Single Shot High Dynamic Range Imaging using Power Law Transformation and Exposure Fusion

Athira Raveendranath & Anoop K. Johnson
Department of Electronics & Communication Engineering
Mar Baselios College of Engineering & Technology
Thiruvananthapuram, Kerala, India

***Abstract*— High Dynamic Range Imaging (HDRI) is an emerging technique for the generation of high quality images. Most commonly adopted method for generating HDR images is the fusion of multiple exposure Low Dynamic Range (LDR) images. But in such cases the output image can get affected by certain artifacts such as image misalignments, ghosting etc. Single shot HDR Imaging is an efficient approach to overcome these artifacts. In this paper, we propose a method for the generation of high dynamic range image from a single input image using power law transformation. Power law transformation generates differently exposed images by varying the gamma value of the input image. Once the multiple exposure images are generated, they are fused together based on certain quality measures such as contrast, saturation, well exposedness etc. The result shows the effectiveness of the proposed approach which is verified qualitatively and quantitatively.**

***Index Terms*— High Dynamic Range, Power law transformation, Contrast, Saturation, Well-exposedness**

I.INTRODUCTION

High-dynamic-range (HDR) imaging is a technique used to reproduce a greater dynamic range of luminosity than standard digital imaging techniques. High contrast ratio, high bit depth and increased details are the main features of HDR images. Traditional imaging devices are not capable of capturing the entire dynamic range of intensity levels present in natural scene. For the direct capture of full intensity levels, specialized cameras are required but they are quite expensive.

A variety of techniques have been adopted for the generation of HDR images. The most commonly used approach is by taking differently exposed images of a particular scene and then merge them into an HDR image. This approach is referred to as Multiple Exposure Fusion. The idea of multiple exposure fusion for generating HDR image was first introduced in the middle of nineteenth century. It is broadly classified into two categories: fusion in radiance domain and fusion in image domain.

In radiance domain fusion, the camera response function (CRF) is estimated. Based on this radiance maps are calculated for each input image. All these radiance maps are then combined to form the final HDR image. Later, tone-mapping is done so that the final output image can be displayed on a normal display device. In [1] Mann and Picard discussed a technique for estimating the CRF by modelling it as a gamma function. Several other techniques for estimating CRF has been discussed in [2] and [3]. In [2], CRF has been estimated by assuming it as a higher order polynomial whereas in [3] it has been estimated using the principle of reciprocity.

In image domain fusion, the input images are directly combined to form the final HDR and hence CRF is not estimated. Here the best parts from each input image is preserved in the final output image. Some techniques of generating HDR images based on the concept of image domain fusion have been discussed in [4] and [5].

In both radiance domain fusion as well as in image domain fusion if the scene is static, capturing differently exposed images and then fusing them was quite a simple and efficient method of generating HDR images. But in real life scenario not all scenes are static. While considering scenes with moving objects sometimes the images cannot be captured properly. Artifacts such as ghosting and misalignment are some of the common issues faced in such situations. In addition to the moving objects, camera movements can cause problems while capturing images. Several global alignment techniques can be used for correcting the problems generated due to the camera movement. Inorder to avoid problems such as ghosting, several ghost removal techniques are also available [6, 7, 8]. Some of the commonly used ghost removal techniques are specified in [9]. Jacobs *et al* [10] proposed a ghost detection method based on entropy computation. Khan *et al* introduced an iterative ghost removal method in [11]. In this method HDR image is generated by calculating the probability of pixels belonging to the background or moving objects. Several other effective ghost removal techniques were also introduced later. The main problem related with such techniques is that these are computationally very complex and thus are not reliable for real life applications.

