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# Image Quality Enhancement for Tone Mapped HDR Image Using Wavelet Based Fusion

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## ABSTRACT

*Tone-mapping operators (TMOs) that convert high dynamic range (HDR) to low dynamic range (LDR) images, so as to visualize HDR images on standard displays. Different TMOs create different tone-mapped images and a natural question is which one has the best quality. this paper introduces a fusion technique based on wavelet transforms that combines the output of several operators in a single image, based on objective quality maps that do not depend on the dynamic range of neither the input nor the output images, thus offering a better detail preservation capability compared to the case where each operator is independently applied. Here an algorithm is proposed for fusing the LDR image outputs obtained by applying different TMOs on the same HDR input image.*

**KEYWORDS:** *Tone mapping operator, high dynamic range images.*



## I. INTRODUCTION

High Dynamic Range (HDR) imaging was first introduced in order to obtain an image that correlates as much as possible with real world scenes, as there is no human-made electronic device that can capture a scene as the eye can observe it. The aim of HDR imaging is to cover the entire range of light and present the full information in a scene. However, a fundamental problem is encountered by the limitations of standard display that cannot reproduce an image with a high ratio between light and dark areas, and therefore not allowing for a correct visualization of HDR images. Tone mapping operators (TMOs)[3] are used to overcome this problem by reducing the dynamic range of the HDR image in a way suitable for the display, while maintaining, to some extent, the visual appearance of the scene.

A TMO performance is usually discussed subjectively by analyzing the visual appearance of the mapped output. The perceptual quality of a tone-mapped image depends not only on its dynamic range and the TMO used, but also on the captured scene itself. In other word, there is no best operator that can be used to always obtain the best results. Additionally, a TMO could perform well in some regions of an image, while another TMO could perform better in other regions. Therefore, fusing several tone-mapped images obtained by applying different TMOs [6] on the same HDR image could be beneficial for improving the LDR output.

This can be seen as similar to exposure fusion where several LDR images are fused. However, in exposure fusion, the original LDR versions of a scene, captured at different exposures, are available for processing without constructing an HDR image. In this paper, we consider the case where only an HDR image is available, and thus it is the only reference that can originally describe the captured scene. Several TMOs are applied and the original HDR image is used for evaluating the performance of each TMO at each pixel coordinates, based on the objective quality maps derived in. Finally, several approaches for fusing the different LDR images in a unique output are proposed.

## II. IMAGE QUALITY ASSESMENT

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. 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 . The original SSIM algorithm [2] is applied locally and contains three comparison components − luminance, 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

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

where $\sigma_x$ , $\sigma_y$ and $\sigma_{xy}$ 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. Compared with the SSIM definition, 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.

*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. An interesting study of naturalness in the context of subjective evaluation of tone mapped images was carried out 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 [7]. The results showed that among all attributes being tested, brightness and contrast have more correlation with perceived naturalness[3]. This motivates us to build our statistical naturalness model based on these two attributes. This choice may be over simplifying 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. Recent studies suggested that brightness and contrast are largely independent quantities in terms of both natural image statistics and biological computation. As a result, their joint probability density function would be the product of the two. Therefore, we define our statistical naturalness[3] measure as

$$N = \frac{1}{K} P_m P_d \quad (2)$$

where $K$ is a normalization factor given by $K = \max\{P_m \;\; P_d\}$.This constrains the statistical naturalness measure to be bounded between 0 and 1.

## III. QUALITY ASSESSMENT MODEL

The structural fidelity measure $S$ and the statistical naturalness measure $N$ characterizes different aspects of the quality of tone mapped images. They may be used individually or jointly as a vector valued measure. In many practical applications, however, users prefer a single score that indicates the overall quality of the image. Therefore these parameters should be combined in some manner. In the literature of IQA, there had been earlier work that combines image statistics and measures of structure and contrast, though in a different context. Here we define a three-parameter function to scalarize the joint measure, resulting in a Tone Mapped image Quality Index

$$Q = aS^{\alpha} + (1 - a)N^{\beta} \quad (3)$$

where $0 \le a \le 1$ adjusts the relative importance of the two components, and $\alpha$ and $\beta$ determine their sensitivities ,respectively. Since both $S$ and $N$ are upper-bounded by 1, the overall quality measure is also upper-bounded by 1.

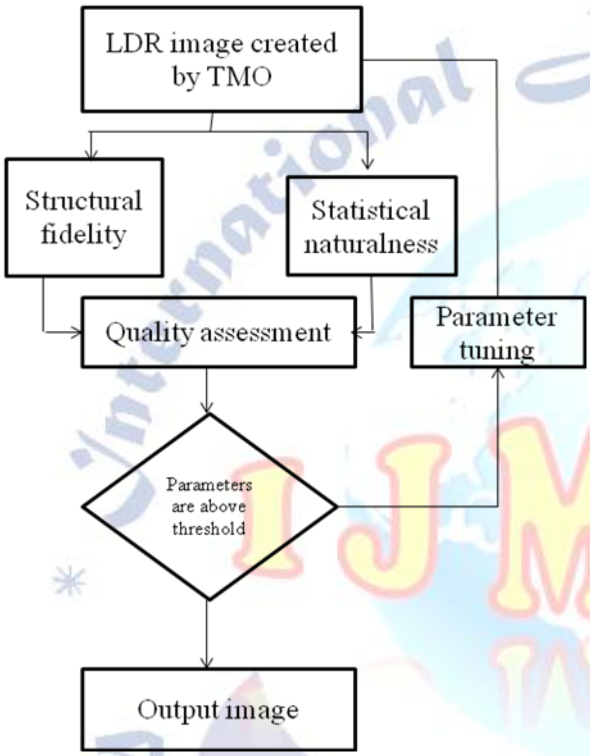


Fig 1.Flow chart of quality assessment method

## IV. PROPOSED FUSION TECHNIQUE

Image fusion is a technique of image processing, to combine two or more images of same size with little dissimilarity to obtain more quality image compared to input images. Discrete Wavelet Transform is more vital role play in image fusion technique it minimizes structural distortions.

