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Assessing the Quality of Tone Mapped Images Based On Structural Similarity

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Abstract— with recent advances in imaging and computer graphics technologies, HDR images are becoming more widely available. To display high dynamic range (HDR) images onto conventional displayable devices that have low dynamic range (LDR) such as monitors and printers, an increasing number of tone mapping operators (TMOs) that convert HDR to LDR images have been developed. In order to assess the quality of several TMO, an objective quality assessment algorithm named Tone Mapped image Quality Index (TMQI) is proposed for tone mapped images. Initially the HDR image is generated for which the three low, Mid and high exposure images are subjected to HDR image generation and the created HDR image is stored in .hdr format which serves as the input to Tone mapped Images Quality Index Algorithm (TMQI). It combines a multi-scale signal fidelity measure based on a modified structural similarity (SSIM) index and a naturalness measure based on intensity statistics of natural images. It converts high dynamic range (HDR) to low dynamic range (LDR) images and also generate the multi scale structural fidelity measure. Then the laplacian pyramid is computed for Exposure images. Finally the structural fidelity and laplacian pyramid images are fused which produces the tone mapped images.

Index Term— Dynamic Range; Tone Mapping; Quality Assessment; Structural Similarity

I. Introduction

In recent years, there has been an increasing interest in developing objective image quality assessment (IQA) methods that can automatically predict human behaviors in evaluating image quality [1]–[3]. Such perceptual IQA measures have broad applications in the evaluation, control, design and optimization of image acquisition, communication, processing and display systems. 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[4]-[5] .Subjective rating may be a reliable evaluation method, but it is expensive and time consuming, and it is difficult to be embedded into optimization frameworks.

TMO assessment in the past mostly relied on human subjective evaluations. In [6], perceptual evaluations of 6 TMOs were conducted with regard to similarity and preferences. An overview and a subjective comparison of 8 TMOs were reported in [7]. HDR capable monitor was employed in [8] to compare 6 TMOs in a subjective experiment using a paired comparison method. In [9], 14 subjects were asked to rate 2 architectural interior scenes produced by 7 TMOs based on basic image attributes as well as the naturalness of the LDR images. A more comprehensive subjective evaluation was carried out in [10], where tone mapped images generated by 14 TMOs were shown to 2 groups of 10 human observers to rate LDR images, concerning overall quality, brightness, contrast ,detail reproduction and color.

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The value of subjective testing cannot be overestimated. However, they have fundamental limitations. First, it is expensive and time consuming. Second, it is difficult to be incorporated into an optimization framework to automatically improve TMOs and adjust their parameter settings. Furthermore, important image structures contained in HDR images may be missing in tone mapped images, but human observers may not be aware of their existence. In this sense, subjective evaluation should not be regarded as a golden standard for the quality of tone mapped images.

The purpose of the current work is to develop an objective IQA model for tone mapped LDR images using their corresponding HDR images as references. Moreover a method is proposed which combines a multi-scale structural fidelity measure and a statistical naturalness measure, leading to Tone Mapped image Quality Index (TMQI).

II. FRAMEWORK OF PROPOSED SYSTEM

The *Figure.2* is represents the architecture for the proposed system. The various steps in proposed methodology is as follows:

- HDR Image Generation
- TMQI
- Laplacian Pyramid
- Adaptive Fusion
- Analysis

The rest of the paper is organised as follows. Section III presents about the proposed system model. Section IV displays the experimental results and Section V provides the concluded proposed methodology.

III. SYSTEM MODEL

(a)HDR Image Generation

The Dynamic Range of real world scenes can be quite high-ratios of 100,000:1 are common in the natural world HDR stands for High Dynamic Range. Common digital cameras can only capture a limited range of luminance range of the scene. Therefore, all the details of the scene will not be present in the captured image.

