Objective quality assessment of tone-mapped images

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Abstract – Tone mapping operators plays an important role to compress high dynamic range (HDR) images to low dynamic range images. High dynamic range images have plenty of applications especially in space and medical fields. For visualization of HDR images on standard low dynamic range (LDR) display devices becomes a valuable issue, which develops a variety of tone-mapping operators(TMOs). To compare different LDR images which are created by TMOs researchers provided a subjected rated tone mapped image data base. And later they developed a full reference objective tone-mapped image quality index (TMQI). TMQI method based on success of two design principles in image quality assessment literature. TMQI evaluated on measurement of multi-scale signal fidelity and statistical naturalness. Instead of that in this paper considering basic property of HDR images about details preservation mainly taken in to account. With it deduce that high quality tone-mapped images are capable of showing more details. Therefore we can propose a blind quality metric by estimating the amount of details in generated image by darkening or brightening original tone-mapped image. Experimental results confirm that proposing method despite of no reference is robust and statistically give better results than TMQI method.

***Key Words*: Image quality assessment (IQA), high dynamic range (HDR), no reference, tone-mapping operator, details preservation.**

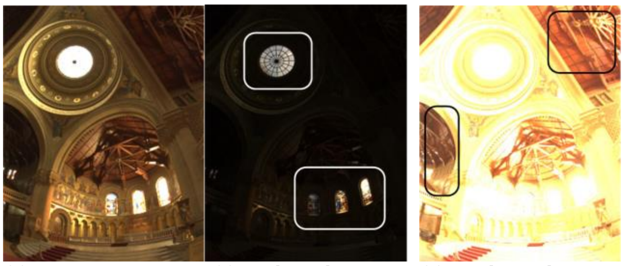
1. INTRODUCTION

High dynamic range (HDR) images have greater dynamic ranges of intensity levels than standard or low dynamic range (LDR) images, so as to capture the wide luminance variations in real scenes, where the range of intensity levels could be order of 10000:1. Nowadays many people are using low dynamic range images and related 8-bit monitors because of only 256 intensity levels are involved and LDR images may be lead to missing important details in some specific fields such as medicine and space. Therefore researchers expect HDR images to accurate represent the luminance variations which ranging from direct sun light to faint starlight and protect detailed information. Till now HDR images permeated in to numerous kinds of fields. A common problem is how to display HDR into standard display devices example, CRT or LCD monitors which have limited dynamic range. To solve this problem the concept of tone-mapping operators (TMOs) come into existence, converting HDR to LDR images. Because of the reduction in dynamic range and unideal performance of existing algorithms, TMOs inevitably cause information loss. Therefore, the best tone mapped images that are transferred from HDR images is still require a human-assisted step, in which subjects compare a large set of distinct LDR products created by different TMOs with different coefficients to pick the most satisfied tone mapped image. From the last several years TMO assessment generally depends on subjective evaluation method. But subjective quality assessment method contains some limitations. 1) It is usually laborious, expensive and time-consuming; 2) it is hard to be used to automatically pick the optimal parameters so as to validly improve TMOs and obtain the best-quality LDR images. In this sense, subjective evaluation should not be taken as perfect method for the quality of a tone mapped images. The authors therefore provided a subject-rated tone mapped image database, as well as a novel full-reference (FR) objective tone-mapped image quality index (TMQI) that is illuminated by two successful design principles in image quality assessment (IQA). The first is the structural similarity (SSIM) approach and its multi-scale derivations 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.