Another solution for avoiding the ghosting effect and misalignment is to generate the multiple exposure images using a single input image. In [12] Nayar *et al* proposed a method for single shot HDR image generation using spatially varying pixel exposures. The main drawback of this method was that the information about the underexposed as well as the overexposed pixels always remain unknown. Later, Celebi *et al* [13] introduced a method of generating high quality image using a single input image. Here a histogram seperation method [14] was used for obtaining the multiple exposure images. Also a fuzzy logic based fusion method was adopted for fusing the images generated. The pixel visibility criteria is taken into account for the fusion process. In [15], a method for generating HDR images using the concept of histogram seperation and exposure fusion has been discussed. The main drawback of these methods is that the number of multiple exposure images that can be generated using these methods are very limited.

In this paper, we propose a more simple and convenient multiple exposure image generation technique based on the power-law transformation by varying the gamma value. Linear Stretching (LS) and Contrast Limited Adaptive Histogram Equalization (CLAHE) is then used to improve the overall appearance of the images. After generating the multiple exposures of the input image, these are fused together by considering different quality measures such as saturation, contrast and well-exposedness. Finally the quality of the output image is measured both quantitatively and qualitatively.

II.POWER LAW TRANSFORMATION

Power law transformation is an image enhancement technique which usually creates a better looking image by adjusting the intensity depending on the value of gamma. The method adopted for the generation of multiple exposure images is by varying the gamma value. The basic equation of power law transformation is given by

$$S=C^{\gamma} \qquad (1)$$

where S is the output image, C the input image and γ is the gamma value. Changing the gamma values generates different images having different exposures.

In this paper the input image is first converted into its HSV colour space because RGB colour information is often more noisy than the HSV information. Power law transformation is applied on the V-channel of the input image for generating the multiple exposure images. The ideal value of gamma is assumed to be one. But the variation in gamma value beyond a particular limit completely degrades the image. So inorder to prevent the degradation, the value of gamma should be limited within a particular range. The range of gamma value is selected in such a way that the entropy of the multiple exposure images should not be below a particular threshold value.

After generating different exposure images, for efficient utilization of the entire dynamic range, linear stretching is performed on the generated images.

$$V_{i\_LS}(x,y) = \frac{V_i(x,y) - \min(V_i(x,y))}{\max(V_i(x,y)) - \min(V_i(x,y))} \qquad (2)$$

where $V_i(x,y)$ denotes the multiple exposure image generated using power-law transformation, $V_{i\_LS}(x,y)$ represents the linear stretched version of $V_i(x,y)$.

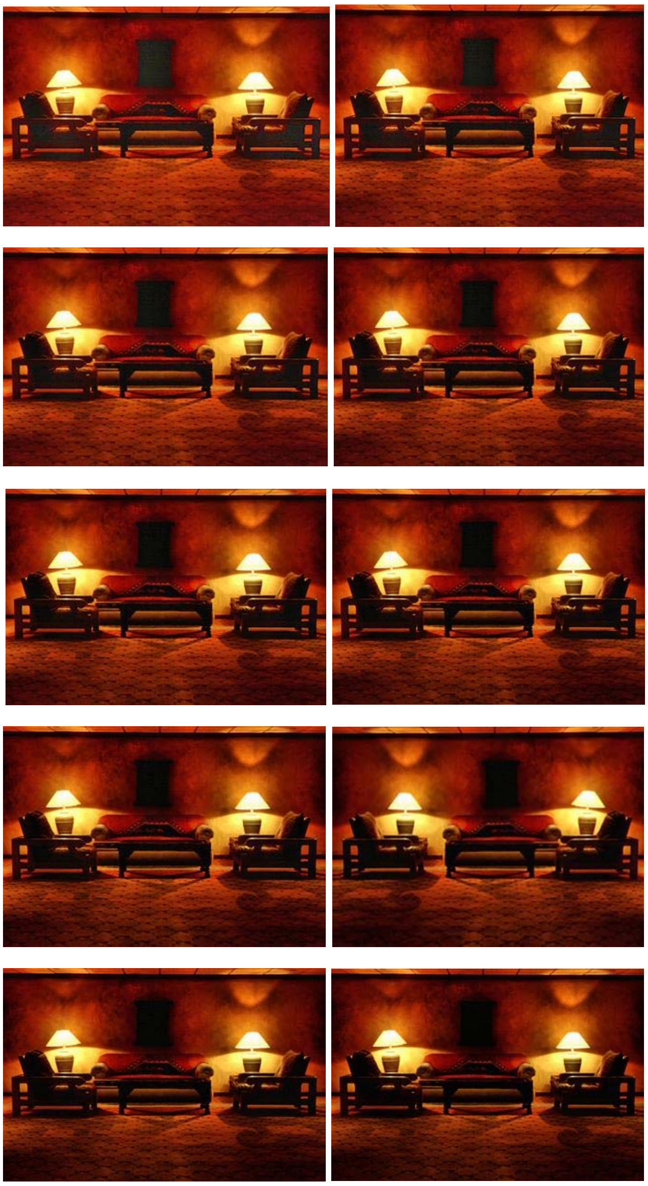
After performing linear stretching, CLAHE is performed on each of the linearly stretched multiple exposure images. Adaptive Histogram Equalization (AHE) is a local contrast enhancement technique. CLAHE is an extended version of AHE which helps in enhancing the local details present in an image.