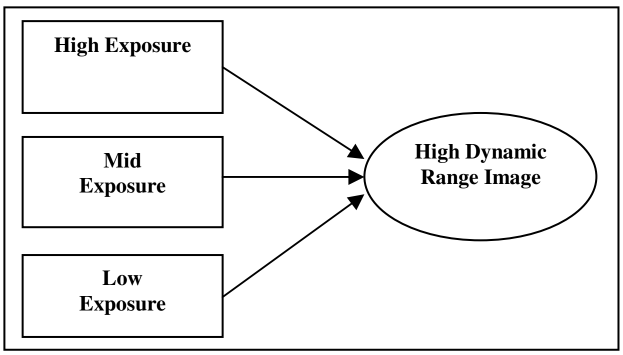

Figure.1. HDR Image Generation

A HDR image is created by combining multiple low dynamic range LDR images captured at different exposure times is shown in this figure.2

HDR Rendering is also called HDR Lighting or HDR Imaging. Creates more accurate lighting in games, digital photos, and movies than is possible using standard lighting. Normal representation of lighting in 3D graphics has a low dynamic range. Light is represented as a floating point value between 0.0 for complete darkness (black) or 1.0 for peak brightness (white).In Direct3D 8.1 – 9.0, light is an integer value between 0 and 255.

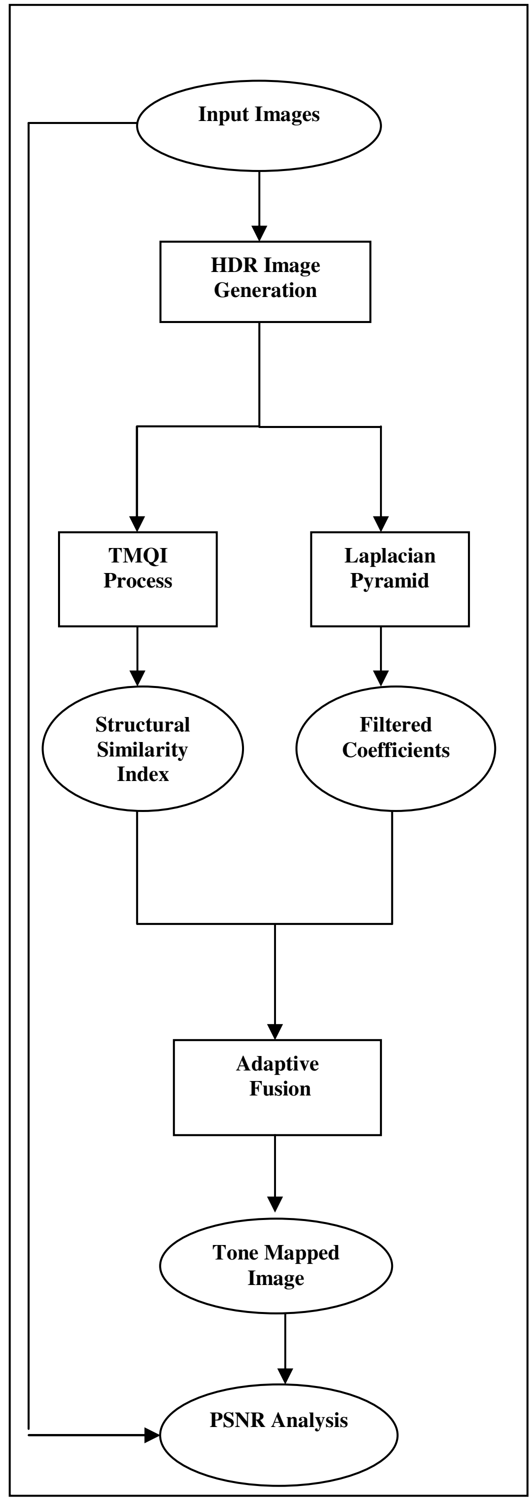

Figure.2. Flow chart

(b)TMQI

Tone Mapped image Quality Index (TMQI) is an objective quality assessment algorithm for tone mapped images by combining 1) a multi-scale signal fidelity measure based on a modified structural similarity index(SSIM); and 2) a naturalness measure based on intensity statistics of natural images. it is a method for measuring the similarity between two images.