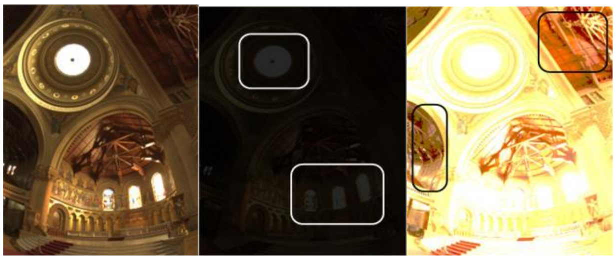
Here we are considering the basic property of HDR images about details preservation. From this we can say that better tone-mapped image should maintain much more detailed information. And high quality converted LDR images capable of showing more details (have large entropy value), especially in over dark or over bright conditions. So, we are proposing blind quality metric method in which, measuring the entropies in nine images transferred from a tone-mapped image by darkening or brightening its original brightness. And then we are implementing support vector machine (SVM) regress or (SVR) to map the above nine entropies to a quality score. On testing tone-mapped image data base our blind algorithm leads to statistically better performance than full reference TMQI method.

2. BLIND QUALITY METRIC MTHOD FOR TONE MAPPED IMAGES

It is may be a great difficulty having the difference between original HDR images and relevant 8-bit image, its darkened and brightened images, which are darkened to 1/64th and brightened to 32 times original brightness which tells about the fundamental property of HDR images about details preservation. We can see the comparison between a high dynamic range image and normal 8-bit image in the following figure.



(a) HDR image (c) Darkened image (e) Brightened image



(b) 8-bit image (d) Darkened image (f) Brightened image

For convenient display and comparison, we have labeled some noticeable distinguished regions with white rectangles in darkened images (c)-(d) and black rectangles in brightened images (e)-(f). So, we can evaluate the quality of tone mapped image by estimating the detailed information by darkening or brightening its original brightness. The transferred images are generated by

$$\tau_j = \min(\max(\tau * mul_j, 0), 255)$$

Where τ is a tone-mapped image, and mulj indicates the jth multiplier. The max and min operators are used to clip the transferred image into the range of 0 ~255.

The details should be measure with help of information entropy which is an important concept in statistics. We can also implement TMQI method which is a full reference method for comparison with our blind quality method.

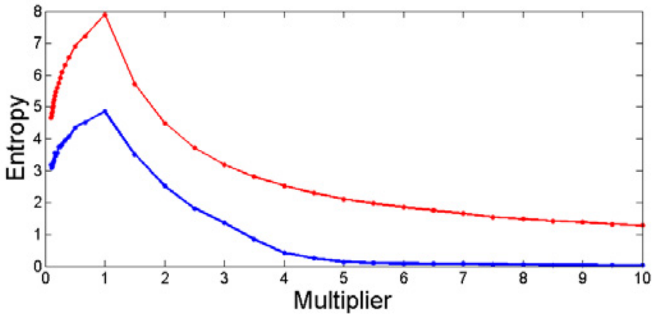
By measuring the average unpredictability of an arbitrary signal, entropy represents its disorderly degree. We accordingly apply entropy to quantify the volume of details in the tone-mapped image signal I and its transferred image signals τj as follows

$$H_j = -\sum_{i=0}^{255} p_{i(\tau_j)} \cdot \log_2 p_{i(\tau_j)}$$

Where Hj indicates τj 's entropy, and pi (τj) is the probability density of i-th grayscale in the transferred image τj .

This is explained by with the following procedure and relevant diagrams.

(a) (b)



(c)

We display two relevant tone-mapped images in Fig. (a)-(b). Among them, (a) shows a high-quality tone-mapped image, while (b) indicates an over-bright LDR image. We then, for each tone-mapped image, create 37 transferred images with mul = {1, n, 1/n; n = 1.5, 2.0 ...9.5, 10} and compute corresponding 37 entropies. Fig. (c) shows how the entropies H varies with the changes of the multipliers mul. The red and blue curves separately correspond to (a) and (b). It is easy to find that, with a small decrease/increase of luminance in(b), the entropy value quickly falls down to a quite low level, indicating its weak ability for details maintenance. In contrast, (a) presents a good performance to resist the fast fading of entropy and preserve details. Referring to the subjective ratings in (a) really has a higher subjective score than (b). It is obvious that using 37 entropies as features is too much, making the quality metric being difficult to implement in real time. In our test, we

choose only 9 entropies that are measured with mul = {1, n, 1/n; n=3.5, 5.5, 7.5, 9.5} as features. In practice, it is observed that increasing the number of features cannot lead to remarkable performance improvement. A mapping is finally learned from the feature space to quality scores using a regression module, yielding an estimation of tone-mapped image quality.
Here we are also implementing support vector machine (SVM) regressor (SVR) to map the above nine entropies to a quality score.

