Thus to compare, two local patches 'x' and 'y' are taken from the HDR and tone mapped image respectively. Thus the local structural fidelity measure is given as in Eqn. 3.1

$$S_{local}(x,y) = \frac{2\sigma_x'\sigma_y' + C_1}{{\sigma_x'}^2 + {\sigma_y'}^2 + C_1} \cdot \frac{\sigma_{xy} + C_2}{\sigma_x\sigma_y + C_2} \quad \ldots(3.1)$$

Where σ_x , σ_y and σ_{xy} 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 positive stabilizing constants.

Finally the total structural fidelity is determined by Eqn. 3.2

$$S_l = \frac{1}{N_l}\sum_{i=1}^{N_l} S_{local}(x_i, y_i) \quad \ldots(3.2)$$

Where N_l is the number of patches in the l-th scale.

The overall structural fidelity is calculated by combining scale level structural fidelity scores as in Eqn. 3.3.

$$S = \prod_{l=1}^{L} S_l^{\beta_l} \quad \ldots(3.3)$$

There are several parameters in the implementation of structural fidelity model. First, when computing S_{local}, the values are set as follows C_1=0.01 and C_2=10, and it is found that the overall performance of the structural fidelity model is insensitive to these parameters within an order of magnitude. Finally, the mean intensity value is set to be the mean of the dynamic range of LDR images, i.e. μ = 128. Finally, when combining the measures across scales, the values are set to $L = 5$ and $\{\beta_l\}$ = {0.0448, 0.2856, 0.3001, 0.2363, 0.1333}, which follows the psychophysical experiment results reported by [16].

A high quality tone mapped LDR image should not only faithfully preserve the structural fidelity of the HDR image, but also look natural. It is found that Brightness and Contrast have more correlation with perceived naturalness [17] as shown in Eqn. 3.4

$$N = \frac{1}{k} P_m P_d \quad \ldots(3.4)$$

Where brightness is expressed through Normal Probability Density function (Pm) and contrast is expressed through Beta Probability Density function (Pd) and K is a normalization factor.

Thus the value of structural fidelity and statistical naturalness calculated in Eqn. 3.3 and in Eqn. 3.4 must be joined in order to produce a single score. It is done as in Eqn. 3.5.

$$Q = aS^{\alpha} + (1-\alpha)N^{\beta} \quad \ldots(3.5)$$

Where $0 \le a \le 1$ adjusts the relative importance of the two components, and α and β determine their sensitivities, respectively. Since both S and N are upper bounded by 1, the overall quality measure is also upper bounded by 1. The value of a = 0.8012, α = 0.3046, and β = 0.7088 is found as the best parameters using subjective data.

B. Dynamic Parameter Value Selection

There has been many tone mapping operators discovered in the past. But it is impossible to conclude which tone mapping operator is the best. There has been many tone mapping operators like Exponential TMO, Gamma TMO, Reinhard TMO, etc. A single tone mapping operator cannot be suitable for all images and also within a single TMO the quality of the images varies according to few dependent variables. Hence the parameter determines the value of the quality. Hence there arises a need where the TMO should produce its optimal quality independent of the image.

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 4, Special Issue 2, April 2014)
National Conference on Computing and Communication-2014 (NCCC'14)

Hence here an adaptive way of selecting a value for the dependent variable is proposed thereby the quality of the tone mapped image is maximum i.e. the value of TMQI will be maximum for that parameter.

Here a gamma tone mapping is used to determine the best tone mapped image as in Eqn. 3.6

$$Y = round(255 * X^{\gamma}/\max(X^{\gamma})) \qquad \ldots(3.6)$$

where X is a set of values in the HDR image and γ is a constant.

The variable which contributes to the overall quality of the image is identified as the dependent variable and it is altered and the value for which the value of TMQI is maximum is identified.

In this tone mapping operator, the dependent variable is gamma and its value can vary from 0.1 to 5. Hence the value determines the overall quality of the tone mapped image. Here it is dynamically determined without any manual intervention. The value of gamma is varied from 0.1 to 5 and the value for which the TMQI is the maximum. This function finds the closest element for which the mapping is known and replaces that value.

Initially the value of gamma is fixed at 0.1 and the HDR image is tone mapped to get an LDR image. Then the value of TMQI is calculated using the LDR image derived from the HDR image using a particular gamma value. Then the value of gamma is incremented and the process is repeated. The gamma value for which the TMQI is the maximum is chosen and the HDR image is tone mapped to the best LDR image that can be derived.

C. Performance Evaluation

The database includes 8 data sets, each of which contains images generated by [7] well-known TMOs such as Drago, Durand & Dorsey, Fattal *et. al..*, Reinhard *et. al.* and Mertens *et. al*. The experiments were carried out in MATLAB R2011a. The value of gamma was initially set as 0.1 initially then was varied till 5.

Table. 3.1.
TMQI Values got using Dynamic Gamma Tone Mapping Operator

S. No	HDR Image	Static Gamma Tone Mapping	Dynamic Gamma Tone Mapping
1	1	0.8420	0.86068
2	2	0.7892	0.80398
3	3	0.8884	0.9151
4	4	0.8720	0.8850
5	5	0.8226	0.84542
6	6	0.8246	0.8350
7	7	0.7922	0.8164
8	8	0.8106	0.82592

The quality i.e. Tone Mapped Image Quality Index (TMQI) obtained using the Dynamic Tone Mapping Operator which applies the objective evaluation of tone mapped image as an optimization framework is much higher than the quality obtained using various static Tone Mapping Operators

The quality of the tone mapped image varies according to image. It ignores the manual intervention and creates a dynamic algorithm by which the resultant tone mapped image is always having the best possible quality.

