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A Comparison and Study of Tone Mapping Methods for High Dynamic Range Images

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Abstract: This paper presents comparative study of different Tone mapping method of high dynamic range (HDR) images for image reproduction. The main aim is to provide the mapping between the light emitted by the original scene and display values. The dynamic range of the captured scene is smaller or larger than that of the display device, tone mapping expands or compresses the luminance ratios and adjust the image in such a way that all parts in the image can display and recognise properly. Tone and retrieve the visual impression of light sources placed in the field of view and the quality of resulting image will not reduce. The proposed system developed using Reinhard method. To create HDR and tone mapping the MATLAB functions are used.

Keywords: Tone Mapping, MATLAB Software, High Dynamic Range Images.

I. INTRODUCTION

High Dynamic Range images can be created using sequence of images captured at different exposure times. It is very difficult to capture the full dynamic range images by using the modern digital camera. Combining different low dynamic range (LDR) images with different exposure time the HDR image can be created. In 1997 the algorithm was developed which can create high dynamic range radiance maps. algorithm can store the HDR image in RGBE form [1],[10].

Fig. no. 1: Low Dynamic Range photograph with short, medium and long exposure time

Fig. no. 1 represents three shots taken under different exposure values of the camera. The first one is underexposed image which shows contrast image similarly, the third one is overexposed image which shows brighten image. The medium exposure value image is not able to present all luminary information of image. To overcome from this problem the tone mapping method was invented. From all 3 LDR images the HDR image can be generated using tone mapping method. The block diagram of HDR image processing system is as shown in Fig. no.2 [2], in which 7 blocks are present different functions. The multi exposure digital camera can take N number of images, by adding those images pixel values individually and RGB pixel values can taken separately the HDR image found, by applying tone mapping the HDR images are converted into LDR images, which can be able to display on device. The block diagram shows very simple method of HDR image generation.

HDR images not displayable on device, again convert into LDR image.

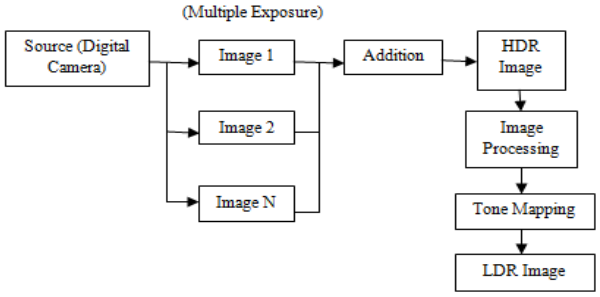

Fig. no. 2: Block Diagram of HDR Image processing system

II. RELATED WORK

Lot of work has been done on the High dynamic range images.

A] Generation of HDR Image

Jinto et al. [4] represents the creation of high dynamic range images using tone mapping and inverse tone mapping, single image with different exposure values that represents multiple low dynamic range images. The exposure value is in increasing order, using this technique the Jinto et al. created a HDR image. Vavilin and Jo [5] generated a HDR by using segmentation method, region wise decomposition of HDR image is taken and for each segmented region the tone mapping is applied, using local mapping the image get reconstructed.

B] Tone Mapping

Tone mapping is the method of finding appropriate image which is able to display the darkest and brightest part of image clearly. While calculating contrast it compresses the darkness range of image. Drago et al. [6] proposed

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luminance vales logarithmic compression of image. Using contrast enhancement and histogram adjustment technique the visualization of image done. Li et al. [7] describes adaptive algorithm to display the high dynamic range image, which presents two compression approaches that are global and local operator. In global operation point to point matching function and in local operation detailed luminance range taken under consideration. Statistical based histogram adjustment technique used for global mapping to convert base layer into LDR image and spatial filter used for local mapping.

C] HDR Image Evaluation

Alvaro and Guillermo [8] defined visualization of HDR images. Cadik et al. [9] evaluated HDR tone mapping methods using perceptual attributes. The identification of relationship between different attributes became essay using perceptual attributes method. Table 1 presents evaluation of different tone mapping methods.