3. RESULTS AND ANALYSIS

The above method and its results can understand as follows We can divide the results into different steps as follows for easy understand;

Step 1: HDR generation and HDR image about details preservation.

Step 2: Calculation of entropy

Step 3: Quality assessment (using SVR)

Step 4: Comparisons

An HDR image is commonly made by taking three photos of same scene, each at different shutter speed. The result is a bright, medium and dark photo based on the amount of light that got through the lens.

HDR generation

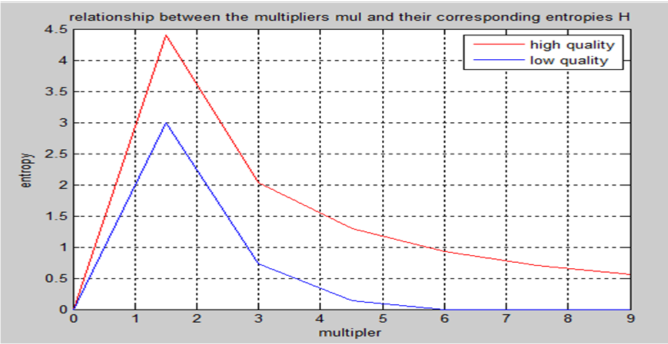
As shown above we can take three image for input, which having low exposure, medium exposure and high exposure valve. We can combine them to form high dynamic range image.

HDR image

(a) high quality tone-mapped image

(b) low quality tone mapped image

As shown in above (a) & (b) figures indicates a high quality tone mapped image and over bright LDR image. We can choose 9 entropies that are measured with mul = {3.5, 5.5, 7.5.9.5} as features. And finally quality scores are find out using SVR module.



(c)Graphical representation

Figure (c) is graphical interpretation of high quality and low quality tone-mapped images. It is clearly visible that high quality tone-mapped image have large entropy value which is indicated by red curve and low quality tone-mapped images curve is blue have low entropy. The values are like below;

Table: comparison table

Multiplier values	High quality image	Low quality image
1	7.4681	5.2458
3.5	1.7139	0.4038
5.5	1.0344	0
7.5	0.6991	0
9.5	0.5117	0
1/3.5	5.7375	4.2328
1/5.5	5.1061	3.8319
1/7.5	4.6856	3.6000
1/9.5	4.3499	3.4265

The above table indicates 9 entropies at different multiplier values. These values are mapped as a quality score using support vector regression. Quality should be calculated using following formula.

Quality (q) = $(\gamma 1-\gamma 2)/\ (1+\exp\ (-\ (q-\gamma 3))/\gamma 4)\ +\ \gamma 2$

Where q indicates the input score, Quality (q) is the mapped score, and {($\gamma 1$, $\gamma 2$, $\gamma 3$, $\gamma 4$} are free parameters to be confirmed during the curve fitting process.

Quality (q) = 0.8587

Likewise we can evaluate the quality of tone-mapped image using blind quality metric method, despite of no reference is robust and statistically give better results than TMQI method.

4. CONCLUSIONS

Gaining control of loss of information is important. However quality based tone mapped images are capable of displaying much more details. So appropriate quality oriented tone mapping operator has to be selected depends upon the application.

Future scope: Traditional method cannot adapt to and satisfy the current image technology high-development of demand. Therefore, image quality evaluation methods of development directions are that the traditional subjective evaluation methods combine with objective evaluation methods and integrate characteristics of HVS.

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