(a)

(b)

Fig 1 a) Input Image-1 b) Multiple exposure images generated using power law transformation (range of γ varies from 0.56 to 1.37)

(a)



(b)

Fig 2 a) Input Image-2 b) Multiple exposure images generated using power law transformation (range of γ varies from 0.33 to 1.56)

(a)

(b)

Fig 3 a) Input Image-3 b) Multiple exposure images generated using power law transformation (range of gamma γ varies from 0.56 to 1.71)

III.EXPOSURE FUSION

Exposure fusion generates high quality HDR image by preserving the best parts present in each of the input images. Images may contain some flat or colourless regions. These regions are usually assigned a low weight whereas the brighter regions are assigned a high weight so that the best parts can be preserved in the final output. These best parts are evaluated based on certain quality measures such as contrast, saturation and well-exposedness.

Contrast is calculated by applying a Laplacian filter to the grayscale version of the input image and the absolute value of the filter response is taken whereas saturation value is obtained by taking the standard deviation each of the R, G, B channels. Well-exposedness is calculated by looking into the raw intensities within a channel. The intensity values between one and zero should be maintained [5]. Comparing all the three qualities a weight map is assigned to each of the input images and a weighted blending of all the input images is taken to obtain the final high quality output image. Weight is given by,

$$W_{ij,k} = C^{w_c} \times S^{w_s} \times E^{w_e} \tag{3}$$

where C, S, E represents the contrast, saturation and well-exposedness quality measures and w_c, w_s and w_e represents the corresponding weighing exponents which are either 0 or 1. For obtaining a consistent value, the normalized weight is given by,

$$\widehat{W_{ij,k}} = \left[\sum_{k=1}^{N} W_{ij,k}\right]^{-1} W_{ij,k} \tag{4}$$

where $\widehat{W_{ij,k}}$ is the normalized weight value. The final image is obtained by blending the input images using the calculated weight.

$$R_{ij,k} = \sum_{k=1}^{N} \widehat{W_{ij,k}}\, I_{ij,k} \tag{5}$$

Due to the presence of different absolute intensities sometimes the direct blending of the multiple exposure images creates unsatisfactory results. Inorder to avoid such problems, first the input image is decomposed into a Laplacian pyramid. Blending is carried out separately for each level. The N input images contain N different normalized weight masks. Let the l-th level in the decomposition of an image P be $L\{P\}^l$ and let $G\{Q\}^l$ be the Gaussian pyramid of image Q [5].

$$L\{R\}_{ij}^{l} = \sum_{k=1}^{N} G\{\widehat{W}\}_{ij,k}^{l}\ L\{I\}_{ij,k}^{l} \tag{6}$$

where L{I} is the Laplacian pyramid decomposition of the input and G{W} is the Gaussian pyramid decomposition of the normalized weight map. This image blending technique actually blends the image features instead of image intensities [5]. Since the blending is computed at each scale separately, sharp transitions in the weight map can only affect sharp transitions present in the original images. Flat regions are less affected by the sharp variations in the weight function [5].