TABLE 1 ABBREVIATIONS OF EVALUATED TONE MAPPING METHODS

Abbreviation	Method description	Global/ Local
Drago03	Adaptive Logarithmic Mapping for Displaying High Contrast Scenes	G
Ashikhmin 02	A Tone Mapping Algorithm for High Contrast Images	L
Choudhury03	The Trilateral Filter for High Contrast Images and Meshes	L
Chiu93	Spatially Non uniform Scaling functions for High Contrast Images	L
Durand02	Fast Bilateral Filtering for the display of HDR Images	L
LCIS99	Low Curvature Image Simplifier	L
Fattal02	Gradient Domain High Dynamic Range Compression	L
Pattanaik02	Adaptive Gain Control for HDR Image Display	L
Tumblin99	Revised Tumblin-Rushmeier Tone Reproduction Operator	G
Schlick94	Quantization Techniques for Visualization of HDR Pictures	L
Reinhard02	Photographic Tone Reproduction for Digital Images	L
Ward94	A contrast-based scale factor for luminance Display	G
Ward97	A Visibility Matching Tone Reproduction Operator for HDR Scenes	G

III. COMPARATIVE PERFORMANCE ANALYSIS OF VARIOUS TONE MAPPING METHODS

Tone mapping method is used to reproduce the image and provides mapping between luminance of original scene to output device display values. The problem with standard displays is that they are unable to display High Dynamic Range images. To solve this problem the tone mapping technique was invented, it can display the maximum luminance image on standard display without compromising quality of image by converting High Dynamic Range image into Low Dynamic Range image.

The classification of tone mapping operators in four classes: global, local, gradient domain and frequency domain operator. Table 2 presents Comparisons of Various Tone Mapping Operators [1]. Following list represents different well known tone mapping methods used in study:

1] Logarithmic (LTM)

The logarithm is used for compressing purpose for values larger than 1, so that by mapping luminance the range compression may be achieved, base of logarithm is adjusted according to each pixel value [1].

2] Modified Logarithmic (MLTM)

For each image channel it adopts a separate luminance function. The modified logarithmic functions may be extended the curve to handle a wider dynamic range images than the simple Operators. For each channel of RGB image the luminance was computed and compressed [1].

3] Exponential (ETM)

A mapping which converts world luminances to display luminances by means of the exponential function is called exponential mapping [1].

4] Modified Exponential (METM)

Similar to modified logarithmic method, the modified exponential function may work. For each channel of RGB image separated luminance mapping is generated [1].

5] Reinhard et al. global operator (RGTM)

Compression of luminance is done by using Reinhard at al. operator. It is a modified technique of exponential operator, the luminance key is variable so due to that the compression of luminance may be controlled [11].

6] Reinhard et al. local operator (RLTM)

Reinhard et al. Local operator works similar as Reinhard global operator, the difference is that a blurring function is applied on High Dynamic Range image before applying tone mapping [11]. For very high-dynamic-range images, local contrast may be preserved better with the local version that implements dodging and burning.

7] Garrett et al.

They used image appearance model, iCAM, to render high dynamic range images for display and to develop a tone map curve [12].

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IV. EVALUATION OF HDR IMAGES

In this work, the combination of HDR generation methods and tone mapping algorithms are taken under consideration. The HDR generation methods are classified in two types namely Linear HDR generation method and Nonlinear HDR generation method. Firstly, different images were captured at different exposure time. Then for generating HDR images two HDR generation methods were applied. After that tone mapping algorithms are used to convert the high dynamic range image to low dynamic range image format so it can be displayed in normal display devices. Finally, the obtained image has been evaluated subjectively and objectively [1].

The implemented methods have been implemented firstly on standard HDR images in order to evaluate the performance of the tone mapping methods. After that, HDR images have been created using the linear and nonlinear LDR combination methods.

A] Tone Mapping for Standard HDR Images

RGTM and RLTM methods achieved the best quality of image by preserving the scene details. ETM shows good visualization with fewer loses in image details. Other techniques have poor images; the logarithmic tone mapping (LTM and MLTM) has very dark image. GTM produced a greyish image while the METM lost details in bright areas.