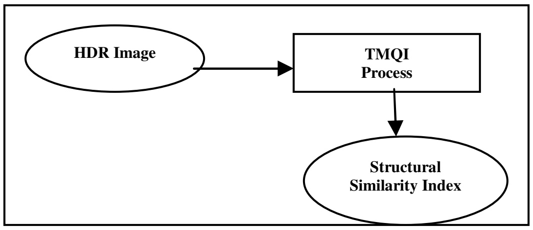

Figure. 3. TMQI Process

The figure.3 shows the input to the HDR images applied to the TMQI process it will produce the multi scale signal fidelity measures. The SSIM index is a full reference metric which the measures the image quality by taking the uncompressed or distortion-free image as reference. It is designed to improve on traditional methods like peak signal to noise ratio (PSNR) and mean squared Error (MSE), which have proven to be inconsistent with human eye perception. The difference with respect to other techniques mentioned previously such as MSE or PSNR is that these approaches estimate *perceived errors*; on the other hand, SSIM considers image degradation as *perceived change in structural information*. TMQI is based on the idea that the pixels have strong inter-dependencies especially when they are spatially close. These dependencies carry important information about the structure of the objects in the visual scene.

(c)Laplacian Pyramid

Laplacian pyramid is a technique in image processing that uses the concept of pyramids. It is very similar to Gaussian pyramid with the alteration that it uses a Laplacian transform instead of a Gaussian. The general class of linear transform decomposes an image into various components by multiplication with a set of transform functions. Some examples are the Discrete Fourier and Discrete Cosine Transforms, the Singular Value Decomposition, and finally, the Wavelet Transform, of which the Laplacian Pyramid and other sub band transforms, are simple ancestors.

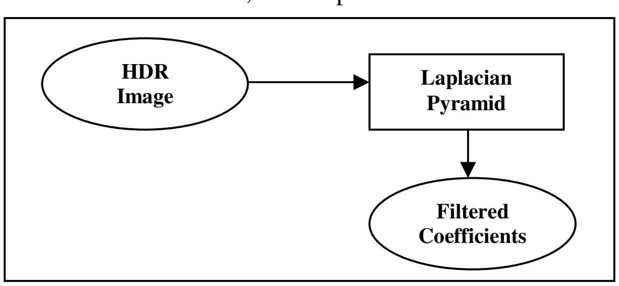

Figure. 4. Laplacian Pyramid Process

In the proposed work, the Laplacian is then computed as the difference between the original image and the low pass filtered image as shown in this figure.4.This process is continued to obtain a set of band-pass filtered images (since each is the difference between two levels of the Gaussian pyramid). Filtered coefficients are obtained by passing the HDR image into laplacian pyramid.

(d)Adaptive Fusion

Image fusion techniques may be employed to combine multiple tone mapped images. And an objective quality measure can play an important role in this process

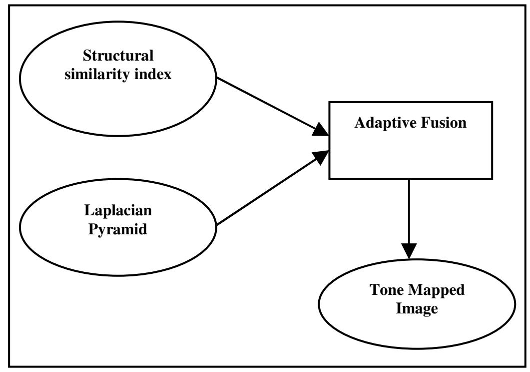

Figure. 5. Adaptive Process

Laplacian pyramid transform is applied which decomposes the images into different scales. In the pyramid domain, multiple coefficients at the same scale and the same location are resulted; each corresponds to a different TMO. A fusion strategy is applied in the above figure.5 it combine multiple coefficients into one before the application of inverse Laplacian pyramid transform is employed to reconstruct a fused image. Finally it generates the tone map image.