IV.EXPERIMENTAL RESULTS

In this paper, using the power law transformation images of different exposures were created. In order to prevent degradation of the image quality due to varying gamma values, the range of gamma value is selected such that the entropy of the multiple exposure image should not be below 95% of the entropy of the actual image. Later linear stretching and CLAHE are applied to these input images for enhancing the local details present in them. After applying LS and CLAHE, depending upon the pixel characteristics, weight is assigned to each pixels. Pixels having high weights are preserved in the final image thereby preventing information loss in the under exposed and over exposed regions.

The factor used for measuring the quality of the final image formed is the visual quality itself. In addition to that, quality measures based on the entropy values, tenengrad and squared gradient values have also been performed. More the entropy means more information content is present in the image. So entropy is being used as the major measure for analyzing the quality of the output image formed by this method.

(a)

(b)

Fig 4 a) Input Image-1 b) Output image generated by the proposed method.

(a)

(b)

Fig 5 a) Input Image-2 b) Output image generated using the proposed method

(a)

(b)

Fig 6 a) Input Image-3 b) Output image generated using the proposed method

(a)

(b)

Fig 7 a) Input Image-4 b) Output image generated using the proposed method

(a)

(b)

Fig 8 a) Input Image-5 b) Output image generated using the proposed method

TABLE I: IMAGE QUALITY ASSESSMENT (Entropy Measure)

Input	Original Image	HDR Image Generation using Histogram Seperation and Fuzzy Fusion	HDR Image Generation using Power Law Transformation and Exposure Fusion
Input-1	7.5644	7.6458	7.8522
Input-2	5.9054	6.4452	7.0824
Input-3	7.4656	7.5915	7.6219
Input-4	7.1947	7.2823	7.5527
Input-5	7.6058	7.7228	7.9166

TABLE II: IMAGE QUALITY ASSESSMENT (Tenengrad Measure)

Input	Original Image	HDR Image Generation using Histogram Seperation and Fuzzy Fusion	HDR Image Generation using Power Law Transformation and Exposure Fusion
Input-1	5.3611e+08	4.5042e+08	1.2300e+09
Input-2	6.4592e+07	6.4664e+07	1.3062e+08
Input-3	1.4409e+08	1.5593e+08	7.3048e+08
Input-4	2.6208e+08	2.8166e+08	4.7101e+08
Input-5	4.5123e+08	7.7688e+08	2.8416e+09

TABLE III: IMAGE QUALITY ASSESSMENT (Squared Gradient Measure)

Input	Original Image	HDR Image Generation using Histogram Seperation and Fuzzy Fusion	HDR Image Generation using Power Law Transformation and Exposure Fusion
Input-1	35.8080	37.5384	54.4618
Input-2	6.6008	8.7140	13.8637
Input-3	29.1409	32.4938	43.0615
Input-4	25.6789	29.9948	37.4852
Input-5	42.9028	49.9202	67.2716

Comparing the input images and their corresponding output HDR images, the output images 4 (b), 5 (b), 6 (b), 7(b) and 8(b) are found to be both quantitatively and qualitatively better than their input images 4 (a), 5 (a), 6 (a), 7(a) and 8(a).

V. CONCLUSION

A novel method for generating HDR images using a single input image is described in this paper. This method utilizes the power law transformation for the generation of multiple exposure images and later they are fused together depending upon certain characteristics of the images.

The proposed method helps generating ghost free high dynamic range images as it uses a single input image for multiple image generation. Thus they are least affected by the moving objects and camera movement. Moreover the final image generated is visually more pleasant and informative than any of the input images.

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