As mentioned earlier, a TMO might better preserve details than other TMOs in some image regions, while others could be better detail-preserving operators in other regions of the same image. Therefore, combining the output of different tone-mapping operators in a single image could be beneficial for improving the final result. Our proposed algorithms for fusing the LDR outputs obtained by applying different TMOs on the same HDR input image.

Usually the real world object contains structures at different scales and resolution. so objects can also be process at different scales and resolutions this is called as multi-resolution theory. The basic idea of all multi resolution fusion schemes is motivated by the human visual system being primarily sensitive to local contrast changes, In the case of wavelet transform fusion all respective wavelet coefficients from the input images are combined using the fusion rule. Since wavelet coefficients having large absolute values contain the information about the salient features of the images such as edges and lines, a good fusion rule is to take the maximum of the corresponding wavelet coefficients. The discrete wavelet transform (DWT) decomposes the signal into wavelet coefficients from which the original signal can be reconstructed again.

The wavelets-based approach is appropriate for performing fusion tasks for the following reasons:

(1) It is a multi-scale (multi resolution) approach well suited to manage the different image resolutions. In recent years, some researchers have studied multi-scale representation of a signal and have established that multi-scale information can be useful in a number of image processing applications including the image fusion.

(2) The wavelets transform (WT) allows the image decomposition in different kinds of coefficients preserving the image information.

(3) Such coefficients coming from different images can be appropriately combined to obtain new coefficients, so that the information in the original images is collected appropriately.

(4) Once the coefficients are merged, the final fused image is achieved through the inverse wavelet transform (IWT), where the information in the merged coefficients is also Preserved Two approaches to design image fusion are Spatial Fusion and Transform fusion In Spatial fusion, the pixel values from the source images are manipulated in spatial domain to calculate the activity measure to form the pixel of the composite image at that location. Transform fusion uses transform for representing the source image suitable in a form to calculate the activity measure more accurately. Multi-resolution transforms are used in image fusion to represent the source image at multi scale. The most widely used multi resolution transform for image fusion is Discrete Wavelet Transform (DWT) since it reduces structural distortions. The Discrete Wavelet Transform (DWT) of image signals produces a

non-redundant image representation, which provides better spatial and spectral localization of image formation.

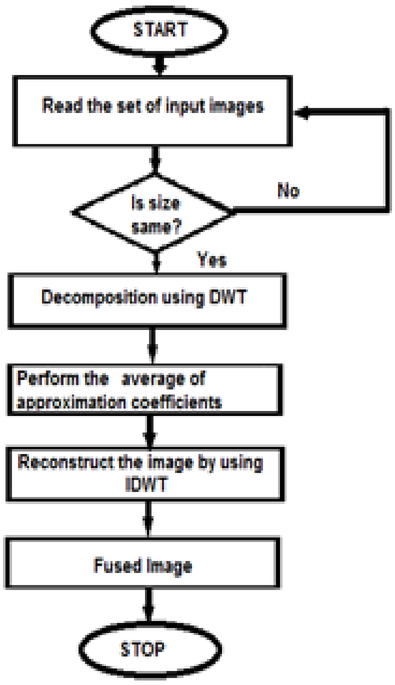


Fig 1.Flow chart of image fusion process

The process of Image fusion is shown in Fig.1

The proposed fusion algorithm is as follows

- Read the set of input images which are of same size
- Apply wavelet decomposition on the images using discrete wavelet transform.
- Perform the average of approximation coefficient of decomposed images.
- Now apply wavelet decomposition on the images to reconstruct the image. Display the final fused image.

(a)

b c

d e

(f)

Fig. (a) high dynamic range image. Fig. (b)-(e) Tone mapped low dynamic range images Fig. (f) Fusion image.

The Fig.(a) shows high dynamic range image .By using tone mapping operators LDR images are generated which are shown in Fig (b)-(e) and quality of the LDR images are assessed. To improve the Quality of generated tone mapped images an image fusion using DWT is used. The comparative results are shown in table.

Table1. Performance evaluation of proposed method.

| Image | N | Q | S |
|---|---|---|---|
| LDR image1 | 0.8516 | 0.9606 | 0.9281 |
| LDR image2 | 0.8516 | 0.9365 | 0.8377 |
| LDR image3 | 0.8516 | 0.9529 | 0.8986 |
| LDR image4 | 0.8516 | 0.9598 | 0.9250 |
| Fused image | 0.8625 | 0.9635 | 0.9321 |


Fig. Performance evaluation graph

## V CONCLUSION

In this paper, an objective quality assessment is introduced to compare high dynamic range image with tone mapped LDR images using Statistical Naturalness and structural fidelity. To improve the quality of LDR image an image fusion algorithm using DWT with S,N,and Q values.In the proposed method,if S,N values increases the quality of LDR images improved.

Finally, the current method is applied and tested using natural images. The application scope of HDR images and TMOs is beyond natural images.The future scope is modern medical imaging devices often capture HDR medical images that need to be tone-mapped before visualization.

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