(e) Analysis

Peak signal-to-noise ratio, often abbreviated PSNR, is an engineering term for the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. Because many signals have a very wide dynamic range, PSNR is usually expressed in terms of the logarithmic decibel scale.

PSNR is most commonly used to measure the quality of reconstruction of lossy compression codec's. The signal in this case is the original data, and the noise is the error introduced by compression.

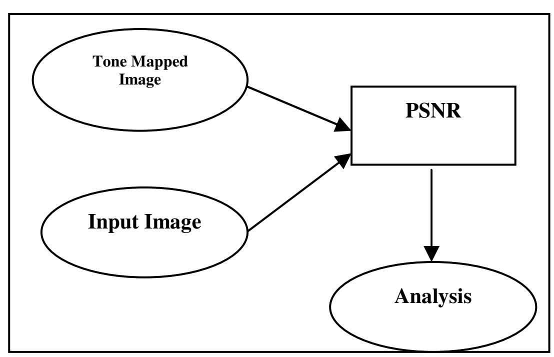

Figure. 6. Analysis

When comparing compression codec's, PSNR is an *approximation* to human perception of reconstruction quality. Although a higher PSNR generally indicates that the reconstruction is of higher quality, in some cases it may not. One has to be extremely careful with the range of validity of this metric; it is only conclusively valid when it is used to compare results from the same codec and same content.

MSE is defined as:

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j)-K(i,j)]^2$$

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j)-K(i,j)]^2$$

The PSNR is defined as:

$$PSNR = 10.\log_{10}\left(\frac{MAX_I^2}{MSE}\right)$$

$$= 20.\log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right)$$

$$= 20.\log_{10}(MAX_I) - 10.\log_{10}(MSE)$$

IV. EXPERIMENTAL RESULTS

The simulations are developed in MAT LAB.

(a)Main GUI (Graphic User Interface)