TABLE 2

Method	Definition	Advantage	Disadvantage	Different Operators
Global Operator	reduce dynamic range of image, treat each pixel independently	computationally efficient, real time, Faster, low complexity	For extremely high dynamic range images it may not always preserve visibility	Miller's operator, Tumblin–Rushmeier's operator, Ward's scale factor, Ferwerda's operator, Ferschin's exponential mapping, Logarithmic mapping, Drago's logarithmic mapping, Reinhard's global photographic operator, Reinhard and Devlin's photoreceptor model, Ward's histogram adjustment, Schlick's uniform rational quantization
Local Operator	Compute an adaptation level individually for each pixel by considering the pixel itself and a set of neighbouring pixels.	More flexible and adaptive	More expensive and resource demanding	Chiu's spatially variant operator, Rahman and Jobson's multiscale retinex, Johnson and Fairchild's iCAM, Ashikhmin's operator, Reinhard's local photographic operator
Frequency Domain Operator	Dynamic range of image is reduced by compressing luminance component with spatial frequency	Used in edge preserving operations	High frequency components within an image cause rapid changes in luminance	Horn's lightness computation, Fattal's gradient domain compression
Gradient Domain Operator	A derivative of image is modified	Adjustment of image is possible	Too much compression has the visual effect of exaggerated small details	Oppenheim's operator, Durand's bilateral filtering

B] Tone Mapping on Images Generating Using Linear HDR Generation methods

Using the linear combination method, the tone mapping algorithms were applied on the generated HDR images. Similar the standard HDR images, Reinhard et al.

Methods (RGTM and RLTM) achieved the good quality images followed by the modified exponential method. Garrett et al. has higher quality images than the previous set. MLTM and METM, both achieved low quality because the image is very purplish.

C] Tone Mapping on Images Generated Using Nonlinear HDR Generation Methods

In nonlinear combination method [3], the selected tone mapping algorithms were applied on HDR images.

Reinhard et al. methods and the modified exponential tone mapping techniques achieved the highest quality of image. LTM method achieved good quality images compared to the previous sets. MLTM, METM and GTM show very poor quality. The HDR images obtained by the linear production techniques have better quality than the nonlinear technique. The images obtained by the nonlinear technique are very greenish and they lost the details of the bright and dark regions.

V. PROPOSED METHODOLOGY

The proposed system fig. no.3 takes different exposure images from camera by placing the camera in one place and by changing the exposure value, more than 3 images

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are taken, those images are low dynamic range, so they can easily display on device which has very poor clarity. Very bright and very dark areas of LDR images are not recognize properly. MATLAB is used for pre input generation process that is HDR creation.

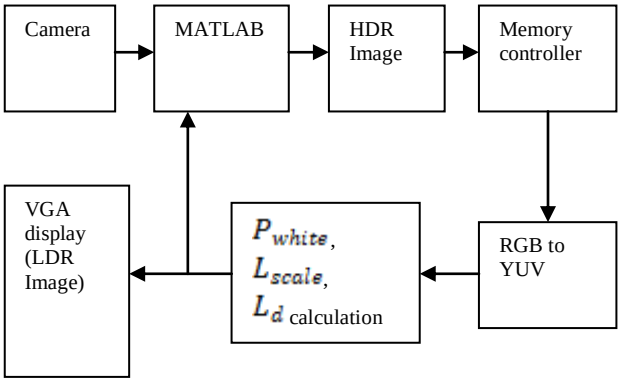

Fig.no.3: Proposed system architecture

The HDR image can't display on device, placed in memory controller block. Where optimization of memory and time required complete the process are measured. Reinhard method is used for tone mapping, the white point, scaled luminance and display luminance are calculated by using tone mapping method.
Algorithm of the System

- Take more than 2 shots under different exposure setting of camera.
- Place images in one folder for applying them as an input
- Create HDR image.
- Get exposure value from each image information.
- Find exposure time.
- Apply tone mapping function to HDR image.
- Tone mapped image display on device.

VI. RESULTS

Fig. no. 4 shows HDR image which is not displayable on device, the HDR images are very high dynamic and most of the display devices is not able to display that image properly. Fig. no. 5 shows the LDR image which has very less dynamic range and easily display on device.

Fig.no.4: HDR Image (not displayable on device)

Fig.no.5: Tone mapped image (displayable on device)

VII. CONCLUSION

This paper presented a subjective evaluation of various tone generation and tone mapping techniques. HDR images are generated from a sequence of differently exposed images using either a linear and nonlinear combination technique. Linear HDR generation produces images with better quality and more visually pleasing than the nonlinear ones. The paper presented the comparative study of various tone mapping methods and shows proposed Reinhard tone mapping method with higher visual quality of image.

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