IV. APPLICATIONS

The application of this Objective evaluation method is that it can be standard quality measuring method in the field of Tone Mapping. It can be used as an optimization technique thereby getting the maximum out of each TMOs. The parameter value can be tuned using the TMQI.

V. CONCLUSION

An approach to measure the quality of the tone mapped image objectively rather than a subjective measure is implemented. It not only looks into the structural fidelity measure but also considers the naturalness measure. It also provides an exact score which is not possible in subjective measure as it is dependent on the subject who is measuring the quality. It is time efficient because of no manual intervention. Thus it is possible to attach an optimization framework within the tone mapping operator. It also provides a method to evaluate different tone mapping operators and decide on an optimal parameter value. Using this objective evaluation a dynamic tone mapping operator is implemented Gamma Tone Mapping operator. Thereby the quality of the tone mapped image is higher than the static algorithm.

As a part of future work the same procedure can be used to implement many more TMOs thus allowing the user to choose between the different high quality image at all case and independent of the input High Dynamic Range (HDR) image. The quality of the best tone mapping thus achieved can be enhanced in such a way that the tone mapped Low Dynamic Range (LDR) image does not leave any valid information. It is also possible to create a dynamic tone mapping operator which can choose different parameters for each structural maps thereby different tone mapping operator can be applied to different patches in an HDR image.

REFERENCES

[1] Zhou Wang, Alan C. Bovik, "Image quality assessment: From error visibility to structural similarity," IEEE Trans. Image Process., vol. 13, no. 4, pp. 600–612, Apr. 2004.

[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] M. Song, D. Tao, C. Chen, J. Bu, J. Luo, and C. Zhang, "Probabilistic exposure fusion," IEEE Trans. Image Process., vol. 21, no. 1, pp. 341–357, Jan. 2012.

[4] H. Grabner and H. Bischof, "On-line boosting and vision," in Proc. IEEE Conf. Comput. Vision Pattern Recogn., Jun. 2011, pp 260–267.

[5] 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.

[6] 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.

[7] A. M. Eskicioglu and P. S. Fisher, "Image quality measures and their performance," IEEE Trans. Communications, vol. 43, pp. 2959–2965, Dec. 1995.

[8] Z. Wang and A. C. Bovik, "Mean squared error: Love it or leave it? A new look at signal fidelity measures," IEEE Signal Process. Mag., vol. 26, no. 1, pp. 98–117, Jan. 2009.

[9] Guoping Qiu, Jian Guan, Jian Duan, Min Chen, "Tone Mapping for HDR Image using Optimization–A New Closed Form Solution,"in Pattern Recognition, 2006. ICPR 2006. 18th International Conference on Volume: 1 Page(s): 996 - 999

[10] F. Drago, K. Myszkowski, T. Annen, and N. Chiba, "Adaptive logarithmic mapping for displaying high contrast scenes," Comput. Graph. Forum, vol. 22, no. 3, pp. 419–426, 2003.

[11] 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.

[12] 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.

[13] Hojatollah Yeganeh, Zhou Wang, "Objective Quality Assessment of Tone-Mapped Images", IEE Trans. Image Process., vol.22, no.2, pp. 657-668, Feb.2013

[14] R. Mantiuk, S. Daly, K. Myszkowski, and S. Seidel, "Predicting visible differences in high dynamic range images—model and its calibration," Proc. SPIE, vol. 5666, pp. 204–214, Dec. 2005.

[15] T. O. Aydm, R. Mantiuk, K. Myszkowski, and H. Seidel, "Dynamic range independent image quality assessment," in Proc. Int. Conf. Comput. Graph. Interact. Tech., 2008, pp. 1–69.

[16] Z. Wang, E. P. Simoncelli, and A. C. Bovik, "Multi-scale structural similarity for image quality assessment," in Proc. IEEE Asilomar Conf. Signals, Syst., Comput., Pacific Grove, CA, Nov. 2003, pp. 1398–1402.

[17] E. P. Simoncelli and B. A. Olshausen, "Natural image statistics and neural representation," Annu. Rev. Neurosci., vol. 24, pp. 1193–1216, May 2001.

[18] Patrick Ledda, Alan Chalmers, Helge Seetzen "HDR Displays: a Validation Against Reality" in 2004 IEEE International Conference on Systems, Man and Cybernetics, vol.3 , Page(s): 2777 - 2782

[19] Zicong Mai, Colin Doutre, Panos Nasiopoulos, and Rabab K. Ward "Subjective Evaluation Of Tone-mapping Methods On 3d Images," in International Conference on Communication Systems and Network Technologies, 2013, Page(s): 1 - 6

[20] Jonghyun Bae, Kyungman Kim, Yu-Jin Yun and Jaeseok Kim, "Adaptive tone-mapping operator for HDR images based on image statistics," in TENCON 2011 - 2011 IEEE Region 10 Conference Publication Year: 2011 , Page(s): 1435 - 1438

[21] Zicong Mai, Hassan Mansour Panos Nasiopoulos, "Visually Favorable Tone-Mapping with High Compression Performance in Bit-Depth Scalable Video Coding," IEEE Trans. Multimedia., vol. 13, no. 4, pp. 520–531, Apr. 2013.

[22] Rahul Kumar Chaurasiya, K. R. Ramakrishnan "High Dynamic Range Imaging," in International Conference on Digital Signal Processing (DSP), 2011 17th Publication Year: 2011 , Page(s): 1 - 6

[23] Erik Reinhard, Greg Ward, Sumanta Pattanaik, and Paul Debevec, High Dynamic Range Imaging: Acquisition, Display, and Image-Based Lighting, Morgan Kaufmann, 2005.

Online References

[1] www.google.co.in

[2] www.wikipedia.com

[3] www.mathworks.com

[4] www.elsevier.com/locate/eswa

[5] www.sciencedirect.com

[6] www.ieee.org