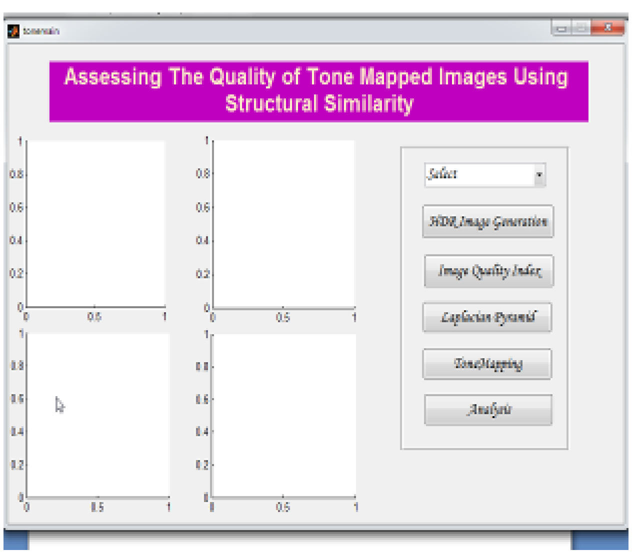

Figure.7. Main GUI for the proposed work

(b)Loading an Image

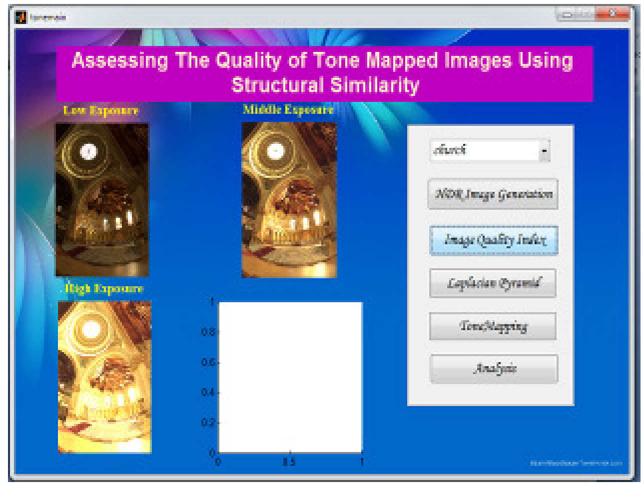

Figure.8. Loading an Image

(c)Generation of HDR Image

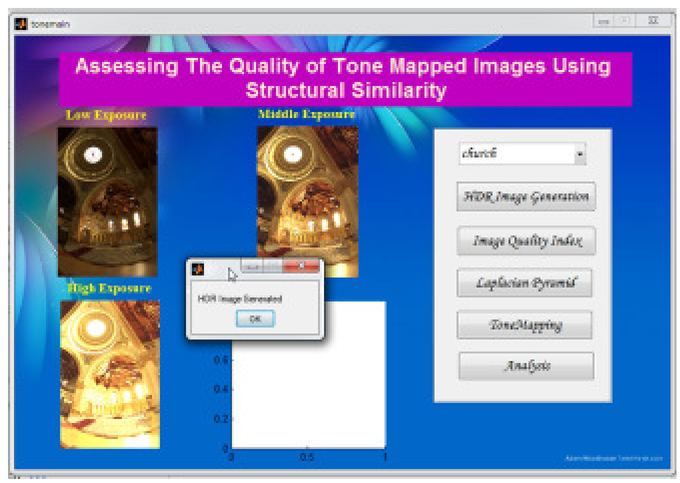

Figure.9. HDR Image Generation

(d) Application of TMQI

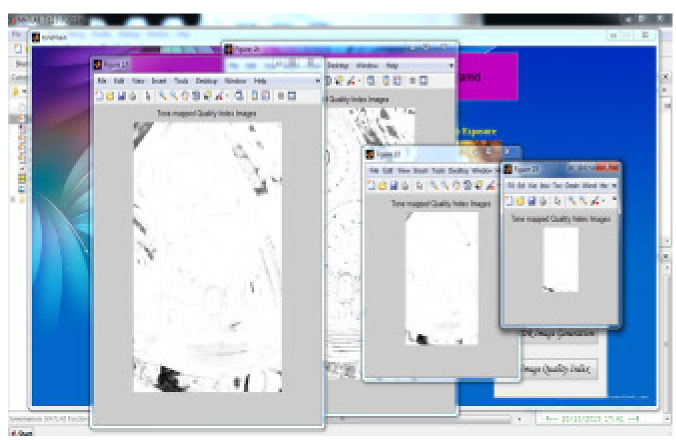

Figure.10. TMQI Process

(e) Laplacian Pyramid

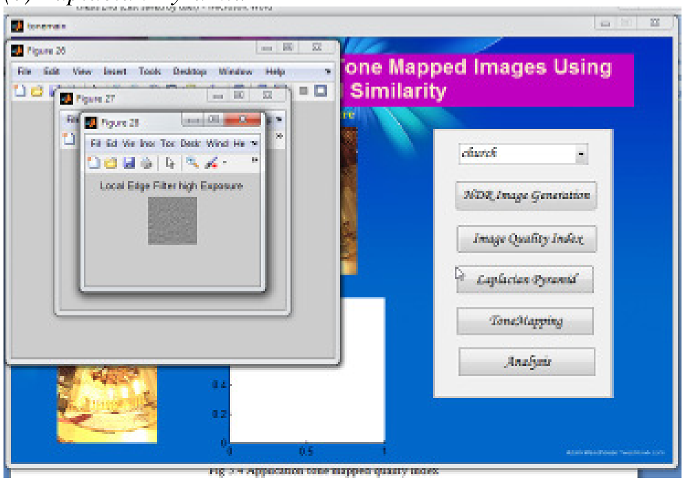

Figure.11.Different Levels Of Filtered coefficients

(f) Tone Mapping

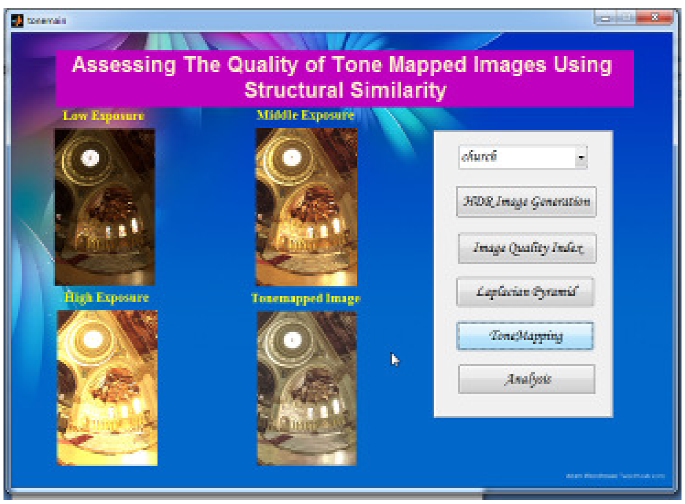

Figure.12. Tone Mapped Image

(g) Analysis

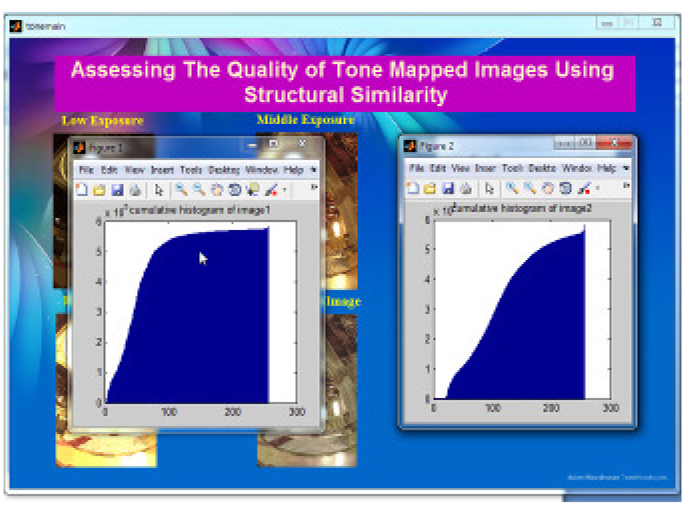

Figure.13. Analysis of image

PERFORMANCE MEASURES

The validation process is conducted by comparing our objective quality assessment results with subjective data. Two evaluation metrics are employed which are given as follows

1) Spearman's rank-order correlation coefficient (SRCC) is defined as

$$SRCC = 1 - \frac{6\sum_{i=1}^{N} d^2}{N(N^2-1)}$$

Where di is the difference between the ith image's ranks in subjective and objective evaluations. SRCC is a non-parametric rank-order based correlation metric, independent of any monotonic nonlinear mapping between subjective and objective scores.

2) Kendall's rank-order correlation coefficient (KRCC) is another non-parametric rank correlation metric computed as

$$KRCC = \frac{N_c - N_d}{\frac{1}{2}N(N-1)}$$

Where Nc and Nd are the numbers of concordant (of consistent rank order) and discordant (of inconsistent rank order) pairs in the data set, respectively.

V. CONCLUSION

An objective model is developed 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. The experiments show that TMQI is reasonably correlated with subjective evaluations of image quality. Moreover, the usefulness of TMQI in automatic parameter tuning of tone mapping algorithms and fusing of multiple tone mapped images is demonstrated. A method for generating the Tone mapped Quality Index Images and the Laplacian pyramid of the multiple Exposure images is proposed. The Generated image is passed to adaptive fusion technique which provides the tone map image which gives better result than the Existing method.

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